**PROPOSED FINAL
ENVIRONMENTAL STATEMENT**

**LIQUID METAL
FAST BREEDER REACTOR
PROGRAM**

VOLUME V
DECEMBER 1974

U.S. ATOMIC ENERGY COMMISSION

MASTER

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ENVIRONMENTAL STATEMENT

LIQUID METAL FAST BREEDER REACTOR PROGRAM

VOLUME V

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Larry O. Williams
Authorizing Official

Date: 07/26/2007

U.S. ATOMIC ENERGY COMMISSION

DECEMBER 1974

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VOLUME V

APPENDIX

**COMMENT LETTERS
1-25 AND RESPONSES**

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INTRODUCTION TO VOLUME V

Volumes V through VII contain copies of all comments received on the Draft Environmental Statement and the AEC's replies thereto. These comments, contained in sixty six letters, were received from Federal, State and local agencies, environmental and public interest groups, members of the academic and industrial communities, and individual citizens. An index to these letters indicating the number assigned to each letter and other pertinent information is provided in Table V-1.

These comment letters were systematically and comprehensively analyzed in the preparation of the Final Environmental Statement to identify and categorize the points raised. This analysis served to identify ten major topics of concern, which are listed in Table V-2 along with the assigned number of the letter(s) in which each topic appears. Further examination of each topic identified about a dozen major issues, which reappeared throughout most of the letters. The procedure followed in addressing the issues in the Final Statement has been to state the problem, express the AEC view, cite responsible opposing and/or supporting views, and arrive at a conclusion with the bases for that conclusion supported by the best available information. When views other than those of the AEC are cited, the name of the commenter or organization espousing those views is identified, and the letter and page number in which those viewpoints are discussed are indicated in the Final Statement by footnote, e.g., Environmental Policy Center, Comment Letter 42. p. 1. The objective of this procedure was to provide an efficient means of handling the various viewpoints presented, and to be responsive to the issues raised.

In broad terms, the major opposing theses put forth by commenters on the Draft Statement, and which are addressed in the enclosed responses and in the body of the Final Statement, are that:

- (1) The LMFBR will introduce unacceptable risks to public health and safety (or, alternatively, that risks need to be better identified and quantified before supportable decisions can be reached on whether or not to proceed with demonstration and subsequent commercialization of the LMFBR).
- (2) There are more acceptable (e.g., lower risk) alternatives available for the generation of electricity or which could be made available, when needed, through adequately supported research and development programs.
- (3) Projected growth in electric generating capacity and electric energy use is overstated and will not materialize. Also, practical energy conservation measures could and should be taken, which would make development of the LMFBR option unnecessary.

- (4) Prospective quantities of relatively high grade uranium resources in the U.S. could be sufficient to support the increased use of economically competitive nonbreeder power plants, which could delay or eliminate the need for the LMFBR option.

The comment letters in which these issues have been raised represent only part of the multiple opportunities and invitations that have been provided by the Atomic Energy Commission to the public to make suggestions, to comment or otherwise be involved in the preparation of the Draft and Final Statements. One of the earliest such invitations was published in the Federal Register on October 4, 1973, in which the Commission solicited suggestions from all interested persons who desired to submit suggestions for consideration in the preparation of the Draft Statement. Twenty five letters were received in response to this notice. These have been identified in footnotes throughout the Statement as "Predraft Letters" and assigned letter numbers as shown on Table V-3. These letters are available for examination at the AEC Public Document Room, 1717 H St., N.W., Washington D.C.

In accordance with CEO guidelines, a Draft Statement was issued on March 14, 1974. The public and government agencies were requested to submit comments within 45 days. (As noted earlier, Volumes V through VII of the Final Statement contain all the so-called "Comment Letters" that were received on the Draft Statement.) Toward the end of this comment period, the Commission held a legislative-type public hearing on April 25-26 at AEC Headquarters. Appropriate references to issues raised in these hearings have been made in the Final Statement. It is to be noted that while direct replies were sent only to those persons submitting comment letters on the Draft Statement, the procedure employed to ensure incorporation in the Final Statement of views expressed in these comment letters was also applied to the Pre-Draft letters and to the testimony and record of the public hearing. That is, all these sources of input were utilized to identify responsible opposing (or supporting) views that are addressed and referenced in the Final Statement.

An extra element was added to the approach taken in response to the letter received from the Environmental Protection Agency (EPA). In recognition of the critical comments by EPA and the significant nature of the issues they raised, the AEC subsequently met with EPA in an attempt to assure a better understanding of the matters and issues involved and to resolve the differences. The record of the public meeting held on August 13, 1974 may be examined at the AEC Public Document Room.

In summary, the various actions taken by the AEC to solicit and address public participation in the preparation and revision of the LMFBR Program Environmental Statement have resulted in four major categories of input. These are:

1. Predraft Letters
2. Public Hearing of April 25-26, 1974
3. Comment Letters on Draft Statement
4. Public Meeting with EPA

The record of items 1, 2 and 4 are maintained at the AEC Public Document Room; the comment letters on the Draft Statement (item 3) are reproduced herein. The purpose of obtaining and addressing these multiple public inputs was to assure that all issues pertaining to environmental and other potential impacts of the LMFBR were identified and that the Final Statement is in full compliance with the letter and spirit of NEPA and CEO guidelines.

Table V-1

COMMENT LETTERS RECEIVED ON DRAFT ENVIRONMENTAL STATEMENT

<u>Comment Letter No.</u>	<u>Commenter</u>	<u>Organization</u>	<u>Date</u>
1.	Bessie Simon	No Affiliation Listed	3/17/74
2.	Velmar W. Davis	U.S. Dept. of Agriculture	3/25/74
3.	Wilfred Beaver	No Affiliation Listed	3/30/74
4.	R. I. Price	U.S. Dept. of Transportation	4/15/74
5.	K. W. Boer	University of Delaware	4/8/74
6.	J. G. Speth	Natural Resources Defense Council, Inc.	4/16/74
7.	Richard Daifuku	No Affiliation Listed	4/11/74
8.	Gaylord & Ilene Younghein	No Affiliation Listed	4/15/74
9.	Richard Wilson	Harvard University	4/16/74
10.	Roy Dycus	Shirley's Enterprises	Undated
11.	R. J. Chamberlin	Atlantic Richfield Co. International	4/17/74
12.	L. D. DeNike	Zero Population Growth	4/17/74
13.	H. L. Barrows	U.S. Dept. of Agriculture, Agricultural Research Service	4/22/74
14.	James J. Barker	No Affiliation Listed	4/22/74
15.	Hamilton Treadway	No Affiliation Listed	4/15/74
16.	John T. Edsall	Harvard University	4/21/74
17.	W. C. Guyker	Allegheny Power service Corp.	4/22/74
18.	Leonard F. C. Reichle	Ebasco Services, Inc.	4/22/74
19.	Michael T. Carter, et al	No Affiliation Listed	4/22/74
20.	Dean E. Abrahamson	Natural Resources Defense Council, Inc.	4/24/74
21.	John C. Sheppard	Washington State University	4/23/74
22.	Diane Tegtmeier, et al	Mid-America Coalition for Energy Alternatives	4/24/74
23.	Neva Dawkins	No Affiliation Listed	4/24/74
24.	John Legakes	No Affiliation Listed	4/24/74
25.	Chauncey Kepford	No Affiliation Listed	4/26/74
26.	Barry J. Smernoff	Hudson Institute	4/26/74
27.	Donald P. Geesaman	University of Minnesota	4/26/74
28.	Lloyd K. Marbet	Coalition for Safe Power	4/24/74
29.	W. Donham Crawford	Edison Electric Institute	4/26/74
30.	Russell H. Ball	No Affiliation Listed	4/24/74
31.	R. I. Price	U.S. Dept. of Transportation	4/23/74
32.	Robert W. Freedman	No Affiliation Listed	4/25/74
33.	Samuel H. Nelson	Institute for Environmental Studies	4/26/74
34.	Norval E. Carey	General Atomic Company	4/29/74
35.	Hamilton Treadway	No Affiliation Listed	4/25/74
36.	William J. Cahill	Consolidated Edison Company	4/29/74
37.	Theodore B. Taylor	International Research & Technology Corporation	4/29/74
38.	J. G. Speth	Natural Resources Defense Council, Inc.	4/29/74
39.	Edward A. Pryzina	Minnesota Pollution Control Agency	Undated

Table V-1 (cont.)

<u>Comment Letter No.</u>	<u>Commenter</u>	<u>Organization</u>	<u>Date</u>
40.	Unsigned	Environmental Action of Colorado	4/26/74
41.	Gerald M. Schaflander	Consumers Solar Electric Power Corporation	4/29/74
42.	Wilson Clark and Mark Messing	Environmental Policy Center	4/26/74
43.	Thomas G. Ayers	Breeder Reactor Corporation	4/25/74
44.	James A. Oppold	Tennessee Valley Authority	4/29/74
45.	George L. Edgar	Morgan, Lewis and Bockius, Counselors at Law	4/29/74
46.	John W. Anderson, Jr.	East Tennessee Development District	4/29/74
47.	Richard A. Henderlight	State of Tennessee, Office of Urban and Federal Affairs	4/26/74
48.	Charles Custard	U.S. Dept. of Health, Education & Welfare	4/29/74
49.	Robert Allen Karasek	Massachusetts Institute of Technology	4/28/74
50.	John Claydon	No Affiliation Listed	Undated
51.	Malcolm F. Baldwin	Environmental Impact Assessment Project	5/1/74
52.	Sidney R. Galler	U.S. Dept. of Commerce	4/30/74
53.	Sheldon Meyers	U.S. Environmental Protection Agency	5/5/74
54.	R. Balent	Atomic International Division, Rockwell International	4/26/74
55.	Gene I. Rochlin and John P. Holdren	University of California, Berkeley	4/30/74
56.	Ronald W. Pederson	State of New York, Dept. of Environmental Conservation	5/3/74
57.	John L. Menke	No Affiliation Listed	5/6/74
58.	C. R. Lewis	No Affiliation Listed	5/10/74
59.	Charles Brawman	No Affiliation Listed	5/7/74
60.	Dr. John Huber	No Affiliation Listed	5/13/74
61.	Carol Benson	No Affiliation Listed	5/6/74
62.	Royston C. Hughes	U.S. Dept. of the Interior	5/20/74
63.	T. A. Phillips	U.S. Federal Power Commission	5/16/74
64.	P. M. Murphy	General Electric Company	5/15/74
65.	Robert A. Karasek	Massachusetts Institute of Technology	5/24/74
66.	Charles Custard	U.S. Dept. of Health, Education & Welfare	6/4/74

Table V-2

INDEX FOR PRINCIPAL TOPICS APPEARING IN COMMENT LETTERS

<u>Topic</u>	<u>Comment Letter No.</u>
1. Safeguards	8, 9, 10, 12, 16, 19, 20, 22, 24, 25, 27, 34, 37, 38, 40, 45, 48, 50, 51, 54, 55, 58, 59, 60, 62
2. Safety	7, 8, 11, 16, 20, 22, 24, 25, 26, 27, 30, 32, 38, 39, 40, 42, 45, 48, 50, 51, 52, 53, 54, 55, 57, 58, 59, 62
3. Uranium Resources	11, 14, 18, 19, 26, 38, 55
4. Plutonium Toxicity	1, 3, 6, 7, 8, 12, 16, 23, 27, 32, 38, 40, 45, 51, 53, 54, 57, 58, 59, 61, 66
5. Alternative Technology Options	1, 3, 5, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 22, 25, 26, 32, 34, 35, 38, 39, 40, 41, 42, 45, 51, 52, 53, 55, 56, 57, 59, 60, 61
6. Waste Management	3, 7, 8, 16, 22, 24, 25, 28, 32, 38, 39, 40, 42, 47, 48, 51, 52, 53, 54, 55, 58, 59, 60, 62, 66
7. Transportation Accidents	16, 22, 25, 32, 38, 42, 44, 47, 51, 53, 55, 64
8. Cost-Benefit Analysis	9, 11, 12, 14, 15, 17, 18, 19, 21, 25, 26, 32, 33, 34, 38, 39, 40, 42, 45, 48, 51, 52, 53, 54, 55, 56, 58, 59, 60, 62, 64, 65
9. Energy Strategies	8, 9, 11, 14, 15, 16, 18, 19, 22, 24, 25, 26, 29, 32, 34, 36, 38, 39, 41, 42, 43, 45, 50, 51, 52, 53, 55, 60, 64
10. Miscellaneous	
a) General Environmental Effects	7, 13, 14, 19, 21, 25, 34, 38, 40, 42, 47, 48, 51, 52, 53, 54, 56, 62, 64
b) Resources and Land Use	2, 7, 19, 21, 22, 38, 42, 43, 46, 48, 49, 52, 54, 56, 62, 65
c) Sociopolitical Impacts	19, 22, 38, 40, 48, 49, 56, 62, 65

Table V-3

PREDRAFT COMMENT LETTERS

<u>Predraft Letter No.</u>	<u>Commenter</u>	<u>Organization</u>	<u>Date</u>
1.	J. G. Speth	Natural Resources Defense Council (NRDC)	8/14/73
2.	J. Landis	Gulf General Atomic Company (GGA)	9/24/73
3.	R. C. Axtman	Princeton University	9/25/73
4.	T. B. Cochran and J. G. Speth	Natural Resources Defense Council (NRDC)	10/3/73
5.	E. A. Farber	University of Florida	10/16/73
6.	L. D. DeNike	Zero Population Growth (ZPG)	10/31/73
7.	A. R. Tamplin	Natural Resources Defense Council (NRDC)	11/1/73
8.	J. H. Anderson, Jr.	Sea Solar Power, Inc.	11/6/73
9.	D. F. X. Finn	Geothermal Energy Institute	11/10/73
10.	A. R. Tamplin	Natural Resources Defense Council (NRDC)	11/13/73
11.	J. Legakes	No Affiliation Listed	11/17/73
12.	E. A. Farber	University of Florida	11/19/73
13.	P. Tebow	No Affiliation Listed	11/20/73
14.	R. I. Goldsmith	Syracuse University	11/20/73
15.	J. G. Speth	Natural Resources Defense Council (NRDC)	11/20/73
16.	T. B. Cochran	Natural Resources Defense Council (NRDC)	11/20/73
17.	G. Lewis	No Affiliation Listed	11/21/73
18.	W. H. Millerd and A. J. Futsch	Center for Science in the Public Interest	11/21/73
19.	J. G. Speth	Natural Resources Defense Council (NRDC)	12/4/73
20.	T. B. Cochran	Natural Resources Defense Council (NRDC)	12/5/73
21.	T. B. Cochran	Natural Resources Defense Council (NRDC)	12/5/73
22.	J. G. Speth	Natural Resources Defense Council (NRDC)	12/21/73
23.	A. R. Tamplin	Natural Resources Defense Council (NRDC)	12/26/73
24.	T. A. Milne	No Affiliation Listed	1/25/74
25.	J. H. Anderson, Jr.	Sea Solar Power, Inc.	3/28/74

March 17, 1974
Route 1
Ojai, Ca. 93023

Dr. Dixey Lee Ray, Chairman
Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. Ray,

Here they are, stacked up in front of me, all four volumes, five fat books, containing the draft environmental statement on the Liquid Metal Fast Breeder Reactor. Mr. Pennington and Mr. Livermore have asked for my reaction, and here it is —

I was awake at 3 a.m. this morning thinking about it and turning on the flashlight in bed to write down the thoughts as they came.

I thought why wait until I have read the whole report before replying. I know right now that I am against the entire fission program. There is no sense in going over the report point by point to see if you are planning to comply with the suggestions of the National Resources Defense Council. I am against the whole insane idea period. I am highly aware and alerted to the fact that my well-being, even my life, is being threatened. So whether there were five volumes or one hundred volumes it would make no difference.

The Report says in the "Summary-Background" that the Court ruled in Scientists' Rights for Public Information, Inc. v. AEC, that you must make the environmental impact statement. Why didn't you make it without being forced to? So I know what kind of people I am dealing with. I do not mean to be rude, but this calls for plain talk.

I am trying to be sensitive enough to pick up the overtones of the report, not just words, and cannot help but feel that the whole project is mischievous. The report sounds big, but so much of it is hypothetical and unreal, such as the

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section on "Plutonium Toxicity." I send a smirk behind the words; that you are not really serious in its proclaimed efforts to help humanity.

I am bitterly opposed to growth. It is the people who have advocated and pushed growth who have gotten us into this mess. How infuriating to read such statements as the very first sentence in your report about the "growing demand (for energy) from all sectors of the economy of the U.S.," as if we have absolutely no control over it, therefore we must have breeder reactors.

We go thundering on, trying to meet all the demands and cravings of an over-breeding, greedy, insatiable society, instead of drastically cutting down the population so that the temptation to overuse our resources, and the illusory need for fission-type generators, is eliminated.

What is the responsibility of the AEC regarding over-population? You will probably say, none whatsoever. But in my mind unless you do everything in your power to reduce the demand for energy, you have not done your duty as citizens and have absolutely no right to threaten us with nuclear power plants.

You have access to Congress, why don't you get it moving to pass laws to require people to buy a license to have a child, to eliminate income tax deductions for children and double the tax for every extra child; to require the people with children to pay all the school taxes, etc.? Then we won't need to take these appalling risks with the LMFBR. It is just as much your responsibility, Dr. Ray, as it is mine.

I wonder sometimes if you yourselves really understand the deadly momentum this vicious idea has attained. You seem determined to press on for what reason even you are not certain.

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you have labored prodigiously and produced these five volumes stating everything you are willing to do, in order to ~~be~~ permitted to do what you should not do. Any project that takes all that "doing" to assure the people it is O.K. obviously is not O.K. It has become cold-blooded premeditated assault. You seem to say, "we know you don't like it, but you have to have it whether you want it or not, so what consolations and considerations do you prefer?"

There are some of the overtones that are coming up like fumes from the stacks of volumes here before me.

You say other nations have also accorded priority to the L.A.B.P. (It is like showing one a den of rattlesnakes and asking, now which one do you prefer to have bite you?) But as I understand it, the Russians are way ahead of us in realizing the odds against fission, especially the fast breeder. If they can learn from the experience they had with a breeder explosion, why can't we learn from our Fermi experience?

If a project is stupid and unwise, no matter how carefully it is handled, it is still stupid and unwise.

It all seems like a weird, insane dream. Yet at the same time a display of incredible arrogance in the misuse of the atom, and defiance of the laws of nature. You know you are asking for trouble. Great people, intellectual leaders and scientists have warned you time after time. As David Lilienthal, the first AEC chairman said, "Once a bright hope shared by all of mankind, including myself, the rash proliferation of atomic power plants has become one of the ugliest clouds overhanging America." (N.Y. Times, July 20, 1969).

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So I look at this stack of volumes and say, "What a waste - it can never be - it must never be."

In genuine humility,
Bessie Simon

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Ms. Bessie Simon
Route 1
Ojai, California 93023

Dear Ms. Simon:

Thank you for your letter of March 17, 1974 to Dr. Ray commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. This letter provides further response to some of the specific points you raised.

In preparing the Draft Statement, the AEC considered the extensive suggestions of the Natural Resources Defense Council and other interested parties. Moreover, in preparing the Final Statement we took into account their later suggestions, testimony and comments. While the LMFBR Program is qualitatively similar to the light water reactor (LWR) program, we have considered safety and all other issues separately, both in light of the experience with the LWR Program and independently for the LMFBR Program. Throughout the long history of AEC research and development on nuclear reactor programs there has been the utmost effort to insure the safety of the public and of the employees involved.

Some of your comments refer to growth of population and growth in the demand for electricity. We have selected both high and low estimates of future growth without advocating either as such. For example, reference 14 listed on page 10.3-3 of the Final Statement uses an assumption that the Nation might reach a stabilized, no-growth population by the year 2050. This assumption is a form of conservatism as used on page 10.2-10 of the Final Statement in projecting future work force. On the other hand, the electric load projections used for the year 2020 may be higher than some people would advocate, but our use of the higher figure is a form of conservatism which translates into a fairly high estimate as to the number of electric plants needed at that time and consequently a probable overstatement of the environmental impact potential.

In reading your letter as a whole it is observed that your chief concern is safety. The AEC shares that concern both because of the human health and safety aspects and also because plants must be designed for reliable

Ms. Bessie Simon

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and economical operation over their entire service life. Nuclear power plants must be made safe for the operating people at the plant site and they must be safe at each fuel handling and processing step. We are attempting a total safety approach. At each step alternatives are rejected that do not meet our safety-in-depth philosophy. Nuclear powerplants are designed on a fail-safe basis with extensive provisions for contingencies and combinations of contingencies. Assurances to the public are based on concepts of safety unprecedented in modern industry. Nonetheless, some risk will remain. This risk is very small and we are determined to make it even smaller.

We hope this letter is responsive to your concerns. Your interest in the LMFBR Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

UNITED STATES DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
WASHINGTON, D.C. 20250

March 25, 1974

Mr. James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Liverman:

Examination of the environmental statement on the Liquid Metal Fast Breeder Reactor Program reveals two factors that potentially impact this Nation's capacity for agricultural production. These factors are water and land requirements for operation of the LMFBR. According to the impact statement, a 1,000 MWe plant can be expected to need 500 acres of plant siting and 2,000 acres for cooling lakes. With a wet cooling tower the water requirement is expected to be approximately 1,400,000 gpd for a model 1,000 MWe plant.

It has been estimated that by the year 2000 as much as 400,000 MWe of LMFBR capacity could be installed in the U. S. This translates into a possible land requirement of 1 million acres and a potential water requirement of 560 million gpd. In relation to agriculture's use of land and water, these figures are comparatively small. In 1969, 333 million acres of land was used for crops and approximately 73,000 million gpd of water was used for irrigation. Land and water for 400,000 MWe of LMFBR capacity, therefore, amounts to 3 percent and 8 percent respectively of current land in crops and water used for irrigation. However, the impact on agriculture could be significant depending on the location of specific LMFBR.

At this point in time, any conclusion about the impact of a LMFBR program upon agriculture would be rather premature. The actual impact will have to be evaluated on a site specific basis. Suffice to say that at the local level the location of a plant can have a significant impact upon agriculture if land and water are withdrawn from agricultural production. This competitive relationship should be considered and properly accounted for when evaluating alternative plant sites.

Sincerely,

VELMAR W. DAVIS
Deputy Director
Environmental Studies

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Velmar W. Davis
Deputy Director
Environmental Studies
United States Department of Agriculture
Economic Research Service
Washington, D.C. 20250

Dear Mr. Davis:

Thank you for your letter of March 25, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received. A copy of the Final Statement is enclosed for your information.

In your comments it was noted that water and land requirements for future LMFBRs could potentially have a significant impact and possibly conflict with the water and land requirements for agricultural production. The estimated land requirement of one million acres would be an upper limit for the 400,000 MWe of LMFBR capacity projected to be installed in the U.S. by the year 2000, since this estimate is based on each 1,000 MWe LMFBR having a 500 acre site and a 2,000 acre cooling pond. Realistically, most 500 acre sites would probably contain two or more 1,000 MWe LMFBRs and many LMFBRs would use cooling towers rather than cooling ponds. Even if this upper limit of one million acres were used, it would represent only 0.3 percent of the land presently used for crops instead of the 3 percent noted in your comments.

With a wet cooling tower, the water requirement for a 1,000 MWe LMFBR would be 14,000,000 gpd instead of 1,400,000 gpd. If 50 percent of the 400,000 MWe of LMFBR capacity in the year 2000 were to use wet cooling towers, a total of 2,800 million gpd of water would be required. This would represent about four percent of the water presently used for irrigation and about two percent of the water projected to be required for irrigation in the year 2000.

Mr. Velmar W. Davis

2

The actual impact of land and water use will be evaluated on a site specific basis. At the local level the location of a plant can have a significant impact upon agriculture if land and water are withdrawn from agricultural production, and such withdrawal would be considered and properly accounted for when evaluating alternative plant sites.

We trust the above information is sufficiently responsive to the points you raised. Thank you for your comments and for your interest in the LMFB Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFB Program (WASH-1535)

W.H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research
U.S. Atomic Energy Commission
Washington, D.C. 20545

MARCH 30, 1974

Dear sir:

This statement is a reply to your letter of March 14, 1974, in which you asked for comments on the Liquid Metal Fast Breeder Reactor Program Draft Environmental Statement. Thank you for the library of books dealing with the LMFBR sent to me but, to read through them all would take me beyond the time limits you set.

Acting as chairman of the Monroe County (Wisc.) Environmental Protection League, I am sending you the objections I have and am stating the alternative power sources which should be enlarged on.

I found that the LMFBR Program was formed to develop a broad technological and engineering base so that a viable commercial breeder reactor option is attained in the 1980s. We state that there are environmental dangers inherent in the LMFBR fuel cycle which includes fuel fabrication and reprocessing, waste management and the problems of transportation (Your statements).

You say that there will be little difference from the effects of light water nuclear power plants using a similar uranium-plutonium fuel cycle, but you have not convinced many people yet.

We support, instead alternative energy sources such as solar energy and fossil fuels. We support hydroelectric dams and power generators which can supply electricity. These are the "safe" alternatives nature has given us to use. We support the exploitation of our coal reserves as a second line of defense and suggest fuel lines to carry coal slurry across vast distances. The use of coal "slurry" or slush coal and water is a fact and the government could hurry programs of this nature along instead of gambling on nuclear recycling programs. This statement can be interpreted as as negative LMFBR...we support alternative energy sources.

page 2

We are convinced that all fossil fuels, such as coal, crude oil, natural gas and liquid petroleum should be exploited.

Coal supplies appear to be sufficiently plentiful (your own words, not mine. I am convinced that our coal supplies are even more plentiful than has been said) to provide for our electrical generation needs well beyond the next century, so that the choice between nuclear and fossil power generation will be made on economic considerations taking all costs, including pollution control, into account. The letter I am submitting has the effect of pointing an accusing finger at this administration and those before it who failed to curb the drain on our resources and stockpile energy sources, while researching energy alternatives such as solar, wind-power, etc. If this had been done, the present concern over the burying of nuclear fission wastes, transportation to the breeder reactor sites for recycling and the built-in dangers inherent, would not now be forcing me to object in this manner.

It is serious enough that we now have the LWR fuel cycle without any recycling of plutonium fuel. You have stated that this terrifying plutonium recycle will become a significant factor in all LWR power plant operation before 1980. It will be limited by the even greater danger of the LMFBR into the power economy because plutonium is much more valuable as a breeder fuel than as a LWR fuel. This will mean that plutonium waste would be stockpiled for this purpose. If breeder use is not initiated (as we are hopeful of) utilities would decide to use the plutonium in existing LWRs and reduce the inventory and storage charges incurred from storing the plutonium for long periods of time. From 1980 on, the decision to recycle plutonium will be made on the economic consideration of balancing inventory and storage costs against the increased value of using the plutonium in future breeders. Light water reactor (LWR) is operated using

page 3

plutonium recycle fuel, the fuel cycle from the cascade step onward is qualitatively similar to the feared LMFBR fuel cycle.

Another point of concern is of reactor gaseous wastes. The radioactive gas removal systems installed in the commercial LMFBR are to be designed to remove virtually all fission products from the primary system cover gas...these are YOUR words! From the few sources available to a layman, there are everpresent dangers of holding security systems for gaseous wastes. Your book of April 1972 LMFBR Demonstration Plant has been helpful in further pointing out dangers present not only from gaseous, but from Liquid and Solid Wastes. Their storage, transportation and recycling present problems as the LMFBR program goes into effect.

I am sending you this first letter so that it will come under your imposed deadline but I promise to add to it if there is still any time left to do so. You have not shown me that the Program is safe, will not present problems and actually is needed.

My suggestions for energy alternatives are not only my own but my members and most everyone I have spoken before. You have supplied me with valuable text which will only be used to cement the arguments of environmentalists everywhere and we hope that you will deliberate before going further in this recycling of atomic wastes. We have been buried under an avalanche of energy "crisis" propaganda which we find hard to believe. There has been a little change in our life styles over a period of the last two years and yet prices have risen, we have been "blinded" by professional people who had been supplied to convince the public of energy shortages. Save the taxpayers money and halt the present "scare" tactics of those who wish to benefit from them.

Thank you for taking the time to read my statement.

Wilfred Beaver
Mr. Wilfred Beaver
418 E. Main St. Sparta, WI.
54656

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Wilfred Beaver
418 E. Main St.
Sparta, Wisc. 54656

Dear Mr. Beaver:

Thank you for your letter of March 30, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the enclosure to this letter for specific responses to your comments.

We understand the concern you have expressed over several issues and appreciate your taking the time to make your views known to us. We hope that this response and the enclosed Final Statement will answer any remaining questions you may have and alleviate at least some of your concerns. It is our conclusion after careful study of all the issues, as expressed in the Statement, that the LMFBR is an essential element of this country's energy program, and that LMFBR's can be built and operated without undue risk to the public or to the environment. Thank you for your interest in these important matters.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement, LMFBR Program (WASH-1535)

Enclosure 1

AEC Staff Response to Specific Comments by Mr. Wilfred Beaver#1. Comment:

"...there are environmental dangers inherent in the LMFBR fuel cycle which includes fuel fabrication and reprocessing, waste management and the problems of transportation."

AEC Response:

The AEC recognizes that this concern is shared by many other people and organizations. However, it is our belief after careful consideration and study of all relevant issues, culminating in the preparation of this Environmental Statement, that such concerns are not completely justified by the facts. Although there are areas in which further research and development effort is required, we are convinced that these efforts will be successful and that LMFBRs can be built and operated without undue risk to the environment. A full discussion of the basis for this belief and the research and development efforts planned or underway to verify this conclusion is included in Sections 4 and 7 of the enclosed Statement.

#2. Comment:

"We support, instead alternative energy sources such as solar energy and fossil fuels. We support hydroelectric dams and power generators which can supply electricity. These are the "safe" alternatives nature has given us to use."

AEC Response:

Your support of alternative energy sources such as solar energy and fossil fuels is understandable, and the AEC agrees that additional effort to develop all viable energy sources is warranted if the Nation is to maintain its economic growth. Nevertheless, as you will see from examination of Section 6 of the Statement, it is our belief that development of the LMFBR is an essential element of the program for meeting the Nation's energy needs. We do not feel that it is prudent to rely solely upon alternatives such as solar energy which require extensive research and development to bring to the point of large scale commercial utilization, regardless of the great potential it appears to hold in principle. Similarly, those techniques which are already developed and in use, such as fossil fuels and hydroelectric power, have recognized limitations. For example, Section 6A.3.4 states,

"Even though an absolute increase is expected, the proportion of total electric capacity attributable to conventional hydroelectric plants will decline from the present 15% to about 7% in 1990."

With regard to fossil fuels, oil and gas are in short supply and must effectively be ruled out as fuels for future central station electric power generation. Although the Nation's coal resources are very large they cannot be relied upon as the sole source of electricity generation, since in that event these large resources would be exhausted in less than a century even if no other requirements for coal (industrial, commercial, residential) are considered (See Section 11.4.1.1.2). Finally, with respect to "safe" alternatives you are referred to Section 11.3.2.2 which discusses human health and safety aspects of electrical energy generation. In particular, note Table 11.3-1 and Figure 11.3-1 in which coal is depicted as causing by far the largest number of fatalities, non-fatal injuries and occupational man-days lost of all six systems considered (coal, oil, gas, LWR, LMFBR, and HTGR) and the LMFBR the least.

#3. Comment:

"We support the exploitation of our coal reserves as a second line of defense and suggest fuel lines to carry coal slurry across vast distances. The use of coal "slurry" or slush coal and water is a fact and the government could hurry programs of this nature along instead of gambling on nuclear recycling programs."

AEC Response:

The AEC also supports the exploitation of our coal reserves and, as indicated above, recognizes they will be needed along with other energy sources to meet the Nation's energy requirements. Their use is reflected in the tabulation of projections of domestic coal consumption in Section 6A.1.2.5 of the enclosed Final Statement, which reflects the sharply increased rates of coal utilization anticipated during the next several decades. However, constraints on availability of needed equipment, manpower, water, and capital may render attainment of the higher projections - e.g., $1.5-1.9 \times 10^9$ tons/yr by 1985 - quite difficult. Coal slurry pipe-lining is discussed in Section 6A.2.1.3.2.2. As noted therein, a recent article (E. J. Wasp and T. L. Thompson, The Oil and Gas Journal, pp. 44-50 December 24, 1973) indicates that a large number of long-distance, high-volume coal-slurry pipelines from Western coal fields to Midwestern load centers are being planned, including a 1000-mile, 38-in.-diameter line that will transport 25 million tons of coal per year."

#4. Comment:

"Coal supplies appear to be sufficiently plentiful to provide for our electrical generation needs well beyond the next century, so that the choice between nuclear and fossil power generation will be made on economic considerations taking all costs, including pollution control, into account."

AEC Response:

Though our in-place coal reserves are adequate for the stated purpose, the utilization of these reserves in an economically competitive, safe, and environmentally acceptable manner to provide all our new electrical generating capacity over the next four decades has been considered unrealistic by every study group of which we are aware. The Ford Foundation, e.g., has stated: "Our analysis on alternative energy scenarios... shows that as long as this nation continues on a track of rapid growth in energy, nuclear fission energy will be needed to meet demand. Only under a long term commitment to substantial energy conservation could curtailment of nuclear power growth be taken seriously" (Exploring Energy Choices, A Preliminary Report of the Ford Foundation's Energy Policy Project, p. 28, 1974). In the long term, of course, we cannot rely on fossil fuels since it is universally agreed that they will be essentially depleted within a few centuries at most.

#5. Comment:

"It is serious enough that we now have the LWR fuel cycle without any recycling of plutonium fuel. You have stated that this terrifying plutonium recycle will become a significant factor in all LWR power plant operation before 1980. It will be limited by the even greater danger of the LMFBR into the power economy because plutonium is much more valuable as a breeder fuel than as a LWR fuel."

AEC Response:

The AEC recognizes the potentially hazardous properties of plutonium whether used as a fuel in LWRs or LMFBRs. Experience to date in handling plutonium at LMFBR fuel fabrication and fuel reprocessing plants is discussed in the Final Statement in Sections 4.3 and 4.4, respectively. In addition, engineering features (filters, etc.) for reducing the release of plutonium from these facilities are also described. Similar information is given in Sections 4.2 and 4.5 for LMFBR power plants and for transportation. Detailed information concerning plutonium toxicity is presented in Section 4.7 and Appendix II.G of the Final Environmental Statement and in AEC responses to the comments of the Environmental Protection Agency, Environmental Impact Assessment Project, and Natural Resources Defense Council on this subject. It is believed that plutonium can be safely used and contained through appropriate engineering measures, such as those discussed in the referenced Sections of the Final Statement and the appendices referring thereto.

#6. Comment:

"Another point of concern is of reactor gaseous wastes. The radioactive gas removal system installed in the commercial LMFBR is to be designed to

remove virtually all fission products from the primary system cover gas... there are ever present dangers of holding security systems for gaseous wastes."

AEC Response:

The problems of collecting and storing gaseous wastes are also amenable to engineering solutions. These matters are discussed in Section 4, as are those of all other radioactive wastes produced in the operation of LMFBRs and the LMFBR fuel cycle. In particular, the design of the LMFBR power plant radioactive waste processing systems is discussed in Section 4.2. Fission products would be removed from the primary system cover gas by use of HEPA filters, charcoal filters and cryogenic distillation columns. It is our opinion that the "dangers" or risks of maintaining control over gaseous wastes have been reduced to acceptable levels.

**DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD**

MAILING ADDRESS:
U.S. COAST GUARD (G-WS/73)
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE: (202) 426-2262

• 15 APR 1974

Mr. James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Liverman:

This is in response to your letter of 14 March 1974 addressed to Mr. Martin Convisser concerning the Draft Environmental Statement, WASH-1535-Liquid Metal Fast Breeder Reactor Program.

The Department of Transportation has reviewed the material submitted. We have no comments to offer nor do we have any objection to the program.

The opportunity to review this draft statement is appreciated.

Sincerely,

A handwritten signature in dark ink, appearing to read "R. I. Price", is written over a large, stylized, light-colored oval or loop.

R. I. PRICE
Captain, U. S. Coast Guard
Deputy Chief, Office of Marine
Environment and Systems
By direction of the Commandant

See response to letter 31 for combined reply to letters 4 and 31.

UNIVERSITY OF DELAWARE
NEWARK, DELAWARE
19711

INSTITUTE OF ENERGY CONVERSION
K. W. BOER, DIRECTOR
PHONE: 302-738-8481

April 8, 1974

Office of the Assistant
General Manager for Biomedical
and Environmental Research
and Safety Programs
US Atomic Energy Commission
Washington, DC 20545

Dear Sirs:

I have been contacted by Mr. Arthur R. Tamplin from the Natural Resources Defense Council, Inc., quoting a statement in the Draft Environmental Statement of the LMFBR Program, Page A.5-34: "The outlook appears to be that solar energy has little potential as an economical major source of electricity for several decades."

As a member of the NSF/NASA solar energy panel and of several NSF solar energy workshops, I feel that the above statement can be misinterpreted and needs some clarification:

To the best of my knowledge it is the feeling of the overwhelming majority, if not the consensus of the solar energy specialists in the field of solar energy conversion into electricity, that techno-economic feasibility of at least one mode of such conversion is highly probable. Progress obtained through NSF and NASA sponsored research and development during the last two years is very encouraging. Several industrial organizations are already involved and sponsor initial commercialization. Power utilities show increasing interest, including active research sponsorship.

Although it is estimated that it may take as long as ten years before installations can be built which can compete in cost with conventional installations, the majority of the photovoltaic specialists are convinced that shortly thereafter large scale production of solar cells could indeed provide a valid additional source of electric energy for large scale terrestrial use. It was with great restraint that this group of specialists estimated a modest market penetration with a slope similar to other fields in modern technology. Thus, indeed, it will take several decades from today before solar conversion into electricity will become a major factor in our national energy budget.

However, this is not different from other forms of energy conversion, as e.g. nuclear energy has taken almost three decades to operate in excess of 2% of the US electric energy budget.

On the other hand it could be expected that solar energy conversion into electricity, after proven economically attractive, may grow at a much faster rate, since environmental concern gives preference to solar energy.

Office of the Assistant
General Manager
April 8, 1974
Page Two

Using a figure of 10% of our currently installed electric power capacity (50 Million kW) as criterion for a market impact, this is equal to 1 Billion square meters of solar cells with a conservative total system efficiency of only 5%. If deployed on roofs of only currently existing single family dwellings, this would amount to less than 20% of such houses. The current roofing industry produces annually almost this quantity in roofing material. A more sophisticated product, e.g. photographic film is also produced annually in similar quantities.

With sufficient pressure applied through the extensive need for electric energy, it is quite probable that only a few years after the first plant for mass production of solar cells is established--(in the CdS/Cu₂S thin silm solar cell field a level of 1 to 10,000,000 m²/year production rate is estimated to run such a plant profitably)--many other plants will come on line. It is well conceivable that such plants can be built within four years from design to full operation. Given sufficient pressure to produce, it may only take eight more years from the first successful mass production, or less than 20 years from today, to have 1 Billion m² of solar cells produced, equivalent to more than 50 Million kW installed.

It is with deep concern to point out that such possibility exists with high probability only if sufficient funds are planned for the necessary research and development in this field. Research centers with overcritical size must be established swiftly and sufficient attention must be given to a field which is judged desirable and by its experts very probably techno-economically feasible.

But to the best of my knowledge, I am convinced that given this support, solar conversion into electricity can contribute by the end of the 1980's more electric energy to our energy budget than nuclear power today. I sincerely feel that solar energy conversion to electricity is a valid contender to help alleviate the energy shortage within the '80's.

Sincerely yours,

K. W. Böer

KWB/rh

Enclosure (reprint of July 1973 ChemTech article, "The Solar House and Its Portent")

V.5-3

CHEMTECH

The Innovator's Magazine JULY 1973

**The
solar house
and its
portent 394**

K. W. Böer

The solar house and its portent

No more could any single fuel have met all our past energy needs than will any single form of solar energy conversion meet all future demands. The Solar Home now seems able to shave peak load by controlling the climate generating its electricity.

K. W. Böer

Although solar energy is used in many ways some are often not normally associated with the sun. There is of course photosynthesis. But consider also hydroelectric power, wind, ocean currents, vertical temperature gradients in water and air, solar heating and solar conversion using photovoltaic cells. Let us examine the efficiency of each of these means for using the sun's rays and then focus on the state of the art on the last and newest—photovoltaic cells.

Solar radiation in mid-U.S. provides an input of 5 kWh/m² day as a yearly average. If converted into mechanical energy, sun shining on the U.S. could lift in one day the entire crust of our nation, 1,000 m thick, about 1 meter into the air, and with it all our cities, lakes, and forests. Solar energy impinging at high noon on an area of 35 km × 35 km equals the total peak capacity of all existing power plants combined. Obviously there is enough solar energy to satisfy our energy demands. Even if we continue to increase our demand to the ultimate saturation level estimated at 45 kW per capita (22 times the current level), and even if the U.S. population increases to 500 million people, only 0.3% of the solar energy impinging the U.S. would be needed to fill the resulting gigantic demand.

Because of solar irradiations fluctuating nature at the earth's surface, only these modes that have an easy means of energy storage can satisfy the consumer. Photosynthesis is the classical example: fossil fuels yield the benefit of millions of storage years while about 70 billion tons of carbon is fixed by assimilation in forests (1). Phytoplankton fix 40 billion

tons, and other vegetation 10 billion tons per year. These processes use about 10% of the CO₂ of the atmosphere, which corresponds to about 130 g carbon fixed per m² year. With an average solar irradiation of about 10 million Btu/m² year this carbon fixation rate corresponds to an average of 0.5% solar conversion efficiency.

Hydroelectric power also exhibits a low solar energy conversion efficiency. A typical hydroelectric plant's water reservoir (Philadelphia Electric Co.'s 512,000 kW Conowingo Plant) has an area of 13.4 square miles (2). It produces yearly about 3 billion kWh, although the solar radiation on this area is 68 billion kWh/year. Furthermore, the water feeding the reservoir is collected from an area estimated to occupy 27,000 square miles (2); hence the solar conversion efficiency of such a hydroelectric plant is less than .002%.

Winds, though powerful when concentrated in hurricanes, usually represent only a minute fraction of the solar energy transmitted to earth. Nevertheless, windmills may have a place in supplementing other energy sources where winds are reasonably constant (mountains or certain islands). Again windmills are most useful when energy storage facilities are feasible.

Many newer concepts are currently being discussed to convert solar irradiation into useful energy at considerably higher conversion efficiencies; these include solar heating and direct energy conversion. Two of these bold approaches involve a large area of several square miles covered with solar collectors.

The concept promoted by Arden Meinel (3) involves conversion of solar energy into high-grade heat and steam to produce conventional shaft work. For thermodynamic reasons these installations must

be "large": thousands of kW's. They also require focusing, hence they need locations with a sufficient amount of clear days, since focusing relinquishes benefits from diffuse radiation from hazy or cloudy skies. This idea has the advantage of using conventional rotary equipment for electric energy conversion and could easily interconnect with the current grid.

Another concept of Peter Glaser (4) is even more advanced. Glaser suggests putting in a parking orbit a giant satellite with several square miles of solar cells. It would convert solar energy into electric energy 24 hours per day and beam this energy to earth via microwaves.

It will probably take years of a concerted effort to show techno-economical feasibility of these concepts and it cannot be expected that they will impact on the national energy budget before the early 80's.

Solar houses

The use of solar energy in a spacially distributed fashion may offer a possibility to achieve an impact on the national energy budget at an earlier date. Since both solar energy and energy consumers are spacially distributed, investigation of a direct interface match is obvious. Photovoltaic solar conversion contains no thermodynamic bias toward the large single conversion installation, hence capital costs for its distribution, problems, and losses can be avoided. Since already existing "deployment structures," i.e., roofs, can be used as solar collectors, the solar house is a logical resultant.

Figure 1. Power demand and possible solar electric conversion in New Jersey for an average summer day; 300,000 one-family homes

Figure 2. Cross section through a solar electric/thermal flat plate collector as proposed for the solar house

For these economic advantages one has to forego two major advantages of other systems, Glaser's plant factor near 100% and utilization of an already established steam/electricity interface of the Meinel approach. A system involving solar houses means opening a new market involving numerous interfaces: architectural, environmental, legal, sociological and political, to mention just a few. Even if techno-economical feasibility can be shown, what will be the market-acceptance of a solar house?

We have begun to investigate these questions and have developed in a first iteration a solar energy conversion system that may have early market acceptance.

Market acceptance probably requires fulfilling at least five conditions:

- (a) Low first cost: Less than 10% of the cost of the house before solar modification
- (b) Solar energy converted into compatible energy should cost no more than conventional energy
- (c) The solar energy system should have reliability similar to conventional systems.

(d) The solar energy system should perform at least as well as accepted conventional systems with regard to comfort control, etc.

(e) There should be visible incentives for at least one member of the builder/consumer chain without major disincentives for any other member

These conditions can only be fulfilled if solar energy is used as supplemental rather than substitutional energy. Operation of the system in conjunction with electric power utilities offers distinct advantages for both partners, especially in southern parts of the country, as periods of high insolation are closely correlated to periods of high power demand. It is therefore conceivable that solar energy would be used for peak demand relief, while conventional power would be supplied from utilities during night hours and times of inclement weather. Given sufficient incentives, power utilities might subsidize a solar conversion system. Such incentives may include reduced capital need via peak shaving and power they could call on demand from a distributed source of low vulnerability and zero fuel consumption. Subsidies could include relief on first cost.

For simplicity these concepts may be explained using direct solar conversion via solar cells. The single family house can exemplify the main principles involved, and it is also sufficiently small and inexpensive to allow for early experimental verification of various alternatives.

Figure 1 shows for an average summer day a typical power demand curve of New Jersey. If solar cells of 7% conversion efficiency are deployed on 20% of the single family houses in New Jersey, electric energy could be harvested on a sunny day yielding the peak demand reduction shown. However, with only 30% electric storage (e.g., in lead acid batteries at each house), one could arrive at almost perfect peak shaving. The system could be held at optimal levels by radio-controlled successive disconnection of solar houses from the utility grid. Other means of communication from the power utility to the consumer units are currently under investigation for remote meter reading. They too could be employed for switching.

It is proposed that some minimum charge would be maintained in each battery, which could only be used when called for by the power utility in case of a power emergency. The capacity of this emergency reservoir would be large enough to supply a sequence of emergencies interspaced with days of inclement weather with a probability sufficient for utility operation (one possible failure in 10 years, or 99.97% reliability). Maintenance of a relatively large minimum charge in the battery decreases the depth of the charge/discharge cycle and increases the life expectancy of batteries.

In principle, these two concepts—peak shaving and power on demand—can also be applied to thermal energy conversion. Storing thermal energy and disconnecting electrically powered auxiliary equipment (heater and air conditioner) during hours of peak power demand are quite feasible and will now be explained in more detail.

Proposed solar house system

A combined solar electric and thermal collector for rooftop deployment is proposed. Figure 2 shows a

cross-section through one version of such a collector. For economic reasons CdS/Cu₂S thin-film solar cells are suggested for electricity generation. Heat is picked up from the back surface of these cells. Air is used as heat transport fluid, and is ducted for maintaining homogeneity. Two transparent panes at the front and foam insulation at the edges and back of the solar collector minimize thermal losses.

The solar cell arrays are connected to an electric power processing unit that contains a means for electric storage and dc to ac inversion. Figure 3 is a schematic of the system.

The heated air is ducted into a heat processing unit with means for thermal energy storage, heat processing for comfort conditioning, and heat exchange to the living space of the house. For the proposed house a heat pump in conjunction with a base heat reservoir will be employed. The purpose of the base heat reservoir is to decrease the temperature difference that the heat pump has to maintain to achieve comfort conditioning, and hence will increase the efficiency of the heat pump. The base heat reservoir will operate near room temperature, in the 70° to 75°F range.

During a sunny winter day heat will be supplied in the morning to the base heat reservoir and amplified through the heat pump to charge a secondary heat reservoir (near 120°F). This reservoir is interfaced through a heat exchanger with the living space. As noon approaches and the temperature of the solar collector increases sufficiently to heat the secondary reservoir, a direct connection to this reservoir is established and the heat pump is switched off. In late afternoon hours, lower grade heat is again fed into the base reservoir; however, the heat pump is left off to reduce the power load on the external grid. The house is heated via stored heat into early night hours as long as high power demand on the external grid is present. Thereafter the heat pump is switched on to amplify heat from the charged base reservoir and to fill the secondary heat reservoir for use during the next day.

Work of the heat pump is necessary primarily after inclement weather. After a sunny day sufficient heat remains in the secondary reservoir to carry the house through at least one cloudy day. During an extended period of heavy clouds the base reservoir will be charged by additional heat from an auxiliary electric heater.

During a clear summer night the base reservoir will be cooled through air from the collector by radiation cooling. The heat pump will operate mainly during night hours and coolness will be stored in the secondary heat reservoir, typically near 50°F. The capacity of the heat reservoir shall be sufficient to avoid the necessity to operate the heat pump during hours of peak power demand. When operation of the heat pump is necessary during day hours, it will pump heat to the base reservoir, charged at 75°F during night hours (nocturnal cooling), rather than to the hotter outside, hence improving its performance.

The house will be connected to the external grid during night and early morning hours. Harvested electric energy from solar cells will be stored in a lead acid battery of less than a full day's storage ca-

Figure 3. Electric and thermal system for the solar house

capacity. During hours of peak power demand the house will be disconnected from the utility grid and harvested and stored electric energy will be used until a minimum charge (about 40%) or the end of peak power demand (about 9 pm) is reached, at which time the house is reconnected to the utility grid.

The harvested electric energy will be used as dc for certain major appliances (e.g., kitchen stove, heating coil of clothes dryer, auxiliary house heater, universal motor fans, and permanent light fixtures) and through individual inverters as ac for the heat pump and the refrigerator.

Karl W. Böer, Director of the Institute of Energy Conversion and Professor of Physics and Engineering at the University of Delaware received his Dipl. Phys. and Ph.D. degree from Humboldt University in Berlin, where he was finally professor with prof. chair, director of the IV Physics Department and director of the Laboratory of Dielectric Breakdown at the German Academy of Science, Berlin. He is founder and was Editor-in-Chief of *Physica Status Solidi*. After one year at N.Y.U. (1961-62) he joined the Physics Department of the University of Delaware. His main field of research, solid state physics especially related to CdS, is documented in 165 publications. Böer is a member of the OST Solar Energy Assessment Panel, fellow of the American Institute of Physics, senior member of IEEE, member of the International Solar Energy Society, and listed in *Who's Who in the World*.

Figure 4. Solar house model

Future improvements are expected for the electric battery (11) to increase the economically justifiable storage capacity and for a general dc to ac inverter, to improve the houses interconnect to the utility grid.

Present status

A solar house containing the above mentioned features is under construction at The University of Delaware. It contains about 1500 ft² of floor area: living/dining room, two bedrooms, 1½ baths and kitchen on the main floor and a possibility of adding two more bedrooms at second floor level. The garage will be used as an exhibition area. Its 45° roof will contain 24 panels, 4 × 8 ft each (Figure 1). Six additional flat plate thermal collectors will be placed in the south wall of the house for heat boosting during winter. Figure 4 shows a model of the solar house.

Initially only part of the roof will be equipped with CdS/Cu₂S solar cells and make-up electric energy from a power supply, slaved to the solar cell output, will be used to charge an 18 kWh lead acid battery (typically 18 car batteries). As improved CdS/Cu₂S solar cells become available, additional roof panels will be equipped. Such cells are in development at our Institute under a grant from NSF/RANN.

The solar cell

The CdS/Cu₂S solar cell is a thin film sandwich of a metal substrate onto which *n*-type CdS is evaporated at a typical 20 μm thickness. A thin *p*-type layer of Cu₂S is prepared via ion-exchange reaction, on top of the CdS, and a light transparent grid electrode is cemented to this sandwich and sealed with a uv-resistant Mylar sheet (Figure 5a). Such a cell shows, in full sunlight, a current voltage characteristic such as that given in Figure 5b. At the maximum power point a good cell delivers 19 mA/cm² at 0.37 volt with 7% conversion efficiency (5, 6). However, only a small fraction of currently produced cells have such high conversion efficiency. Also most of the cells still degrade markedly when exposed to a

Figure 5a. Cross section through a typical CdS/Cu₂S solar cell

humid atmosphere at elevated temperatures. Recent progress made at our Institute is promising for developing a 10+ year CdS/Cu₂S solar panel for roof deployment and with high production yield. The first panels are currently under life and performance test on the roof of the Institute (Figure 6). Typical traces of the electric output (panel voltage at 40 W load) of such panel is shown for different days of the year in Figure 7.

Heat storage systems

For heat storage purposes salt eutectics that make use of heat of fusion will be utilized. The base reservoir will contain a eutectic salt melting near 75°F, the secondary reservoir will have two eutectics in alternating containers, one melting near 50° and the other near 120°F. These units are being developed by Dr. M. Telkes of the Institute.

Economic analysis

Seven major factors enter into the cost of this system. First cost of the solar system, cost of money (interest), lifetime of the components, maintenance, taxes and insurance, and the annual average of harvested energy.

The first cost of the solar system can only be estimated after we know its "seize," which can be determined from a systems analysis for seize optimization. Such analysis is complex because it includes daily averages of insolation for different seasons, performance as influenced by thermal and electrical energy harvesting, systems definition, price of the different components of the system, storage capacity optimization, load analysis and a number of factors related to different interface incentives, which are usually difficult to quantize. Optimization needs to be performed with respect to the overall earning capacity of the system, hence it involves the other factors of the economic analysis mentioned above and therefore requires iteration.

A few estimates for specific solar thermal systems are available and are used as a basis for the first ite-

Figure 5b. Current voltage characteristic of a typical CdS/Cu₂S solar cell with 4.3% conversion efficiency

ration of the proposed solar house system. Most developed is the Löff/Tybout estimate (7), which indicates that for a climate comparable to Delaware's, system size should provide about 50% of the needed energy from the solar harvesting. This estimate has been extended for a thermal/electric harvesting system by V. M. Puri (8), who essentially substantiated the 50% figure. Both investigations also indicate that the minimum for annual cost of energy using such combined solar/conventional system is rather low, and, for reasons of market acceptance the use of a slightly higher ratio may be justifiable.

We have assumed an 80% solar/20% conventional system for the following discussion. It is based on the current state of the art for all components; however, it assumes that mass production technology can be developed with high production yield. We have also assumed that a life of 15 years can be achieved for all components except the battery, for which a five-year life is used.

For a typical single family dwelling a solar electric/thermal collector area of 800 ft² is assumed.

The cost of CdS/Cu₂S solar cells with mass-production techniques applied has been estimated by Aaron and Isakoff (9) and by Olson (10) at about \$1/ft². For protection and telltale \$0.15/ft² is assumed. The cost to produce collector panels including installation is estimated (8) at \$1.35/ft². Credit for unnecessary plywood and roof shingles and their installation is estimated at \$0.70/ft². Additional thermal equipment is estimated at \$0.45/ft² yielding total cost of the solar collector of \$2.25/ft², or \$1800 for the 800 ft² roof.

To this cost one needs to add the cost of the thermal storage estimated at \$900 and the cost of the electric power processing unit. Using 50% dc with control switching and individual inverters for refrigeration systems plus 3 sets of 9 kWh lead acid batteries at \$28/kWh to be acquired in year 1, 6, and 11, one estimates a leveled process equipment cost for electric power of \$850. Against this cost we apply

Figure 6. Flat plate collector panels for thermal (left background) for electrical (foreground) and for electric/thermal (right background) solar energy harvesting. The small panel (right foreground) produces 12.6 volt at almost 1 amp. The other two panel assemblies produce 110 volt at 700 mA

Figure 7. Electric energy output of the electric/thermal solar panel of Figure 6 on (a) a clear summer day, (b) a cloudy summer day, and (c) a partially cloudy winter day at the end of January. The overshoot in (c) between clouds is due to additional light reflected from clouds

a credit for the cost of an oil heater and tank plus installation minus the cost of an electric heater to maintain base storage at 70°F during inclement winter weather. This cost differential is estimated at \$520 credit.

The total cost of the solar electric/thermal system exceeds a conventional system by approximately \$3000.

With 6.5% interest, 2.5% levelized amortization, 3% maintenance and insurance one obtains \$360/year as cost of energy (12% of first cost).

In Delaware such a system would produce approximately 80 million Btu's of useful thermal energy. With a 6% overall electric conversion efficiency and an average of 5 hours sunshine per day, one would obtain 24 kWh of electric energy. This would be equivalent to \$1.50/million Btu's and 2.7¢/kWh, figures that compare favorably with the current average price of energy in Delaware.

Were power utilities to service this system, one would have to apply at least a 16% rate to convert first cost into annual cost, or \$480/year. This could translate into \$2/million Btu's and 3.7¢/kWh. It is conceivable that the consumer price of energy will be at this level in the late 1970's and that such a system is economically acceptable.

It should be noted that the estimates have been made for 1972 dollars with no allowance for inflationary adjustment. Numerous assumptions have been included with little effort for systems optimization. The given results therefore can only be taken as preliminary. If these findings can be substantiated, a system of the kind proposed here could have an impact on the national energy budget before the end of

this decade, since essentially all components are state of the art and probably need no technology breakthrough to become acceptable. The solar house currently in construction in Delaware will help to establish the degree of possible acceptance. A major research effort, however, is needed to substantiate the findings and to translate the components of the system into mass production items with acceptable production yield, cost, and life expectancy.

Acknowledgment. It is a pleasure to acknowledge countless hours of helpful discussions with Drs. M. Telkes, P. Massicot, and M. K. Selcuk. Major features of the proposed thermal system were suggested by Dr. Telkes. The work is supported by grants from the National Science Foundation, the University of Delaware Research Foundation, Delmarva Power and Light, and the U.S. Office of Naval Research.

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. K. W. Böer
Director, Institute of Energy Conversion
University of Delaware
Newark, Delaware 19711

Dear Mr. Böer:

Thank you for your letter of April 8, 1974 commenting on the statement on page A.5-34 of the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program,

"The outlook appears to be that solar energy has little potential as an economic major source of electricity for several decades."

The AEC has reviewed your letter and believes that it does not basically conflict with the position taken in the Draft Statement as to the time when solar energy can potentially become an economical major source of electricity. We do have some reservations on several of your other projections, covering the growth rate of solar energy utilization as a source of electricity and the contribution it can make to the Nation's electrical supply in the 1980's. You are apparently projecting these optimistic estimates on the basis of individual home installations including conversion of existing homes. We do not believe that conversion to solar power is practical for existing homes because of the associated high capital costs and the preexistence of installed heating and lighting equipment. It is most likely that solar equipment will be largely confined to new housing and will be introduced quite gradually, progressing from those areas where it is most clearly superior to other areas as they become competitive and as the social (housing codes, site restrictions, sun rights, etc.) acceptability grows.

However, even if one accepts your estimates and concedes that 50 million kilowatts could be installed in "less than 20 years from today," this would amount to less than 5% of the projected central station capacity for that time period. Although that certainly would not be an insignificant amount, it could not be considered a major source of electrical energy.

Mr. K. W. Böer

2

Please refer to Section 6A.5.5 of the enclosed Final Statement for a detailed discussion of present and projected applications of solar energy as seen by a number of groups including NSF/NASA, Subpanel IX, and the MITRE Corporation.

In addition, we would like to note that CdS/Cu₂S solar cells may not be a viable source upon which to build a large scale photovoltaic electrical generating industry. This is so partly because the adequacy of the supply of ¹/_{cadmium} to support a large scale industry is not established, ¹/_{and} partly because the environmental implications are not favorable. CdS/Cu₂S solar cells are of interest mainly because they are projected to ultimately have the lowest cost (\$50/kw) of all known practical solar cells materials. Silicon solar cells, which appear to be the practical material for photoelectric application, cost up to \$200,000/m² for space applications, translating to a total capital cost of \$2,000,000/KWe. For terrestrial applications, estimates ²/_{have} been made that capital costs, including collectors, energy storage, and power conditioning equipment might be about \$5,000/KWe average in the year 2000 and that this cost might fall to \$2,500/KWe average by the year 2020. The study indicated that solar costs would exceed conventional power costs by a factor of four in the year 2000 and a factor of 1.7 in the year 2020.

We trust the above discussion places our respective positions on the potential of solar energy in the proper perspective. Thank you for your interest in the LMFBR program and your informed comments.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

- ¹/_{See} Section 6A.5.7.2 in the Final Statement
²/_{MITRE Corporation Report, MTR-6513, "Systems Analysis of Solar Energy Programs," December, 1973}

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W. H. Pennington
Division of Biomedical and
Environmental Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Pennington:

Enclosed are three copies of comments we have prepared regarding the draft environmental impact statement for the Liquid Metal Fast Breeder Reactor (LMFBR) Program and are submitting to you for your consideration pursuant to the notice at 39 Fed. Reg. 9692 (1974). These comments concern Volume II, Part 2, Section 4.G.5 (pages 4.G-89 to 4.G-105) and primarily discuss lung particle dose effects and related issues.

We would appreciate a full response to these comments in the final impact statement.

Sincerely,

J. G. Speth

JGS/ket

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NRDC Comments on WASH 1535

Draft Environmental Statement

Liquid Metal Fast Breeder Reactor Program

Re: Volume II, Part 2, Section 4.G.5,

Particle Lung Dose Effects

Pages 4.G-89 to 4.G-105

Arthur R. Tamplin

Thomas B. Cochran

Introduction

On 13 Nov. 1973 and 26 Dec. 1973, we submitted for consideration in the preparation of this Draft Environmental Statement on the LMFBR Program, our comments relative to the carcinogenic hazard of plutonium.^{1, 2} Subsequently, on February 14, 1974, we submitted a petition to the AEC and EPA asking for radiation protection

1/ Tamplin, Arthur R., "Comments Submitted to the Atomic Energy Commission, 3. Discussion of the Carcinogenic Hazards of Plutonium," Natural Resources Defense Council, 13 Nov. 1973.

2/ Tamplin, Arthur R., Letter to Dr. James L. Liverman, "Re: Additional Comments Concerning the Carcinogenicity of Pu," Natural Resources Defense Council, 26 Dec. 1973.

- 2 -

standards that would be 115,000 fold more restrictive than the present standards when insoluble alpha-emitting hot particles were involved.³ In support of this petition and for consideration in the Draft EIS, we submitted a 50-page report detailing the scientific basis for the requested modification of the standard.⁴

Upon receipt of copies of the Draft Environmental Impact Statement we were appalled at the treatment of this problem in Section 4.G.5, Particle Lung Dose Effects, Volume II, Part 2, pages 4.G-89 to 4.G-105. These pages are shallow, self-serving and not supportive of the conclusion reached on page 4.G-103 that the average lung dose is appropriate for estimating the health consequences from hot particles. For example, one of the references (No. 23) is only an abstract. Apparently, the AEC was only interested in a statement made in the abstract, not in whether the experiment was valid or adequate, or the Commission would have endeavored to find a reference to the complete publication of the experiments. However, as we shall show later, the experiments as described in the abstract are irrelevant to the hot particle risk.

In our report and in our communication of 26 Dec. 1973,⁵ we called attention to the paper of Lushbaugh, et al.,⁶ wherein

3/ NRDC, "Petition to Amend Radiation Protection Standards As They Apply To Hot Particles," Before the EPA and AEC, Natural Resources Defense Council, 14 Feb. 1974.

4/ Tamplin, Arthur R. and Thomas B. Cochran, Radiation Standards for Hot Particles, Natural Resources Defense Council, 14 Feb. 1974.

5/ Ibid, pp. 27-28, and Tamplin, Arthur R., Letter to Liverman, Op. cit.

6/ Lushbaugh, C.C., et al., Arch. of Dermatology, Vol. 86, Oct. 1962, pp. 461-464.

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a single particle of plutonium produced a precancerous lesion in the palm of a mechanic. The Lushbaugh article is significant because it demonstrated the hazard of a single particle. As an example of the self-serving nature of these pages of the Draft Statement, no mention is made of the Lushbaugh article, but reference is made to an article by Richmond, et al., (reference no. 9) seemingly to support the conclusion reached on page 4.G-103. We say seemingly because this article actually supports our arguments; for example, Richmond, et al., state that similar lesions are produced in the lung by hot particles:

"Such a lesion with collagenous degeneration and subsequent liquefaction, due to the large local dose of radiation at a high dose rate, has been reported by Lushbaugh et al.,⁽⁹⁾ whose description of a plutonium lesion found in the dermis is very similar to that observed for plutonium in the lung."⁷

The Hot Particle Hazard

Considering the critical nature of the hot particle problem, and the AEC's budget of \$100 million for biomedical research, it is indeed a sad commentary that the general public has to correct the errors of omission and commission on pages 4.G-89 to 4.G-105.

However, to respond appropriately, it will first be necessary for us to present our analysis of the "Particle Lung Dose Effect."⁸ We shall then discuss varied objections on a page by page basis to pages 4.G-89 to 4.G-105 and demonstrate that these pages have little relevance to the hot particle problem and certainly do not

^{7/} Richmond, C.R., et al., Health Physics, Vol. 18, 1970, p. 406.

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support the conclusion on page 4.G-103 that, "the preponderance of the evidence indicates that the use of an average lung dose is appropriate in estimating health consequences and may well be conservative."

* * * * *

IV. Calculating the Dose Due to Insoluble Alpha-Emitters

The purpose of this section is to examine the assumptions in the radiation standards above that are inappropriate when applied to insoluble alpha-emitting particulates such as aerosols of PuO_2 . The assumptions are introduced through a review of basic definitions of radiation dose and the factors used to calculate the dose..

A. The Dose Equivalent

When an X-ray or the radiation emitted by a radionuclide passes through tissue it transfers energy to the cells in

8/ At this point we shall reproduce a portion of our report, Tamplin and Cochran, Op. cit., pp. 11-34. The next footnote, therefore, becomes number 17, which corresponds to the number in our report. Some footnotes will refer to Op. cit. which occurred earlier in the report. These are listed below:

ICRP Publication 9, Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1966), Pergamon Press, New York, 1966, p. 14.

NCRP Report No. 39, Basic Radiation Protection Criteria, NCRP Publications, Washington, D. C., Jan. 15, 1971, p. 106.

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these tissues. This energy produces chemical changes in the molecule of the cells; for example, such a chemical change could be a mutation in a gene. The radiation dose is actually a measure of the energy transferred to or absorbed by the tissue. The basic unit of dose is the rad (one rad represents the absorption of 100 ergs of energy per gram of material).

In addition to X-rays, radionuclides emit gamma rays (high energy X-rays), beta particles (electrons), and alpha particles (helium nuclei). In radiobiological experiments, it was determined that, while these various types of radiation produced the same biological effects, such as cancer, the magnitude of the effect was not the same per rad. For example, it was found that 100 rad of alpha radiation would produce roughly 10 times as many cancers as 100 rad of X-rays. Moreover, it was found that because of the special way in which Pu-239 deposits in the bone, its alpha particles were 5 times more effective in producing bone cancer than the alpha particles from radium¹⁷. To account for these differences in the magnitude of the observed effects at the same absorbed dose in rad, the maximum permissible dose limits are given in rem rather than rad.

The MPLD is given in rem in Tables I and II. The

¹⁷/ ICRP Publication 11, "A Review of the Radiosensitivity of the Tissues in Bone," Pergamon Press, New York, N. Y., 1967, p. 21.

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rem is the unit of Dose Equivalent (DE)¹⁸. The DE is obtained by multiplying the absorbed dose in rad by modifying factors to correct for these observed differences in the magnitude of the effect. As a consequence, the magnitude of the effect will be the same for a given DE regardless of the nature of the radiation or the manner of radiation.

B. Modifying Factors

At the present time, two modifying factors are employed. One is the Quality Factor (QF) which accounts for differences in producing biological effects among various forms of radiation. The other is the Distribution Factor (DF) which accounts for the modification of the biological effects when a radionuclide is nonuniformly distributed in an organ. For example, the DE for X-ray to bone tissue is determined by using QF=1 and DF=1, while that for Pu-239 in the bone is determined by using a QF=10 (to account for the greater effectiveness of alpha particle irradiation) and a DF=5 (to account for the peculiar distribution of Pu in the bone)¹⁹. A DE=50 rem from X-rays or Pu-239 would thus induce the same number of cancers in bone but the absorbed dose from the X-rays would be 50 rad while that from Pu-239 would be only 1 rad.

^{18/} NCRP Report No. 39, Op. cit., p. 81.

^{19/} ICRP Publication 11, Op. cit., p. 21.

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In obtaining the derived values in Tables I and II, MPLB and MPC_a for Pu-239, a QF=10 was employed. This QF implies, as mentioned above, that the particles of Pu-239, which emit alpha particle radiation, are 10 times more effective in inducing cancer than X-rays. Although the irradiation of tissue by insoluble plutonium particles is highly nonuniform, no DF value has been assigned to these particles and hence, a DF=1 was employed in determining the derived values in Tables I and II. Ideally, the DF should be determined by the ratio of the observed effects in an organ following uniform and nonuniform radiation of the tissue with the same radionuclide; for example:

$$DF = \frac{\text{Number of cancers (nonuniform irradiation)}}{\text{Number of cancers (uniform irradiation)}}$$

Since direct experimental data are not available, it is necessary to derive the DF for insoluble Pu-239 particles from collateral data. In a subsequent section, we shall present the biological evidence that strongly suggests that a DF=1 grossly underestimates the DE for insoluble particulates of Pu-239 and, consequently, that the derived standards, MPLB and MPC_a for this radionuclide, are greatly in error.²⁰ In fact, it will be shown that the biological data strongly suggests that for such particles one should use a DF=115,000.

^{20/} This applies as well to other alpha-emitting actinides in insoluble particulate form.

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Before turning to the biological data it is appropriate to discuss first the radiation field around a particle of PuO_2 and thereby define the fundamental questions that need to be answered by the collateral data from radiobiological studies.

The unique form of tissue irradiation displayed by insoluble particles of Pu-239 occurs because, when Pu-239 decays, it emits an alpha particle with an energy of 5.1 MeV. This particle has a range (produces biological damage) of only some 40-45 u (0.004 cm) in human tissue. In other words, a Pu-239 particle in tissue will only irradiate a volume of tissue enclosed in a sphere of 45 u radius. As one moves inward from the surface of this sphere, the radiation intensity increases geometrically. About half of the alpha particle energy is dissipated at 20 u (that is, with a volume that is 1/8 the total volume). This means that the average dose delivered in the first 20 u is 8 times that delivered in the remaining 20 u. The first column of Table III describes the radiation field around such a particle in soft tissue; e.g., the skin. Since the lung is a spongy tissue with a large air volume, the range of alpha particles is longer in the lung and consequently the mass of irradiated tissue is larger. Professor Donald Geesaman made a detailed analysis of plutonium

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particle irradiation of deep respiratory tissue²¹. The last two columns in Table III describe the radiation field around such a particle in the lung using Geesaman's lung model²². The dose rate to the entire organ is given in column 2 of Table III for comparison. From Table III it is significant to note that with an assumed DF=1, the lung dose from the same particle varies by more than 8 orders of magnitude depending on whether one averages the dose over the entire lung or calculates it on the basis of the tissue exposed.

TABLE III

Radiation Dose Rate Due to a Pu-239 Particle

(1 μ in diameter, 0.28 pCi²³)

	Soft Tissue Irradiated ²⁴	Lung		
		Entire Organ	Tissue Irradiated ²⁵	Closest 20 Alveoli ²⁶
Mass of Tissue	0.4 μ g	1000 g ²⁷	65 μ g	19 μ g
Dose Rate (rem/yr)	730,000	0.0003	4000	11,000

21/ Geesaman, Donald P., An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue, UCRL-50387 and UCRL-50387 Addendum, Lawrence Livermore Laboratory, Livermore, Calif., 1968.

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It would take 53,000 particles of the size illustrated in Table III to reach the MPLB of 0.016 uCi which results in 15 rem/yr to the entire (1000 g) lung. However, as Table III indicates, these particles would irradiate only 3.4 g of this 1000 g to the lung, but at a dose rate of 4000 rem/yr²⁸. Thus, as Table III indicates, these particles result in an intense but highly localized irradiation. A fundamental question is, then: is this intense but localized irradiation more or less carcinogenic than uniform irradiation? Alternatively, is the DF for this particular form of irradiation equal to, greater than, or less than one? In the remainder of this section, we review the guidance, or more appropriately lack of guidance, for dealing with this hot particle problem.

22/ Geesaman, Donald P., UCRL-50387, pp. 8, 15.

23/ Langham, Wright H., The Problem of Large Area Plutonium Contamination, U. S. Dept. of H., E. W., Public Health Services, Seminar Paper No. 002, Dec. 6, 1968, p. 7.

24/ Long, A.B., "Plutonium Inhalation: The Burden of Negligible Consequence," Nuclear News, June 1971, p. 71.

25/ Geesaman, Donald P., UCRL-50387, pp. 8, 15. Based on Geesaman's model for a lung at one-half maximum inflation. Geesaman estimates a total of 68 alveoli at risk, each 8×10^{-6} cm³ in volume, and deep respiratory zone tissue density of 0.12 g/cm³.

26/ See footnote 23.

27/ Based on a lung mass of a standard man = 1000 g.

28/ This assumes that the radiation field of the 53,000 particles do not overlap.

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C. The Hot Particle Problem

It is important to recognize that the ICRP has given no guidance with respect to nonuniform irradiation of the lung by insoluble alpha-emitters such as insoluble plutonium particles. In its Publication 9, the ICRP states:

...In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung.²⁹

In effect, the ICRP is saying that there is no guidance as to the risk for non-homogeneous exposure in the lung, hence the MPC_a and the MPLB are meaningless for insoluble plutonium particles.

The NCRP offers the following and similar statement with respect to these particles:

(210) The NCRP has arbitrarily used 10 percent of the volume of the organ as the significant volume for irradiation of the gonads. There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a single particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung or even over one cubic centimeter may have little to do with this case.³⁰

This hot particle problem is also well recognized in the biological community. The following is extracted from a

^{29/} ICRP Publication 9, Op. cit., p. 4.

^{30/} NCRP Report No. 39, Op. cit., pp. 79-80.

paper by Professor Donald P. Geesaman:

So there is a hot particle problem with plutonium in the lung, and the hot particle problem is not understood, and there is no guidance as to the risk. I don't think there is any controversy about that. Let me quote to you from Dr. K. Z. Morgan's testimony in January of this year before the Joint Committee on Atomic Energy, U.S. Congress. [a] Dr. K. Z. Morgan is one of the United States' two members to the main Committee of the International Commission on Radiological Protection; he has been a member of the committee longer than anyone; and he is director of Health Physics Division at Oak Ridge National Laboratory. I quote: "There are many things about radiation exposure we do not understand, and there will continue to be uncertainties until health physics can provide a coherent theory of radiation damage. This is why some of the basic research studies of the USAEC are so important. D. P. Geesaman and Tamplin have pointed out recently the problems of plutonium-239 particles and the uncertainty of the risk to a man who carries such a particle of high specific activity in his lungs."

At the same hearing, in response to the committee's inquiry about priorities in basic research on the biological effects of radiation, Dr. M. Eisenbud, then Director of the New York City Environmental Protection Administration, in part replied, "For some reason or other the particle problem has not come upon us in quite a little while, but it probably will one of these days. We are not much further along on the basic question of whether a given amount of energy delivered to a progressively smaller and smaller volume of tissue is better or worse for the recipient. This is another way of asking the question of how you calculate the dose when you inhale a single particle." [b] He was correct; the problem has come up again.

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- [a] Morgan, K. Z., "Radiation Standards for Reactor Siting," in Environmental Effects of Producing Electrical Power Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Congress, 1970. Washington, D. C., U. S. Government Printing Office.
- [b] Eisenbud, M. Panel Discussion. In: Environmental Effects of Producing Electrical Power, Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Congress, 1970. Washington, D. C., U. S. Government Printing Office.

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In the context of his comment it is interesting to refer to the National Academy of Sciences, National Research Council report of 1961 on the Effects of Inhaled Radioactive Particles. [c] The first sentence reads, "The potential hazard due to air-borne radioactive particulates is probably the least understood of the hazards associated with atomic weapons tests, production of radioelements, and the expanding use of nuclear energy for power production." A decade later that statement is still valid. Finally let me quote Drs. Sanders, Thompson, and Bair from a paper given by them last October. [d] Dr. Bair and his colleagues have done the most relevant plutonium oxide inhalation experiments. "Nonuniform irradiation of the lung from deposited radioactive particulates is clearly more carcinogenic than uniform exposure (on a total-lung dose basis), and alpha-irradiation is more carcinogenic than beta-irradiation. The doses required for a substantial tumor incidence, are very high, however, if measured in proximity to the particle; and, again, there are no data to establish the low-incidence end of a dose-effect curve. And there is no general theory, or data on which to base a theory, which would permit extrapolation of the high incidence portion of the curve into the low incidence region." I agree and I suggest that in such a circumstance it is appropriate to view the standards with extreme caution.³¹

[c] U. S. NAS-NRC Subcommittee, Effects of Inhaled Radioactive Particles. Report of the Subcommittee on Inhalation Hazards. Committee on Pathologic Effects of Atomic Radiation. National Academy of Sciences - National Research Council, Washington, D. C. 1961. Publication 848. NAS-NRC/PUB-848, 1961.

[d] Sanders, C.L., R.C. Thompson, and W.J. Bair, "Lung Cancer: Dose Response Studies with Radionuclides." In: Inhalation Carcinogenesis. Proceedings of a Biology Division, Oak Ridge National Laboratory, conference held in Gatlinburg, Tennessee, October 8-11, 1969. M.G. Hanna, Jr., P. Nettesheim, and J.R. Gilbert, eds., U. S. Atomic Energy Commission Symposium Series 18, 1970. pp. 285-303. (CONF-691001).

31/ Geesaman, Donald P., "Plutonium and Public Health," Lawrence Livermore Laboratory, Calif., GT-121-70, April 19, 1970, reproduced in Underground Uses of Nuclear Energy, Part 2, Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U. S. Senate, 91st Congress, 2nd Session, August 5, 1970, pp. 1530-1532.

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To these comments, referenced by Geesaman, can be added the comments of Dr. A. B. Long:

"... there is an urgent need to dispell the sense of security and certainty that the present limits for the maximum permissible lung burden and the maximum permissible air concentration bring . . . the public should be informed of the uncertainties that exist in these limits."³²

V. Biological Data Related to Cancer Risk from Insoluble Plutonium Particles

We have shown that insoluble alpha-emitting particles result in intense but localized radiation. They can irradiate at very high doses without being organism- or organ fatal. We said that the available biological data strongly suggests that a $DF=1$ grossly underestimates the DE for insoluble particulates of Pu-239, and consequently, the derived standards MPLB and MPC_a for this radionuclide are greatly in error. We now turn to the experiments involving cancer induction by intense local exposure, since these are especially relevant in judging whether or not insoluble alpha-emitting particles constitute a unique risk. Geesaman collected and analyzed the pertinent experiments, and what follows

^{32/} Long, A.B., Op. cit., p. 73.

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is essentially a review of his analysis³³, which has become known as the "Geesaman hypothesis."

A The Geesaman Hypothesis

Dr. Roy E. Albert and co-workers performed a number of experiments on the induction of cancer in rat skin³⁴⁻³⁶. Albert's study of radiation-induced carcinoma in rat skin gives some quantitative description of a high-dose carcinogenic situation. A skin area of 24 cm² was exposed to electron radiation with various depths of maximum penetration. The dose response curves are reproduced in Figure 1. In all cases the response at sufficiently high doses (1000-3000 rem) was large, ~1-5 tumors per rat by 80 weeks post exposure. It was noted by Albert that when the dose was normalized to a skin depth of 0.27 millimeters, the three response curves became continuous (See Figure 2). Since this

33/ Geesaman, D.P., UCRL-50387 Addendum, Op. cit.

34/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "The effect of penetration depth of electron radiation on skin tumor formation in the rat," Radiation Res. 30, 1967, pp. 515-524.

35/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "Skin damage and tumor formation from grid and sieve patterns of electron and beta radiation in the rat," Radiation Res. 30, 1967, pp. 525-54.

36/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "The association between chronic radiation damage of the hair follicles and tumor formation in the rat," Radiation Res. 30, 1967, pp. 590-599.

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depth is near the base of the hair follicle which comprises the deepest reservoir of epithelial cells of the germinal layer, it was suggestive that this might be a critical region in the observed carcinogenesis. The suggestion gained significance from the observations that most of the tumors are similar to hair follicles, and that in the non-ulcerogenic dose range the number of tumors per rat was in nearly constant ratio (1/2000-1/4000) with the number of atrophied hair follicles. Thus the carcinogenesis in this experiment was remarkably correlated with the dose to and specific damage of a particular skin structure. When exposures were made with stripe and sieve patterns of roughly 1 mm scale, geometrical effects were observed: most notably the cancer induction in the sieve geometry was suppressed at doses of 1700 rad but not at doses of 2300 rad. The reduction, however, was again consistent with the reduction in damage as characterized by atrophied hair follicles.

To summarize this important experiment, a high incidence of cancer was observed after intense local doses of radiation, and the carcinogenesis was proportional to the damage or disordering of a critical architectural unit of the tissue, the hair follicles.

Fig. 1. Tumor incidence with respect to surface dose at 80 weeks for three penetration depths of electrons.

Fig. 2. Tumor incidence with respect to the dose at a depth of 0.27 mm in the skin at 80 weeks for three penetration depths of electrons.

Source of Figures: Albert, R. E., et al., Radiation Res. 30, Op. cit., pp. 515-524, Figures 5 and 7; reproduced in Geesaman, UCRL-50387 Addendum, Op. cit., p. 2.

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Others have observed carcinomas and sarcomas in rats and mice after intense exposure of the skin to ionizing radiation.³⁷⁻⁴³ Cancer induction is generally a frequent event in these experiments. Even at elevated doses, such as 12,000 rad of 1 MeV electrons, Boag and Glucksmann induced ~5 sarcomas/100 cm² in rats³⁷.

A few results for rabbits, sheep, and swine were obtained at Hanford³⁸⁻⁴¹. Despite the small number of animals

37/ Withers, H.R., "The dose-survival relationship for irradiation of epithelial cells of mouse skin," Brit. J. Radiol. 40, 1967, pp. 187-194.

38/ Hulse, E.V., "Tumours of the skin of mice and other delayed effects of external beta irradiation of mice using ⁹⁰Sr and ³²P," Brit. J. Cancer 16, 1962, pp. 72-86.

39/ Boag, J.W. and A. Glucksmann, "Production of cancers in rats by the local application of Beta-rays and of chemical carcinogens," Progress in Radiobiology, J.S. Mitchell, B.E. Holmes, and C.L. Smith, eds. Proceedings of the Fourth International Conference on Radiobiology held in Cambridge, 14-17 August 1955. Edinburgh, Oliver and Boyd, 1956, pp. 476-479.

40/ George, L.A. and L.K. Bustad, "Gross effects of beta rays on the skin," Hanford Atomic Products Operation, Biology Research Annual Report for 1956, HW-47500, 1957, pp. 135-141.

41/ George, L.A. II, R.L. Pershing, S. Marks, and L.K. Bustad, "Cutaneous fibrosarcoma in a rabbit following beta irradiation," Hanford Atomic Products Operation, Biology Research Annual Report for 1959, HW-65500, 1960, pp. 68-69.

42/ Ragan, H.A., W.J. Clarke and L.K. Bustad, "Late effects of skin irradiation," Battelle-Northwest Laboratory Annual Report for 1965 in the Biological Sciences, BNWL-280, 1956, pp. 13-21

43/ Karagianes, M.T., E.B. Howard and J.L. Palotay, Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Vol. I, Biological Sciences, BNWL-714, 1968, pp. 1.10-1.11

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involved, surface doses of 16,000 rad from a P^{32} plaque induced an average of 1 cancer/animal which is indicative that larger mammals are similarly susceptible to skin cancer after intense radiation insult. Again, these gross observations demonstrate that enhanced tumor incidence does occur after very high doses.

Intense localized radiation of the subcutaneous and intraperitoneal tissue of animals by Pu-239 has also been shown to cause a high frequency of cancer induction⁴³⁻⁴⁵.

Now what are these experiments trying to tell us? Certainly a reasonable interpretation of these experimental results is: when a critical architectural unit of a tissue (e.g., a hair follicle) is irradiated at a sufficiently high dosage, the chance of it becoming cancerous is approximately 10^{-3} to 10^{-4} . This has become known as the "Geesaman hypothesis."

B Related Human Experience

Since the above experiments relate to cancer induction in animals, it is pertinent to ask whether man is more or less

44/ Sanders, C.L. and T.A. Jackson, "Induction of Mesotheliomas and Sarcomas From 'Hot Spots' of PuO_2 Activity," Health Physics, Vol. 22, No. 6, June 1972, pp. 755-759.

45/ Lisco, Herman, et al, "Carcinogenic Properties of Radioactive Fission Products and of Plutonium," Radiology, Vol. 49, No. 3, Sept. 1947, pp. 361-363.

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sensitive to such intense localized radiation. C. C. Lushbaugh reported on a lesion that developed as the result of residual Pu-239 from a puncture wound⁴⁶. The particle contained 0.08 ug (0.005 uCi) of Pu-239. Commenting on the histological examination of the lesion, the authors state, "The autoradiographs showed precise confinement of alpha-tracks to the area of maximum damage and their penetration into the basal areas of the epidermis, where epithelial changes typical of ionizing radiation exposure were present. The cause and effect relationship of these findings, therefore, seemed obvious. Although the lesion was minute, the changes in it were severe. Their similarity to known precancerous epidermal cytologic changes, of course, raised the question of the ultimate fate of such a lesion should it be allowed to exist without surgical intervention..." In this case, less than 0.1 ug of Pu-239 produced precancerous changes in human tissue. The dose to the surrounding tissue was very intense. There is every reason to believe that a smaller quantity of Pu-239 would have produced similar changes. This precancerous lesion indicates that a single Pu-239 particle irradiates a significant (critical) volume of tissue and is capable of inducing cancer. The Lushbaugh study was

^{46/} Lushbaugh, C.C. and J. Langham, Op. cit., pp. 461-464.

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published in 1962. At that time the total number of puncture wounds in man was less than 1,000⁴⁷. The treatment of such wounds was excision so that the total number of wounds displaying residual contamination by plutonium particles was certainly less than 1,000. Therefore, this wound data would suggest that insoluble plutonium particles could offer a risk of cancer induction in man that is even greater than 1/1000 per particle. In other words, when a critical unit of tissue is irradiated, man may be more susceptible to cancer than the Albert data as analyzed by Geesaman would suggest.

A second case of plutonium particle induced cancer is that of Mr. Edward Gleason. He was not associated with the nuclear industry but was a freight handler who unloaded, rotated and reloaded a crate that was contaminated by the leaking carboy of Pu-239 solution which it contained. He subsequently developed an infiltrating soft tissue sarcoma on the left palm which eventually resulted in his death. Although this case is not as clear cut as the case of the plutonium worker, there is an overwhelming medical probability that his cancer was induced by plutonium. Mr. Gleason's unfortunate contact with Pu-239 lead to a lawsuit,

^{47/} Vanderbeck, J.W., "Plutonium in Puncture Wounds," HW-66172, Hanford Laboratories Operation, July 25, 1960.

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Edward Gleason, et al v. NUMEC. This suit was eventually settled out-of-court. A discussion of the evidence in this case by one of the authors is presented in the Appendix B of this report.

These two cases, drawn from the relatively small number of individuals so contaminated, strongly suggest that Pu-239 particles offer a unique carcinogenic risk. They indicate that a single particle is capable of delivering an intense radiation dose to a critical volume of tissue and that this disruptively irradiated tissue, like an atrophied hair follicle, has a high probability (maybe as high as 1/1000) of becoming cancerous.

C. Related Lung Experiments

The skin experiments with animals are remarkable in that a highly disruptive dose of radiation to a small portion of repairable mammalian tissue produced frequent carcinogenesis. The chance of producing one cancer per animal is essentially unity. It is reasonable to expect that a comparable development could occur in lung tissue. While a number of radioactive substances have been used to induce lung cancers in mice and rats⁴⁸, it is difficult to derive any characterization of carcinogenesis from these experiments.

48/ Cember, H., "Radiogenic lung cancer," Progress in Experimental Tumor Research, F. Homburger, ed. New York, Hafner Publishing Company, Inc., Vol. 4, 1964, pp. 251-303.

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The work of Laskin, et al, though not specifically involving deep respiratory tissue, does demonstrate a source intensity-response curve for lung tissue⁴⁹. A Ru-106 cylindrical source was implanted in the bronchi of rats, and cancers were observed to arise from the bronchial epithelium. The response curve indicates a substantial response (7 percent) even at 0.008 uCi burden, and a slow, approximately logarithmic increase of tumor incidence over three orders of magnitude in the source intensity. Corresponding first-year doses to adjacent bronchial epithelium varied from 10^3 rad to 10^6 rad⁵⁰. Animals were followed until death and it was observed that the tumor incidence generally increased with the dose accumulated at death. The lowest accumulated dose associated with a cancer was 1400 rad. For an accumulated dose of the order of 10^6 rad the incidence was approximately two-thirds. Cember fortified glass beads (0.3 u diameter) with several microcuries of Sr-90, and single beads were implanted in the lungs of rats. Tumors were observed in 7 of 23 animals. In a second experiment Cember exposed rat lungs to Ce-144 particles. For

49/ Laskin, S., M. Kushner, N. Nelson, B. Altshuler, J.H. Harley and M. Daniels, "Carcinoma of the lung in rats exposed to the beta-radiation of intra-bronchial ruthenium¹⁰⁶ pellets. 1. Dose response relationships," J. Natl. Cancer Inst. 31, 1963, pp. 219-231.

50/ Altshuler, B., "Dosimetry from a Ru¹⁰⁶-coated platinum pellet," Radiation Res. 9, 1958, pp. 626-632.

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a burden range of 0.5 uCi to 50 uCi the observed tumor incidence fluctuated between 0.04 and 0.3⁵¹.

All of these lung experiments involved intense exposures and a significant level of carcinogenesis. Severe damage and disruption of tissue were associated with the exposures.

The most relevant lung experiment is Bair's Pu²³⁹O₂ inhalation study with beagles⁵²⁻⁵⁴. Exposure was to particulates of 0.25 u or 0.5 u median diameter; burdens were in the uCi range. Twenty of the 21 dogs that survived more than 1600 days post exposure had lung cancer. Many of these cancers were multicentric in origin. The cancers again appeared in conjunction with severe lung injury. Since the natural incidence of the disease is small, it appears that at this level of exposure the induction of lung cancer is a certainty during the normal beagle life span. At the same

51/ Cember, H., Op. cit.

52/ Bair, W.J., J.F. Park, and W.J. Clarke, "Long-term study of inhaled plutonium in dogs," Battelle Memorial Institute (Richland), AFWL-TR-65-214, 1966 (AD-631 690).

53/ Park, J.F., W.J. Clarke and W.J. Bair, "Chronic effects of inhaled ²³⁹PuO₂ in beagles," Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Vol. I, Biological Sciences, BNWL-714, 1968, pp. 3.3-3.4.

54/ Park, J.F., et al, "Progress in Beagle Dog Studies with Transuranium Elements at Battelle-Northwest," Health Physics, Vol. 22, No. 6, June 1972, pp. 803-810.

time, since the pathological response is saturated in this experiment, it is inappropriate to draw any inference about the magnitude of the response at smaller burdens. The smallest burden (at death) in a dog showing lung cancer was 0.2 uCi. Presumably this would correspond to a particle burden of about 10^7 particles. Burdens which are smaller by orders of magnitude may still induce a substantial incidence of cancer. Indeed, the cancer risk may, as for skin and soft tissues, correspond to a risk per particle in the neighborhood of 1/1000 to 1/10,000.

VI. Critical Particle Activity

Not all particles would be expected to result in these high cancer probabilities. As the particle size or specific activity per particle is reduced so is the dosage to the surrounding tissue. Indeed, at sufficiently small particle size or specific activity, one would expect the radiation insult to behave similar to uniform irradiation. The study of Albert on induction of cancer in rat skin indicates a precipitous change in the dose response curve as the dosage exceeds 1,000 rem⁵⁵. (See Figure 2). This suggests that a particular level of tissue damage must occur before this unique carcinogenic response occurs. The experiments of

55/ Albert, R.E., et al, Radiation Res. 30, Op. cit., pp. 515-524, Figure 7; reproduced in Geesaman, UCRL-50387 Addendum, Op. cit., p. 2.

Laskin, et al, indicate a significant carcinogenic response in the lung at 1400 rem, suggesting a comparable sensitivity of lung tissue⁵⁶. Geesaman indicates that the tissue repair time in the lung is of the order of one year⁵⁷. It therefore seems appropriate, but not necessarily conservative, to accept as guidance that this enhanced cancer risk occurs when particles irradiate the surrounding lung tissue at a dose rate of 1000 rem/yr or more.

TABLE IV

Particle Activity and Size to Give a Dose of
1000 rem/year to the Surrounding Lung Tissue⁵⁸

	Particle Activity (pCi)	Particle Diameter (u) ⁵⁹	
		²³⁹ PuO ₂	²³⁸ PuO ₂
3/4 max inflated (138 alveoli)	0.14	0.8	0.12
1/2 max inflated (68 alveoli)	0.07	0.6	0.09
Closest 20 alveoli	0.02	0.4	0.06

^{56/} Laskin, et al, Op. cit.

^{57/} Geesaman, Donald P., UCRL-50387, Op. cit., p. 11.

^{58/} Ibid

^{59/} Based upon specific activity given by Langham, W.H., Op. cit., p. 7.

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As seen from Table IV, using Geesaman's lung model, a particle with an alpha activity between 0.02 pCi and 0.14 pCi is required to give a dose of 1000 rem/yr to irradiated lung tissue. For purposes of establishing a maximum permissible lung particle burden we will use 0.07 pCi from long half-lived (greater than one year) isotopes as the limiting alpha activity to qualify as a hot particle. Thus, throughout the remainder of this report, hot particle will imply a particle with at least this limiting alpha activity which is insoluble in lung tissue.

* * * * *

In summary, then, a hot particle is defined as one that delivers a dosage of at least 1000 rem/yr to the surrounding lung tissue. For $^{239}\text{PuO}_2$, such a particle would be 0.6 μ in diameter and contain 0.07 pCi. It would carry a risk of inducing lung cancer of 1/2000. Particles larger than this would contain more pCi and deliver larger dosages to the surrounding tissue, but the risk per particle would still be 1/2000. This implies that 2 particles in the lung (as little as 0.14 pCi) corresponds to risk from uniform irradiation of the lung by 16,000 pCi.

* * * * *

Specific Comments on Section 4.G.5

We shall proceed through this section, 4.G.5, pages 4.G-89 to 4.G-105, making specific comments where appropriate.

Pages 4.G-89 to 90. These pages present background or general material for which little comment is necessary. However two

important sentences appear on page 4.G-90:

"For acute effects occurring shortly after high levels of radiation, limiting the volume of tissue irradiated can greatly ameliorate the outcome. However, adequate data are not available to indicate whether a similar situation exists for late effects, particularly carcinogenesis."

We find this last point to be incredible. There is an abundance of evidence to demonstrate that when small volumes of tissue are irradiated at high dosages cancer is a frequent, almost inevitable occurrence. In fact, it is this evidence that we have used above to argue for the enhanced risk of hot particles. In addition to the experiments that we referenced, Table 4.G.2 on page 4.G-97 presents data from another experiment in which a high frequency of cancer developed following localized irradiation at high dosage.

Pages 4.G-91 to 92. We have previously mentioned the lack of guidance from ICRP (see page 11) and have also indicated that the NCRP offered no guidance in this regard. In the quotation from ICRP Publication 14, it is not at all clear that the authors, an ICRP Task Group, reviewed Geesaman's work before preparing this report. Moreover, while the opinion of the Task Group may be worth noting, it is important to note that it is only an opinion and is totally unsupported in ICRP Publication 14. Considering this in 1974, it is significant that in the intervening 5 years since publication of that report, adequate support for that opinion has not been forthcoming. Quite the contrary, the analysis of Geesaman and our report have emerged to support the opposite.

Page 4.G-94. On this page, this statement appears:

"There appears to be a relationship between the radiation dose and the time of occurrence of malignancies in animals:

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the higher the dose (or in case of internal emitters, the dose rate) the shorter the time required for a cancer to appear. This phenomenon is frequently used to invoke the possibility of an "effective threshold" since the time required to permit cancer formation following a low dose may be so great that it exceeds the normal life span even if induction follows a linear relation with dose."

As Dr. Miriam Finkel has stated, much of the support for the concept of an "effective threshold" is an artifact of experiments in which too few animals were exposed at the lower dosages.

According to Dr. Finkel:

"After a large dose of radiation the point in time when an animal dies with an osteosarcoma may arrive sooner, but this is not necessarily because the actual time elapsing up to the occurrence of irreversible neoplastic change, or the "true" latent period is shorter when the dose is large. We know that "tumour pressure," which is indicated to some extent by final osteosarcoma incidence, is going to be much greater after a large dose--if it is still in the oncogenic range--than after a small one. Therefore, the probability of an animal dying with an osteosarcoma at any particular time will be much greater if it has received an amount of radium that gives a high tumour yield than if it has received an amount that gives a low tumour yield. In other words, if the daily probability of dying with tumour is greater, the chance of seeing a tumour earlier is also greater. Some of us tend to confuse high tumour incidence with short latent period; i.e. we tend to assume that "tumour pressure," if I may again use that term, changes the actual time it takes for radiation to induce a tumour instead of recognizing the fact that "tumour pressure" determines how many tumours there will be, and, as a consequence, determines the probability of there being a tumour at a particular time. This is how I interpret our data. The concept of latent period changing with dose has never made very good sense to me because more of our data contradict it than support it."⁶⁰

^{60/} Finkel, M.P., B.O. Biskis, and P.B. Jenkins, "Toxicity of radium-226 in mice," Radiation-Induced Cancer (Proceedings of a Symposium, Athens, Greece, 28 April-2 May, 1969, Organized by International Atomic Energy Agency in Collaboration with the World Health Organization), Vienna, Austria: also, International Atomic Energy Agency, 1969. pp. 389-390.

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Page 4.G-95 and 96, Table 4.G.21 on page 4.G-97. The concept of overkill or wasted radiation is introduced here and it is stated,

"Such a concept would lead to the conclusion that the larger the particle (in terms of activity) the less effective it would be in producing cancer since dose rates close to the particle would increase as the activity increased, thereby leading to a greater fraction of radiation wasted on dead cells. One experiment showing this effect was reported by Passonneau^{1, 17} using Sr-90 beads on rat skin."^{61, 62}

The concept of overkill is actually incorporated in our analysis of the hot particle risk. However, as stated above on page this does not alter the risk per particle. As the particle becomes larger than the critical activity (volume), the risk per uCi will decrease, but not the risk per particle.

The experiment of Passonneau is quite similar to the experiments of Albert which were discussed above. (See pages 15 - 19 above). The data in Table 4.G.21 show that irradiating a small portion of rat skin with a high dosage will produce a high incidence of cancer. Albert's experiments gave results similar to the differences observed between the bead and plate studies of Table 4.G.21. As we stated on page 16 above:

"When exposures were made with stripe and sieve patterns of roughly 1 mm scale, geometrical effects were observed; most

^{61/} Reference #1, U. S. National Academy of Sciences - National Research Council. The effects on populations of exposure to low levels of ionizing radiation. Report of the Advisory Committee on the Biological Effects of Ionizing Radiations. Washington, D. C. (1972).

^{62/} Reference #17, Passonneau, et al., "Carcinogenic Effects of Diffuse and Point-Source Beta Irradiation on Rat Skin: Final Summary," AEC Document-ANL-4932, 1952.

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notably the cancer induction in the sieve geometry was suppressed at doses of 1700 R, but not at doses of 2300 R. The reduction, however, was again consistent with the reduction in damage as characterized by atrophied hair follicles."

Actually if one chooses to consider these beads as particles, they would give the following cancer risks:

150 uCi/bead	1 cancer/46 beads or particles
75 uCi/bead	1 cancer/61 beads or particles
30 uCi/bead	1 cancer/107 beads or particles

On a microcurie basis, the 150 uCi bead is less effective. But that's not the issue here. The beads demonstrate that irradiation of a small volume of tissue at a high dose leads to cancer. There is no reason for doubting that the cancer induction with these beads also relates to atrophied hair follicles.

Page 4.G-95 (footnote). The discussion leading to the footnote and the footnote are:

"Akin to this concept is that of 'overkill' of single cells close to the particle. A single particle in the lung (or other tissue) may yield dose rates close to the particle which can be high enough such that even a relatively limited time of residence in the tissue will result in the death of cells within a given radius, depending upon the activity of the particle and the type of radiation. Such cells will not reproduce and will not lead to cancer.*

*However, the presence of dead cells, cellular products or fibrosis may be required before a cellular transformation can express itself as a cancer. This possibility requires more study."

The actual killing of cells and the development of a fibrotic lesion surrounding the hot particle is the suggested mechanism of

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carcinogenesis. As Geesaman stated:

"Summing up, intense radiation exposure of mammalian skin and lung tissue commonly results in cancers. Tissue injury and disturbance are a primary consequence of intense radiation insult, and are observed in association with carcinogenesis. Albert has exhibited a simple proportionality between skin carcinomas and atrophied hair follicles. No general description of precarcinogenic injury exists, but in a crude sense the available observations are compatible with the idea of an injury-mediated carcinogenesis. Cancer is a frequent instability of tissue. Since tissue is more than an aggregate of cells, and has a structural and functional unity of its own, it would not be surprising if some disrupted local integrity, a disturbed ordering, comprises a primary pathway of carcinogenesis. The induction of sarcomas with inert discs of Mylar, cellophane, Teflon and Millipore (Brues, et al.¹⁷) is indicative that such a mechanism exists. Presumably mitotic sterilization is an important factor in any carcinogenesis mediated by radiation-induced tissue injury. The functional relation of this factor in the carcinogenic response may be quite different from a linearity in the surviving mitotic fraction.

While regrettably unquantitative, the hypothesis of an injury-mediated carcinogenesis is suggestively descriptive. If the respiratory zone of the lung contains a structure analogous to the rat hair follicle, and if a radioactive particulate deposited in the respiratory zone has the capacity to disrupt one or more of these structures and create a precancerous lesion, then cancer risks of the order of 10^{-3} to 10^{-4} per particle can be expected."^{63, 64}

The footnote on page 4.G-95 recognizes this possibility and indicates that it requires more study. The purpose of our comments here, of our petition and of our report is to indicate that this is a very real possibility and that it leads to greatly enhanced risks when hot particles are involved. Any decision, such as that

63/ Geesaman, Donald P., UCRL-50387, Addendum, Op. cit., pp. 6-7.

64/ Brues, et al.¹⁷, refers to Brues, A.M., H. Auerbach, G.M. De Roche, and D. Brube. Mechanisms of carcinogenesis. Argonne National Laboratory, Biological and Medical Research Division Annual Report for 1967, ANL-7409, 151-155, 1967.

being made relative to the LMFBR, must take this enhanced risk from hot particles into account. The failure to do this when estimating biological effects in this Draft Statement is one of its most serious flaws.

Page 4.G-96. It is incorrect to say that Geesaman⁶⁵ performed an analysis similar to that of Dean and Langham.⁶⁶ The latter calculated the dose to individual cells and then made estimates of the cancer risk based upon these cellular dosages. Geesaman, as discussed above, suggested that, when the dose from a particle to the irradiated tissue mass was sufficient to disturb its architecture, such a disrupted tissue mass in the lung would pose a unique carcinogenic risk -- a risk similar to that posed by a disrupted hair follicle. Nevertheless, regarding both analyses the following criticism is made:

"The results of this work can be questioned on many grounds including extrapolation of the data on tumors in rat skin to tumors in human lung tissue, the finding of Albert that the sensitive cells are at the base of the follicle in the rat skin. . ."

This is another of the rather incredible statements in this section. As the AEC knows, most of our information in radiobiology comes from animal experiments. Since we are interested here in public health and safety, it is difficult to believe, as this statement would suggest, that the AEC is asking us to wait until we have the human corpses.

65/ Geesaman, Donald P. UCRL-50387, Addendum, Op. cit.

66/ Dean, P.N. and W.H. Langham, "Tumorigenicity of Small Highly Radioactive Particles," Health Phys. Vol. 16, 1969, pp. 79-84.

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Moreover, it is important to note that all of the references in this section are to animal data and strangely, no reference is made to the article of Lushbaugh that deals with a precancerous lesion in human soft tissue caused by a plutonium particle. As we indicated on page 21 above, if we had used just the human data in estimating the hot particle risk, we would have had to assign a risk per particle that was greater than 1/1000, rather than the 1/2000 that we assumed. In this respect, it is important to recall (see page 3) that Richmond demonstrated that hot particles produce lesions in the lung of hamsters that are similar to that observed by Lushbaugh in human soft tissue. There is little reason to doubt that such a lesion would develop in the human lung and then progress into a cancerous growth.

Finally, it is stated as fact on this page of the Draft EIS:

"... that the assumed efficiency of production of lung cancer per cell does not conform to the experience with humans in the production of lung tumors from external radiation."

It would be of considerable interest to learn the basis for that statement. Dean and Langham, for example, made no mention of this fact in their article. In fact, the data of Sanders that is referenced later in the section would lead to the opposite conclusion.⁶⁷

Pages 4.G-98 and 101. Here again the experiments of Richmond are mentioned, but again no mention is made of the similarity

^{67/} This is reference #24, cited on page 4.G-102, Sanders, C.L., "Carcinogenicity of Inhaled Plutonium-238 from Crushed Microspheres," Pacific Northwest Laboratories Annual Report 1972, Part 1 BNWL-1750: 28 (1973).

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between the lung lesions produced in these experiments and the human soft tissue lesion described by Lushbaugh.

It is stated,

"In the experiment of Richmond, et al.,⁹ quoted above, the particles were firmly held in the pulmonary capillaries and, therefore, were not representative of particles actually deposited in the alveoli. Movement of inhaled particles is known to occur via movement by the cilia, and by macrophage engulfment."

The AEC is apparently unaware that the alveoli and associated deep respiratory tissue are not ciliated. Macrophage engulfment of the particles does occur, but how this relates to lung clearance is not understood. More significant to the hot particle problem is the measured long term retention of these particles (in excess of 500 days) in the lung, which may be related to the engulfment of these particles by epithelial cells or by cytotoxic effects on macrophages.⁶⁸ The discussion following the above quoted statement again digresses into the irrelevant issue of overkill.

Page 4.G-102. This page is a flagrant example of the shallow and self-serving nature of this Draft Statement. It is an inexcusable product for an organization that has a multi-billion dollar yearly budget, that is requesting funds for a multi-billion dollar LMFBR Program, and that has a biological research budget of over \$100 million per year.

^{68/} Sanders, C.L. and R.R. Adey, Health Physics, Vol. 18, 1970, pp. 293-295.

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Near the top of this page, the following appears:

"The fact that leukemia is a relatively rare occurrence in experimental animals administered plutonium may serve as an indicator that irradiation of a small portion of an organ (the marrow) to a high dose is not particularly troublesome as long as the average dose is low."

There have been no experiments wherein hot particles were introduced directly into bone marrow. As the AEC knows, only "soluble" or "solubilized" plutonium is capable of deposition in the bone. Moreover, as the AEC knows, this plutonium is deposited preferentially in active areas of bone growth (a small portion of the organ). As a result, as discussed above (see pages 5-6), it is 5 times more effective in producing bone cancer than is radium which is more evenly distributed. This statement in the Draft EIS is, therefore, grossly misleading.

Considering what has appeared earlier in this section and also what follows, the reader can not help being confused by the following statement on this page:

"No clear cut, overall picture of the relative effects of uniform versus focal dose can be drawn from the present data."

We would in a qualitative sense agree with this statement, but we must emphasize that the available data strongly suggests that hot particle radiation leads to an enhanced risk of cancer (as much as 100,000 times that of uniform irradiation).

Following the above sentence, this statement is made:

"It appears from the $^{238}\text{Pu}02$ microsphere data and the skin experiments with ^{90}Sr that, in the extreme situation of a single, very active particles, the focal radiation is considerably less damaging."

We have previously discussed both of these experiments (see pages 3,

30-31, 34-35). As we indicated in these discussions, these experiments do not suggest a reduced risk for hot particles. Quite the contrary, they strongly support our analysis of an enhanced risk for hot particles.

Then, with considerable inaccuracy, the next sentence is given as justification for the concluding remark of this section:

"Cember²² concludes that for beta emitters the focal source is less damaging than is the uniformly distributed source."⁶⁹

Cember's experiments could not justify this conclusion and, in fact, he did not so conclude. Cember concluded:

"Experiments with rats have shown that radioactive substances deposited in the lung can lead to pulmonary neoplasia. Radiations from S^{35} , Sr^{90} - Y^{90} , and Ce^{144} elicited bronchogenic carcinoma and alveolar cell carcinoma in addition to several other tumor types. These experiments did not confirm the existence of a unique carcinogenic hazard due to the intense concentration of absorbed energy in the lung tissue immediately surrounding an inhaled radioactive particle."⁷⁰

The major thrust of the Cember article deals with ^{144}Ce particles in the lung. The ^{144}Ce was introduced admixed with stable Ce as either CeF_3 or $CeCl_3$ in particles of about 1 μ in diameter ($0.5 \mu^3$). ^{144}Ce emits a beta particle of 0.275 MeV and its daughter product ^{144}Pr emits a beta of 3 MeV. The rate of energy loss for these beta particles in tissue is about 0.2 Kev/ μ compared to some 94 Kev/ μ for plutonium alpha particles.

This difference in energy loss per micron indicates that the activity of the ^{144}Ce emitters would have to be some 500 times that of the ^{239}Pu in order to deposit the same energy in the tissue

69/ Cember²² refers to Cember, H., "Radiogenic Lung Cancer," Progress in Experimental Tumor Research v4:251 (1964).

70/ Cember²², Op. cit., pp. 289-290.

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irradiated by ^{239}Pu alpha particles. Moreover, since the QF for alpha particles is 10, the ^{144}Ce particles must have an activity $(10) \times (500)$ or 5,000 times that of a $^{239}\text{PuO}_2$ particle to qualify as a hot particle. Since the limiting activity of a $^{239}\text{PuO}_2$ particle is 0.07 pCi, a hot particle of $^{144}\text{CeCl}_3$ would have to contain more than 350 pCi. After correcting for the half-life of ^{144}Ce (288 days) a hot particle would have to contain some 500 pCi.

The geometric mean diameter of the particles in these experiments was 1 micron. The highest exposure group received 50 uCi of ^{144}Ce in 30 ug of CeF_3 . Allowing a density of 6 g/cm³ for the CeF_3 , the beta-activity per particle of 1 u diameter is only 5 pCi. In other words, these experiments did not involve hot particles as defined above. The carcinogenesis observed in these Cember experiments, which was considerable, was related to high total and rather uniform organ dosage (1,000 - 30,000 rad).

Following the mention of the Cember experiments, this statement is made:

"The data of Grossman, et al.,²³ indicate a seeming decrease in the tumor incidence as well as increased survival with focal sources of ^{210}Po on iron oxide particles."⁷¹

As we mentioned previously, this reference is only to an abstract.

The AEC seemed to be more interested in the conclusion than in the validity of the experiment.

^{71/} Grossman, et al.²³ refers to the abstract: Grossman, B.N., J.B. Little and W.F. O'Toole, "Role of Carrier Particles in the Induction of Bronchial Cancer in Hamsters by ^{210}Po Alpha Particles," Rad. Res. 47:233 (1971). We do not know whether a more detailed description of these experiments was published. The information given in the abstract was sufficient to demonstrate that the experiment was irrelevant here, regardless of its overall validity.

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In these experiments, the highest exposure involved 0.2 uCi of ^{210}Po absorbed on 3 mg of ferric oxide carrier particles ($98\% < 0.75 \text{ u}$). Allowing a density of 5 g/cm^3 for the particles, the 3 mg would involve 2×10^9 particles of 0.8 u diameter. The activity per particle would then be only $1 \times 10^{-4} \text{ pCi}$. Again, this experiment does not involve hot particles as defined above. It represents rather uniform irradiation of the lung to high dosage (2,250 to 45,000 rem) and again, these large dosages produce a high incidence of cancer.

Following the reference to the above abstract, this statement appears:

"Sanders,²⁴ as a result of his studies with soluble ^{233}Pu derived from crushed microspheres, arrives at a conclusion that spreading the dose more uniformly results in an increased cancer incidence due to the greater number of epithelial cells involved. This conclusion was based on the observation of '- - a significant incidence of tumors in the lung and in other tissues at radiation doses that have not previously been shown to be carcinogenic in animals.'"⁷²

The conclusion of Sanders is not justified by the experiment described in the referenced article. Sanders indicates that hot particles were not involved in this study. The conclusion that is justified by the results of this study is that the exposure standards for plutonium may be much too high (at least 100 times too high) even when hot particles are not involved. The results indicate that a uniform dose of 15 rem doubled the natural incidence of lung

^{72/} Sanders,²⁴ refers to Sanders, C.L., "Carcinogenicity of Inhaled Plutonium-238 from Crushed Microspheres," Pacific Northwest Laboratories Annual Report 1972, Part 1 BNWL-1750:28 (1973).

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cancer in the exposed rats. A worker is allowed this dose each year and a member of the population could accumulate this dose in 10 years. It is somewhat disturbing that the AEC would reference this experiment and then ignore its implications.

One further point could be made concerning this study. It is not at all clear from the description given in the reference that the exposures did not involve a few hundred hot particles. If this were so, these particles could have been partly responsible for the observed cancers.

Page 4.G-103. Here we find the conclusion reached in this section:

"Therefore, the conclusion is that the preponderance of the evidence indicates that the use of an average lung dose is appropriate in estimating health consequences and may well be conservative."

As we have indicated above, there is no justification for this conclusion so far as hot particles are concerned. In fact, while none of the references detract from our conclusions, one of the references used in this section actually supports our contention that hot particles carry greatly enhanced cancer risks.⁷³ Moreover, the experiment of Sanders suggests that the risk estimates from the BIER Report that were used in the Draft Statement may be serious underestimates of the effects even when hot particles are not involved.

^{73/} Richmond, C.R., et al., Op. cit.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. J. G. Speth
Natural Resources Defense Council, Inc.
1710 N. Street, N.W.
Washington, D.C. 20036

Dear Mr. Speth:

Thank you for your letter of April 16, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. The other enclosure to this letter provides responses to the various points you raised, primarily on particle lung dose effects and related issues. We trust the enclosed information is adequately responsive to your concerns.

Your interest in the LMFBR Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

ENCLOSURE 1

AEC Staff Response to NRDC Comments on Particle Lung Dose Effects

1. NRDC Comment (pp. 2-3):

"In our report and in our communication of 26 Dec. 1973, we called attention to the paper of Lushbaugh, et al.,⁶ wherein a single particle of plutonium produced a precancerous lesion in the palm of a mechanic. The Lushbaugh article is significant because it demonstrated the hazard of a single particle. As an example of the self-serving nature of these pages of the Draft Statement, no mention is made of the Lushbaugh article, but reference is made to an article by Richmond, et al., (reference no. 9) seemingly to support the conclusion reached on page 4.G-103. We say seemingly because this article actually supports our arguments; for example, Richmond, et al., state that similar lesions are produced in the lung by hot particles:

'Such a lesion with collagenous degeneration and subsequent liquefaction, due to the large local dose of radiation at a high dose rate, has been reported by Lushbaugh et al.,⁽⁹⁾ whose description of a plutonium lesion found in the dermis is very similar to that observed for plutonium in the lung.'

AEC Response:

Nowhere in the referenced paper of Lushbaugh, et al., is the statement found that "a single particle of plutonium produced a precancerous lesion..." The authors state that "Their (the tissue changes observed) similarity to known cancerous epidermal cytologic changes..." When used by a pathologist, the term "precancerous" means observations similar to those observed in other precancerous tissues: changes in nuclear and cell size; lagging differentiation alterations and increase in mitoses; and polyploid nuclear forms, hyperchromatism and other changes in staining characteristics. Use of the term does not mean that a malignancy or cancer was present; the pathologist is saying to the informed reader that while changes in cellular appearance, size and number were seen, the changes necessary for a diagnosis of cancer were not seen. That such cytologic changes can be reversed by cellular repair is well known; conversely they can also proceed to degenerate and so are often accompanied by a high cellular death rate when repair processes fail. However, degenerate sterile and dead cells do not participate in carcinogenesis. Obviously, then, there is a considerable difference in cytologic changes being truly precancerous and being similar to such changes.

The changes reported by Richmond, et al., were similar to those seen by Lushbaugh, et al. (see above) which were similar to known precancerous changes. The plutonium in the lung was in the form of 180 μ m diameter

239 ^{PuO₂} particles and injected intravenously into the jugular vein so as to lodge in the vasculature of the lung. (Obviously, the inhalation of particles this size would be nearly impossible.) The changes are stated as being considerably less than would normally be expected from the same quantity of plutonium distributed throughout the lung, and nowhere in the paper are the changes stated to be either precancerous or cancerous.

2. NRDC Comment (pp. 27-28):

"Pages 4.G-89 to 90. These pages present background or general material for which little comment is necessary. However two important sentences appear on page 4.G-90:

'For acute effects occurring shortly after high levels of radiation limiting the volume of tissue irradiated can greatly ameliorate the outcome. However, adequate data are not available to indicate whether a similar situation exists for late effects, particularly carcinogenesis.'

"We find this last point to be incredible. There is an abundance of evidence to demonstrate that when small volumes of tissue are irradiated at high dosages, cancer is a frequent, almost inevitable occurrence. In fact, it is this evidence that we have used above to argue for the enhanced risk of hot particles. In addition to the experiments that we referenced, Table 4.G.2 on page 4.G-97 presents data from another experiment in which a high frequency of cancer developed following localized irradiation at high dosage."

AEC Response:

The heart of this comment seems to be in the statement: "There is an abundance of evidence to demonstrate that when small volumes of tissue are irradiated at high dosages cancer is a frequent, almost inevitable occurrence." There is no doubt that radiation can cause cancer when delivered in high enough doses to relatively large volumes of tissue. The basic issue, however, is whether the number of induced cancers is greater if the radiation energy is concentrated in a small tissue volume or if it is distributed uniformly throughout all of the organ. The "evidence" for a greater effectiveness presented by the NRDC is based largely on a theory of cancer production which is untested and which is referred to by the NRDC as the "Geesaman hypothesis." The examination of information available in the report was intended to look for evidence to see whether the predictions of this hypothesis were correct or whether other plausible hypotheses involving greater cell interactions or multiple interactions in the cell could apply.

We would also submit that the characterization of the cancer outcome at high doses as ".....a frequent, almost inevitable occurrence" (emphasis

added) is unjustified. It is this consideration that compels the radio-therapist to restrict his field of irradiation to as small a volume as possible. He minimizes the field volume so as to reduce the possibility of cancer induction.

Regarding Table 4.G.21, it should be pointed out that there was a lesser risk as the particle became "hotter," i.e., as the activity per bead increased, the number of tumors per microcurie decreased; however, this table has been deleted from the Final Statement since it is now available in the referenced material.

3. NRDC Comment (p. 28):

"Pages 4.G-91 to 92. We have previously mentioned the lack of guidance from ICRP (see page 11) and have also indicated that the NCRP offered no guidance in this regard. In the quotation from ICRP Publication 14, it is not at all clear that the authors, an ICRP Task Group, reviewed Geesaman's work before preparing this report. Moreover, while the opinion of the Task Group may be worth noting, it is important to note that it is only an opinion and is totally unsupported in ICRP Publication 14. Considering this in 1974, it is significant that in the intervening 4 years since publication of that report, adequate support for that opinion has not been forthcoming. Quite the contrary, the analysis of Geesaman and our report have emerged to support the opposite."

AEC Response:

The ICRP and NCRP have periodically considered and addressed this question. However, it is apparent that these knowledgeable bodies consider the use of average organ dose to be acceptable in the absence of any evidence that the non-uniform dose distribution is more hazardous.

It is certain that members of the ICRP and NCRP have been aware not only of Geesaman's hypothesis, but also that it is not substantiated by experimental evidence.

4. NRDC Comment (pp. 28-29):

"Page 4.G-94. On this page, this statement appears:

'There appears to be a relationship between the radiation dose and the time of occurrence of malignancies in animals: the higher the dose (or in the case of internal emitters, the dose rate) the shorter the time required for a cancer to appear. This phenomenon is frequently used to invoke the possibility of an "effective threshold" since the time required to permit cancer formation following a

low dose may be so great that it exceeds the normal life span even if induction follows a linear relation with dose.'

"As Dr. Miriam Finkel has stated, much of the support for the concept of an 'effective threshold' is an artifact of experiments in which too few animals were exposed at the lower dosages. According to Dr. Finkel:

'After a large dose of radiation the point in time when an animal dies with an osteosarcoma may arrive sooner, but this is not necessarily because the actual time elapsing up to the occurrence of irreversible neoplastic change, or the "true" latent period is shorter when the dose is large. We know that "tumour pressure," which is indicated to some extent by final osteosarcoma incidence, is going to be much greater after a large dose--if it is still in the oncogenic range--than after a osteosarcoma at any particular time will be much greater if it has received an amount that gives a low tumour yield. In other words, if the daily probability of dying with tumour is greater, the chance of seeing a tumour earlier is also greater. Some of us tend to confuse high tumor incidence with short latent period; i.e. we tend to assume that "tumour pressure," if I may again use that term, changes the actual time it takes for radiation to induce a tumour instead of recognizing the fact that "tumour pressure" determines how many tumours there will be, and as a consequence, determines the probability of there being a tumour at a particular time. This is how I interpret our data. The concept of latent period changing with dose has never made very good sense to me because more of our data contradict it than support it.'⁶⁰

AEC Response:

The referenced statement does not appear in the Final Statement.

5. NRDC Comment (pp. 30-31):

"Page 4.G-95 and 96, Table 4.G.21 on page 4.G-97. The concept of overkill or wasted radiation is introduced here and it is stated,

⁶⁰Finkel, M. P., B. O. Biskis, and P. B. Jinkins, "Toxicity of radium-226 in mice," Radiation-Induced Cancer (Proceedings of a Symposium, Athens, Greece, 28 April-2 May, 1969, Organized by International Atomic Energy Agency in Collaboration with the World Health Organization), Vienna, Austria: also, International Atomic Energy Agency, 1969, pp. 389-390."

'Such a concept would lead to the conclusion that the larger the particle (in terms of activity) the less effective it would be in producing cancer since dose rates close to the particle would increase as the activity increased, thereby leading to a greater fraction of radiation wasted on dead cells. One experiment showing this effect was reported by Passonneau^{1,17} using Sr-90 beads on rat skin.^{61,62}

"The concept of overkill is actually incorporated in our analysis of the hot particle risk. However, as stated above on page (sic) this does not alter the risk per particle. As the particle becomes larger than the critical activity (volume), the risk per μCi will decrease, but not the risk per particle.

"The experiment of Passonneau is quite similar to the experiments of Albert which were discussed above. (See pages 15-19 above.) The data in Table 4.G.21 show that irradiating a small portion of rat skin with a high dosage will produce a high incidence of cancer. Albert's experiments gave results similar to the differences observed between the bead and plate studies of Table 4.G.21. As we stated on page 16 above:

'When exposures were made with stripe and sieve patterns of roughly 1 mm scale, geometrical effects were observed; most notably the cancer induction in the sieve geometry was suppressed at doses of 1700 R, but not at doses of 2300 R. The reduction, however, was again consistent with the reduction in damage as characterized by atrophied hair follicles.'

"Actually, if one chooses to consider these beads as particles, they would give the following cancer risks:

150 $\mu\text{Ci}/\text{bead}$	1 cancer/46 beads or particles
75 $\mu\text{Ci}/\text{bead}$	1 cancer/61 beads or particles
30 $\mu\text{Ci}/\text{bead}$	1 cancer/107 beads or particles

⁶¹Reference 1, U.S. National Academy of Sciences - National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation." Report of the Advisory Committee on the Biological Effects of Ionizing Radiations, Washington, D.C. (1972).

⁶²Reference 17, Passonneau, et al., "Carcinogenic Effects of Diffuse and Point-Source Beta Irradiation on Rat Skin: Final Summary," AEC Document ANL-4932, 1952.

On a microcurie basis, the 150 μ Ci bead is less effective. But that's not the issue here. The beads demonstrate that irradiation of a small volume of tissue at a high dose leads to cancer. There is no reason for doubting that the cancer induction with these beads also related to atrophied hair follicles."

AEC Response:

The experiments of Albert et al. and that of Passonneau are quite different in that they used different radiation sources and irradiated areas so that the distribution of radiation dose and volume irradiated were not similar. Regardless, both show that the same amount of radiation energy delivered to a given volume will result in a decreasing tumor incidence as the volume of tissue irradiated decreases. This effect may well be due to an "overkill" on cells in the Passonneau experiment. However, in the Albert experiments the doses delivered were close to the optimal for production of the very specific types of tumors investigated in the specific strain of experimental animal.

The statement that the risk per particle is unchanged, of course, is based upon one hypothesis as to the mechanism of cancer production, and it is this hypothesis, along with others which predict different results, that is being examined. To assert that this hypothesis is proven fact is unwarranted; it has been available as a laboratory report since 1968, with little or no general acceptance by the scientific community.

We would also note that the incidence per particle calculated from the ^{90}Sr experiment differs rather significantly from the one in 2000 to one in 4000 quoted by Geesaman as derived from the Albert rat skin experiments. This would indicate a somewhat more complex situation than that envisioned by the NRDC with the response being mediated by some factors other than the simple presence of the particle.

The point at issue is whether or not a given quantity of activity from a radionuclide is more hazardous when spread throughout a relatively large volume or when the activity is concentrated in a relatively few discrete highly radioactive particles. The Passonneau data clearly shows that in terms of tumor induction a few "hot" particles are less effective in causing tumor formation than are more numerous less radioactive particles.

6. NRDC Comment (pp. 31-33):

"Page 4.G-95 (footnote). The discussion leading to the footnote and the footnote are:

'Akin to this concept is that of "overkill" of single cells close to the particle. A single particle in the lung (or

other tissue) may yield dose rates close to the particle which can be high enough such that even a relatively limited time of residence in the tissue will result in the death of cells within a given radius, depending upon the activity of the particle and the type of radiation. Such cells will not reproduce and will not lead to cancer.*

*However, the presence of dead cells, cellular products or fibrosis may be required before a cellular transformation can express itself as a cancer. This possibility requires more study.'

"The actual killing of cells and the development of a fibrotic lesion surrounding the hot particle is the suggested mechanism of carcinogenesis. As Geesaman stated:

'Summing up, intense radiation exposure of mammalian skin and lung tissue commonly results in cancers. Tissue injury and disturbance are a primary consequence of intense radiation insult, and are observed in association with carcinogenesis. Albert has exhibited a simple proportionality between skin carcinomas and atrophied hair follicles. No general description of precarcinogenic injury exists, but in a crude sense the available observations are compatible with the idea of an injury-mediated carcinogenesis. Cancer is a frequent instability of tissue. Since tissue is more than an aggregate of cells, and has a structural and functional unity of its own, it would not be surprising if some disrupted local integrity, a disturbed ordering, comprises a primary pathway of carcinogenesis. The induction of sarcomas with inert discs of Mylar, cellophane, Teflon and Millipore (Brues, et al.¹⁷) is indicative that such a mechanism exists. Presumably mitotic sterilization is an important factor in any carcinogenesis mediated by radiation-induced tissue injury. The functional relation of this factor in the carcinogenic response may be quite different from a linearity in the surviving mitotic fraction.

'While regrettably unquantitative, the hypothesis of an injury-mediated carcinogenesis is suggestively descriptive. If the respiratory zone of the lung contains a structure analogous to the rat hair follicle, and if a radioactive particulate deposited in the respiratory zone has the capacity to disrupt one or more of these structures and

create a precancerous lesion, then cancer risks of the order of 10^{-3} to 10^{-4} per particle can be expected.^{63,64}

"The footnote on page 4.G-95 recognizes this possibility and indicates that it requires more study. The purpose of our comments here, of our petition and of our report is to indicate that this is a very real possibility and that it leads to greatly enhanced risks when hot particles are involved. Any decision, such as that being made relative to the LMFBR, must take this enhanced risk from hot particles into account. The failure to do this when estimating biological effects in this Draft Statement is one of its most serious flaws."

AEC Response:

We continue to believe that the mechanisms for cancer induction do require more study, as was indicated in the footnote. However, to quote one hypothesis as a proven fact, particularly when, except for the NRDC, this hypothesis has gained little acceptance during the six years since its introduction, does not provide evidence of a scientifically justifiable basis for the arguments presented. Present experimental evidence (see Appendix II.G.6) fails to show that "hot particles" are more effective than the same activity uniformly distributed in tissue.

⁶³Geesaman, Donald P., UCRL-50387, Addendum, Op. cit., pp. 6-7.

⁶⁴Brues, et al.,¹⁷ refers to Brues, A. M., H. Auerback, G. M. De Roche, and D. Brube. Mechanisms of carcinogenesis. Argonne National Laboratory, Biological and Medical Research Division Annual Report for 1967, ANL-7409, 151-155, 1967.

7. NRDC Comment (pp. 33-34):

"Page 4.G-96. It is incorrect to say that Geesaman⁶⁵ performed an analysis similar to that of Dean and Langham.⁶⁶ The latter calculated the dose to individual cells and then made estimates of the cancer risk based upon these cellular dosages. Geesaman, as discussed above, suggested that, when the dose from a particle to the irradiated tissue mass was sufficient to disturb its architecture, such a disrupted tissue mass in the lung would pose a unique carcinogenic risk -- a risk similar to that posed by a

⁶⁵Geesaman, Donald P. UCRL-50387, Addendum, Op. cit.

⁶⁶Dean, P. N. and W. H. Langham, "Tumorigenicity of Small Highly Radioactive Particles," Health Physics, Vol. 16, 1969, pp. 79-84.

disrupted hair follicle. Nevertheless, regarding both analyses the following criticism is made:

'The results of this work can be questioned on many grounds including extrapolation of the data on tumors in rat skin to tumors in human lung tissue,, the finding of Albert that the sensitive cells are at the base of the follicle in the rat skin...'

"This is another of the rather incredible statements in this section. As the AEC knows, most of our information in radiobiology comes from animal experiments. Since we are interested here in public health and safety, it is difficult to believe, as this statement would suggest, that the AEC is asking us to wait until we have the human corpses.

"Moreover, it is important to note that all of the references in this section are to animal data and strangely, no reference is made to the article of Lushbaugh that deals with a precancerous lesion in human soft tissue caused by a plutonium particle. As we indicated on page 21 above, if we had used just the human data in estimating the hot particle risk, we would have had to assign a risk per particle that was greater than 1/1000, rather than the 1/2000 that we assumed. In this respect, it is important to recall (see page 3) that Richmond demonstrated that hot Particles produce lesions in the lung of hamsters that are similar to that observed by Lushbaugh in human soft tissue. There is little reason to doubt that such a lesion would develop in the human lung and then progress into a cancerous growth.

"Finally, it is stated as fact on this page of the Draft Environmental Impact Statement:

'...that the assumed efficiency of production of lung cancer per cell does not conform to the experience with humans in the production of lung tumors from external radiation.'

"It would be of considerable interest to learn the basis for that statement. Dean and Langham, for example, made no mention of this fact in their article. In fact, the data of Sanders that is referenced later in the section would lead to the opposite conclusion.⁶⁷"

⁶⁷ This is reference 34, cited on page 4.G-102, Sanders, C. L., "Carcinogenicity of Inhaled Plutonium-238 from Crushed Microspheres," Pacific Northwest Laboratories, Annual Report 1972, Part 1 BNWL-1750: 28 (1973).

AEC Response:

The Dean and Langham and the Geesaman analyses have both similarities and, indeed, differences. Based upon skin tumor experiments in the rat, the Dean and Langham method was "to compute the probability that each cell exposed will form a tumor and to sum for all cells exposed to obtain total tumor probability." In their summary they clearly caution that the tumor probability versus dose-responses curve taken from skin tumor data on the rat may be different for man, that the response of lung tissue may differ from that of skin, and that "many of the biological parameters used in the model are poorly defined or are merely assumptions." On the other hand the NRDC states that Geesaman "suggested that, when the dose from a particle to the irradiated tissue mass was sufficient to disturb its architecture, such a disrupted tissue mass in the lung would pose a unique carcinogenic risk...similar to that posed by a disrupted hair follicle." Unfortunately, the critical "architectural" unit in the lung is not defined. Obviously assumptions are made here also, yet there is no caution expressed regarding their validity.

Nevertheless, while the two hypotheses differ in their approach, and in that Dean and Langham identify the limitations of the direct applicability of the biological data used, both hypotheses rely heavily upon the rat skin tumor data reported by Albert and his associates. Hence the conclusions of either of these hypotheses can be questioned since both make assumptions regarding the applicability of this data.

The AEC extensively relies upon results from animal experiments in attempting to determine the biomedical and general health consequences resulting from a variety of radiation exposure sources. However, as discussed in the AEC responses to the EPA Comment Letter, confidence of qualitative, and in some instances quantitative, relationships to exposure can be made only when comparable results are obtained in several species.

The uncertainties present in extrapolating effects from a single organ of tissue in a single species to the same tissue or organ in another species are generally recognized. To extrapolate from a tissue or organ in one species to a different tissue or organ in another species is clearly a procedure which must be approached with caution and appreciation for the uncertainties involved.

These cautions and uncertainties clearly apply to the extrapolation of the rat skin tumor data in the Geesaman and NRDC hypothesis: there is no known architectural unit in the rat lung or the human lung analogous to the rat skin hair follicle, and comparable skin tumor studies have not resulted in similar results being observed in the mouse or in other strains of rats.

The NRDC use of the Geesaman hypothesis has recently been reviewed by Dr. G. W. Dolphin, National Radiological Protection Board, Harwell, England. He concludes:

"The hair follicle cancers found by Albert et al. in rats were not found in similar experiments carried out by Hulse (1969) using mice. He found only epidermal and dermal cancers. Hence the hair follicle cancers described by Albert et al. may be peculiar to the rat species. If extrapolation from rat skin to mice skin is not possible in this work, then little confidence can exist in the extrapolation from rat skin to human lung tissue."

It is apparent that there is little justification for basing human health decisions regarding the lung upon results observed in the rat skin, especially when these results cannot be verified in mouse and other rat skin studies.

The NRDC statement that Lushbaugh reported "a precancerous lesion in human soft tissue caused by a plutonium particle" and the results reported by Richmond have already been addressed in response to a previous comment on the same subject.

The quoted statement regarding the relative efficiencies of lung cancer production is not in the Final Statement since the quoted statement relied on improper assumptions. Nevertheless, solely for the purpose of illustration, if the assumptions of the Dean and Langham model are used (cell diameter = 23.4 μm ; cell thickness = 6.0 μm ; and tumor probability per cell as a function of dose), and assuming a 570 gram lung with a cell density of unity, one can calculate that the lung contains some 2.2×10^{11} cells, and that a dose of 1500 rad should result in 22,000 tumors (given a tumor probability per cell at that dose of 1×10^{-7}). Although the dose-response curve from the Albert rat skin study shows an apparent threshold at about 700 rad, using the Dean and Langham assumptions, and the fourth power law ("the tumor probability rises as the fourth power of the dose to a maximum at 2000 rad..."), a dose of 400 rad should result in 111 tumors per animal. In contrast, experience with exposure of the human lung from external radiation does not conform to this prediction. The only X-ray exposure of the human lung which the BEIR report considers is the data available from spondylitic patients. The mean lung dose was 400 rads, and the increase in relative risk per rem was 0.0019, or 0.76 per 400 rad (RBE = 1). Thus, the observed incidence in humans from external radiation exposure of the lung is greater than two orders of magnitude below that predicted by the Dean and Langham hypothesis.

8. NRDC Comment (pp. 34-35):

"Pages 4.G-98 and 101. Here again the experiments of Richmond are

mentioned,,but again no mention is made of the similarity between the lung lesions produced in these experiments and the human soft tissue lesion described by Lushbaugh.

"It is stated,

'In the experiment of Richmond, et al.⁹, quoted above, the particles were firmly held in the pulmonary capillaries and, therefore, were not representative of particles actually deposited in the alveoli. Movement of inhaled particles is known to occur via movement by the cilia, and by macrophage engulfment.'

"The AEC is apparently unaware that the alveoli and associated deep respiratory tissue are not ciliated. Macrophage engulfment of the particles does occur, but how this related to lung clearance is not understood. More significant to the hot particle problem is the measured long term retention of these particles (in excess of 500 days) in the lung, which may be related to the engulfment of these particles by epithelial cells or by cytotoxic effect on macrophages.⁶⁸ The discussion following the above quoted statement again digresses into the irrelevant issue overkill."

AEC Response:

The experiments by Richmond and the similarity of the lesion to that described by Lushbaugh have been discussed in the AEC response to the first NRDC comment in this letter. Again, we emphasize that such lesions do not invariably lead to cancer. The statement in the Draft Statement that movement out of the lungs does occur was poorly worded and does not appear in the Final Statement. The intent was to indicate that movement out of the lungs does occur by ciliary action once the particles have been moved by macrophages or other mechanisms to the ciliated regions of the respiratory tree.

9. NRDC Comment (p. 36):

"Near the top of this page, the following appears:

'The fact that leukemia is a relatively rare occurrence in experimental animals administered plutonium may serve as an indicator that irradiation of a small portion of an organ (the marrow) to a high dose is not particularly troublesome as long as the average dose is low.'

⁶⁸ Sanders, C. L. and R. R. Adey, Health Physics, Vol. 18, 1970, pp. 293-295.

"There have been no experiments wherein hot particles were introduced directly into bone marrow. As the AEC knows, only "soluble" or "solubilized" plutonium is capable of deposition in the bone. Moreover, as the AEC knows, this plutonium is deposited preferentially in active areas of bone growth (a small portion of the organ). As a result, as discussed above (see pages 5-6), it is five times more effective in producing bone cancer than is radium which is more evenly distributed. This statement in the Draft Environmental Impact Statement is, therefore, grossly misleading."

AEC Response:

These comments are confusing because it is nowhere implied in the discussion in the Draft Statement that we were discussing hot particles introduced into bone marrow. As we indicated in the Draft Statement, "The outstanding example of an increased carcinogenicity resulting from a deposited radioactive material due to its localization and non-uniform dose-distribution is plutonium in bone." We want to point out that this difference could well be due to the fact that the critical tissue for osteogenic sarcoma could be the surface cells lining the mineralized bone so that the comparison with radium may not completely describe the relative effects unless the radium dose to this surface of the bone was used as the index. Plutonium is five times as effective as radium on the basis of average skeletal dose. The very rare occurrence of leukemia as a result of plutonium administration is a significant observation when considering the effects of non-uniform dose to a sensitive organ. As was indicated, calculations show that a portion of the marrow does receive a localized dose, and this evidence would indicate that such a localized dose does not produce an effect commensurate with local dose. Incidentally, this is not a new conclusion. The Federal Radiation Council (FRC), in its report No. 2 in 1961, when discussing ^{90}Sr (paragraph 4.2.3), notes: "Data on experimental animals indicate that the protection of a small portion of bone marrow from a high dose of radiation may markedly lower the incidence of leukemia. This suggests that, for the case of non-uniformity of radiation dose to the bone marrow, the average dose is a more meaningful index of hazard than the maximum local dose and that, for a given average, a non-uniform distribution of dose may be less hazardous than a uniform deposition."

The NRDC seems apparently unaware of experiments in which "hot particles" have indeed been introduced into the marrow. Both Finkel and Bickis ("Toxicity of Plutonium in Mice", Health Phys. 8: 565-579, 1962) and Rosenthal and Lindenbaum ("Osteosarcomas as Related to Tissue Distribution of Monomeric and Polymeric Plutonium in Mice," In: Delayed Effects of Bone-Seeking Radionuclides (C. W. Mays, W. S. S. Jee, R. D. Lloyd, B. J. Stover, J. H. Dougherty, and G. H. Taylor, eds.), pp. 371-384, University of Utah Press, 1969) injected polymeric ^{239}Pu into mice. The Pu aggregates were taken up by reticulo-endothelial cells in the liver, spleen and bone marrow (see autoradiograph in Rosenthal and Lindenbaum's article). Interestingly,

the incidence of leukemia was not increased, and the main effect from the plutonium was the induction of bone sarcoma.

10. NRDC Comment (pp. 36-37):

Page 4.G-102. "Considering what has appeared earlier in this section and also what follows, the reader can not help being confused by the following statement on this page:

'No clear cut, overall picture of the relative effects of uniform versus focal dose can be drawn from the present data.'

"We would in a qualitative sense agree with this statement, but we must emphasize that the available data strongly suggests that hot particle radiation leads to an enhanced risk of cancer (as much as 100,000 times that of uniform irradiation).

"Following the above sentence, this statement is made:

'It appears from the $^{238}\text{PuO}_2$ microsphere data and the skin experiments with ^{90}Sr that, in the extreme situation of a single, very active particle, the focal radiation is considerably less damaging.'

"We have previously discussed both of these experiments (see pages 3, 30-31, 34-35). As we indicated in these discussions, these experiments do not suggest a reduced risk for hot particles. Quite the contrary, they strongly support our analysis of an enhanced risk for hot particles."

AEC Response:

The "data" to which the NRDC refers as suggesting that particle radiation leads to an enhanced risk of cancer is apparently the hypothesis of cancer formation formulated by Geesman and modified by Tamplin and Cochran and not the results of extensive experimentation. This has been discussed earlier.

11. NRDC Comment (pp. 37):

Page 4.G-102. "Then, with considerable inaccuracy, the next sentence is given as justification for the concluding remark of this section:

'Cember²² concludes that for beta emitters the focal source is less damaging than is the uniformly distributed source.'⁶⁹

"Cember's experiments could not justify this conclusion and, in fact, he did not so conclude. Cember concluded:

'Experiments with rats have shown that radioactive substances deposited in the lung can lead to pulmonary neoplasia. Radiations from S^{35} , Sr^{90} - Y^{90} , and Ce^{144} elicited bronchogenic carcinoma and alveolar cell carcinoma in addition to several other tumor types. These experiments did not confirm the existence of a unique carcinogenic hazard due to the intense concentration of absorbed energy in the lung tissue immediately surrounding an inhaled radioactive particle.'⁷⁰

AEC Response:

The quotation from Cember given by the NRDC clearly indicates that this experimenter has concluded that no unique hazard results from such particulate radiation, at least from beta emitters. If one reads further in the Cember article, we find the following statement: "Furthermore, the experimental results imply that the carcinogenicity of a given amount of absorbed radiation energy increases up to a point, as the absorption of the energy, low-level, continuous exposure of the total lung may be more carcinogenic than the same amount of energy delivered acutely to a restricted volume of tissue." We do not believe that the statement in the Draft Environmental Impact Statement can be characterized as being given "with considerable inaccuracy."

12. NRDC Comment (pp. 37-38):

"The major thrust of the Cember article deals with ^{144}Ce particles in the lung. The ^{144}Ce was introduced admixed with stable Ce as either CeF_3 or $CeCl_3$ in particles of about 1 μ in diameter ($0.5 \mu^3$). ^{144}Ce emits a beta particle of 0.275 MeV and its daughter product ^{144}Pr emits a beta of 3 MeV. The rate of energy loss for these beta particles in tissue is about 0.2 Kev/ μ compared to some 94 Kev/ μ for plutonium alpha particles.

"This difference in energy loss per micron indicates that the activity of the ^{144}Ce emitter would have to be some 500 times that of the ^{239}Pu in order to deposit the same energy in the tissue irradiated by ^{239}Pu alpha particles. Moreover, since the QF for alpha particles is 10, the ^{144}Ce particles must have an activity $(10) \times (500)$ or 5,000 times that of a $^{239}PuO_2$ particle to qualify as a hot particle. Since the limiting activity of a $^{239}PuO_2$ particle is 0.07 pCi, a hot particle of $^{144}CeCl_3$ would have to contain more than 350 pCi. After correcting for the half-life of ^{144}Ce (288 days) a hot particle would have to contain some 500 pCi.

⁷⁰Cember²², Op. cit., pp. 289-290.

"The geometric mean diameter of the particles in these experiments was 1 micron. The highest exposure group received 50 μ Ci of ^{144}Ce in 30 μg of CeF_3 . Allowing a density of 6 g/cm^3 for the CeF_3 , the beta-activity per particle of 1 μ diameter is only 5 pCi. In other words, these experiments did not involve hot particles as defined above. The carcinogenesis observed in these Cember experiments, which was considerable, was related to high total and rather uniform organ dosage (1,000 - 30,000 rad)."

AEC Response:

The discussion concerning the definition of a "hot" particle is related to the recent petition by Tamplin and Cochran to the AEC and EPA concerning radiation standards for particulate actinide elements. The Tamplin-Cochran definition of a "hot particle" is arbitrary. There is no experimental justification for using the Tamplin-Cochran criteria for a "hot particle" to make judgment on Cember's work with beta-gamma emitting ^{144}Ce particles.

13. NRDC Comment (pp. 38-39):

"Following the mention of the Cember experiments, this statement is made:

'The data of Grossman, et al., ²³ indicate a seeming decrease in the tumor incidence as well as increased survival with focal source of ^{210}Po on iron oxide particles.'⁷¹

"As we mentioned previously, this reference is only an abstract. The AEC seemed to be more interested in the conclusion than in the validity of the experiment.

"In these experiments, the highest exposure involved 0.2 μCi of ^{210}Po absorbed on 3 mg of ferric oxide carrier particles (98% $<0.75 \mu$). Allowing a density of 5 g/cm^3 for the particles, the 3 mg would involve 2×10^9 particles at 0.8 μ diameter. The activity per particle would then be only 1×10^{-4} pCi. Again, this experiment does not involve hot particles as defined above. It represents rather uniform irradiation of the lung to high dosage (2,250 to 45,000 rem) and again, these large dosages produce a high incidence of cancer."

⁷¹Grossman, et al ²³ refers to the abstract: Grossman, B. N., J. R. Little and W. F. O'Toole, "Role of Carrier Particles in the Induction of Bronchial Cancer in Hamsters by ^{210}Po Alpha Particles, "Rad. Res. 47: 253 (1971). We do not know whether a more detailed description of these experiments was published. The information given in the abstract was sufficient to demonstrate that the experiment was irrelevant here, regardless of its overall validity.

AEC Response:

The work of Grossman, et al was presented at the Radiation Research Society Meeting in 1971 and at the Hanford Biology Symposium (1972). In addition, the same reference was used by the BEIR Committee.

14. NRDC Comment (pp. 39-40):

"Following the reference to the above abstract, this statement appears:

'Sanders,²⁴ as a result of his studies with soluble ^{238}Pu derived from crushed microspheres, arrives at a conclusion that spreading the dose more uniformly results in an increased cancer incidence due to the greater number of epithelial cells involved. This conclusion was based on the observation of '--a significant incidence of tumors in the lung and in other tissues at radiation doses that have not previously been shown to be carcinogenic in animals.'⁷²

"The conclusion of Sanders is not justified by the experiment described in the referenced article. Sanders indicates that hot particles were not involved in this study. The conclusion that is justified by the results of this study is that the exposure standards for plutonium may be much too high (at least 100 times too high) even when hot particles are not involved. The results indicate that a uniform dose of 15 rem doubled the natural incidence of lung cancer in the exposed rats. A worker is allowed this dose each year and a member of the population could accumulate this dose in 10 years. It is somewhat disturbing that the AEC would reference this experiment and then ignore its implications.

One further point could be made concerning this study. It is not at all clear from the description given in the reference that the exposures did not involve a few hundred hot particles. If this were so, these particles could have been partly responsible for the observed cancers."

AEC Response:

Sanders based his conclusion on the fact that the ^{238}Pu used in his experiment was comprised of extremely small size, readily soluble particles which were deposited throughout the lung giving a more uniform distribution of dose than occurred in his earlier experiment with $^{239}\text{PuO}_2$ particles.

⁷²Sanders, ²⁴ refers to Sanders, C. L., "Carcinogenicity of Inhaled Plutonium-238 from Crushed Microspheres," Pacific Northwest Laboratories Annual Report 1972, Part 1 BNWL-1750:28 (1973).

The relatively uniform distribution of dose was more effective than the non-uniform distribution of dose that occurred with $^{239}\text{PuO}_2$ and in other experiments with particulate $^{238}\text{PuO}_2$. Sanders notes in his study with crushed ^{238}Pu microspheres that about 1% of the initial alveolar burden was present in the lungs after a year and that it was concentrated with hemosiderin-like granules located in peribronchiolar and perivascular areas of the lung. However, most of the lung cancers observed in the experiment did not appear to originate in these areas but in subpleural regions. Further, 80% of the radiation dose was delivered within the first four months after the inhalation exposure, when most of the plutonium in the lung was highly dispersed. Therefore, Sanders attributed the lung cancers that occurred to the diffuse radiation exposure of the lung tissue. In other experiments in which rats inhaled $^{238}\text{PuO}_2$ or $^{239}\text{PuO}_2$ particles, lung burden equivalent to those retained for long times in the experiment with the crushed microsphere ^{238}Pu , did not cause lung cancer in 77 rats observed for about 600 days.*

Sanders calculated an average dose of 32 rads or 320 rem to the lungs of the rats which showed a statistically significant incidence of lung cancer. Because this is the lowest dose at which lung cancer has been observed in experimental animals, because there were less than 100 rats in the experiment, because the results are on only one animals species, and because experiments which will provide information relative to the reproducibility of these results are not yet complete, it is premature to speculate upon the applicability of the results to radiation standards.

15. NRDC Comment (p. 40):

"Page 4.G-103. Here we find the conclusion reached in this section:

'Therefore, the conclusion is that the preponderance of the evidence indicates that the use of an average lung dose is appropriate in estimating health consequences and may well be conservative.'

"As we have indicated above, there is no justification for this conclusion so far as hot particles are concerned. In fact, while none of the references detract from our conclusions, one of the references used in this section actually supports our contention that hot particles carry greatly enhanced cancer risks.⁷³ Moreover, the experiment of Sanders suggests that the risk estimates from the BEIR Report that were used in the

*C. L. Sanders and G. E. Dagle, "Studies of Pulmonary Carcinogenesis in Rodents following Inhalation of Transuranic Compounds," In: Experimental Respiratory Carcinogenesis and Bioassay (J. F. Park and E. Karbe, eds.), Proceedings of a Symposium held at the Battelle-Seattle Research Center, June 23-26, 1974, Seattle, Washington.

⁷³ Richmond, C. R., et al, Op. cit.

Draft Statement may be serious underestimates of the effects even when hot particles are not involved."

AEC Response:

The conclusion of the NRDC is tenable only if we accept one particular hypothesis for the induction of cancer by radiation--the Geesaman hypothesis as modified by Tamplin and Cochran, in preference to a number of other possible hypotheses and the direct results from animal experiments.

The Final Statement contains risk estimates based on animal experiments with transuranium elements as well as estimates based on the BEIR Report.

Richard Dalfuku
44 Russell St.
Boston, Mass. 02215

April 11, 1974

To whom it may concern,

I wish to thank you for providing me with a copy of WASH-1535, the Draft Environmental Impact Statement of the LMEBP program.

Unfortunately, I received the EIS too late to be able to evaluate it in its entirety.

While reading volume 1, I prepared a summary of my objections to the LMEBP and attempted to evaluate the problems besetting the credibility of the USAFC in this and other programs.

I would appreciate if you could keep me informed of future developments.

Sincerely yours,

Richard Dalfuku

In their suit against the US Atomic Energy Commission (USAEC), the Scientists' Institute for Public Information (SIPI) claimed that the liquid metal fast breeder reactor (LMFBR) program involved a "recommendation or report on proposals for legislation and other major Federal actions significantly affecting the environment" under section 102(2)(c) of the National Environmental Policy Act (NEPA), and that the Commission was therefore required to issue a detailed Environmental Impact Statement (EIS) on the program. The District Court held that no statement was presently required since, in its view, the program was still in the research and development stage and no specific implementing action which would significantly affect the environment had yet been taken. Upon appeal from SIPI the decision was reversed in the US Court of Appeals for the District of Columbia (case No. 72-1331) on June 12, 1973.

That the AEC had not deemed fit to comply with the NEPA is startling in light of the Guidelines for the Preparation of Environmental Impact Statements issued by the Council on Environmental Quality on August 1, 1973:

1500.5 - Types of actions covered by the Act.

(2) New and continuing projects and program activities: directly undertaken by Federal agencies; or supported in whole or in part through Federal contracts, grants, subsidies, loans or other forms of funding assistance (CEQ, 1973).

In this report, we shall first analyse the environmental impact of electric power generation, then focus more specifically on the LMFBR. We shall then attempt to demonstrate the negligence of the AEC in assessing the environmental impact of its projects.

BACKGROUND

Human beings naturally expend a certain quantity of bodily energy. Initially each person needed to consume some 2500 to 3000 kcal of energy each day in the form of food. But today in industrialized countries this basic energy need is only a small part of the energy expended. In 1968, the average per capita consumption of energy in the US from all sources was approximately 215000 kcal per day. In terms of the sum of fossil fuels, hydropower, and nuclear power, the US consumed 35% of the world's supply to meet the needs of approximately 6% of the world's population. Energy consumption by the US was nearly 10 times greater than that of all Latin America and approximately four times greater than all of Asia (excluding the USSR). The USSR, the second largest national consumer of energy, used less than one half the amount of the US (Pasmann, 1972).

In the US, between 1947 and 1965, the increase in use of all forms of energy was approximately 2.8% per year; during the same period, the population rose by only 1.7% per year (SIPI, 1970).

By comparing the expected fuel consumption in the year 2000 with the use patterns for 1968, it can be seen that electricity generation will dominate in the future, increasing both absolutely, from 14.0 to 72.3 quadrillion Btu, and relatively to the total gross energy input from 23 to 44% (Mills, Johnson, and Perry, 1971).

In 1950, the per capita consumption of electric power was 2000 Kw-hours. In 1968, the per capita consumption grew to 6500 Kw-hours; and in the year 2000 it is estimated at 25000 Kw-hours (SIPI, 1970).

Table 1OVERALL EFFICIENCIES OF
STEAM ELECTRIC PLANTS

Fossil fueled plant	38 to 40%
Proposed fossil plants with IHID topping cycle	53 to 59%
Present light water nuclear reactor plants	30 to 32%
Proposed advanced nuclear reactor plants	39 to 43%

Source: Scientists' Institute for Public Information, 1979.
Environmental cost of electric power, SIPI, New York, p. 7.

Table 2DEATHS PER YEAR FROM EXPOSURE TO
IONIZING RADIATION IN THE UNITED STATES

Source of ionizing radiation	Average annual exposure in millirems	Number of deaths per year
Natural background exposure	100-150	110000 to 75000
Medical and dental exposure	55-125	5500 to 62000
Fallout from weapons testing	<10	1000 to 5000
Exposure from the nuclear industry	2-10	200 to 5000
Here the entire popu- lation exposed to the maximum allowed by present regulations:	170	170000 to 35000

Source: Morgan, K.L. 1979. Environmental costs of electric power.
SIPI, New York, p. 15.

At present, civilian uses of nuclear power are restricted to the generation of electricity. In 1967, the use of nuclear fuel in the US accounted for less than 1% of the total consumption of energy, but as much as 25% of the total world consumption for that fuel (Dasmann, 1972). In the future, nuclear power is expected to dominate the generation of electricity, accounting for 53% by the year 2020 (Hills, Johnson, and Perry, 1971).

President Nixon's "Project Independence 1980", which he defined as "a series of plans and goals set to insure that by the end of this decade Americans will not have to rely on any resource energy beyond our own", will not influence the building of nuclear power plants, as it would be impossible to build more than those already on the drawing board (Rose, 1974).

FOSSIL AND NUCLEAR PLANTS

SIMILAR FEATURES

In spite of many differences, fossil fueled and nuclear fueled electric power plants have at least four basic aspects in common: both classes of fuel are at present used almost entirely in steam-electric generation plants, and for this reason both create somewhat similar problems of thermal pollution. In addition, both pollute water with chemical additives, and at times great amounts of land are used in transmitting power from the plant to the consumer (SIPI, 1970).

THERMAL POLLUTION

Fossil fueled and nuclear power plants are the major sources of thermal pollution. Significantly, nuclear plants discharge about 50% more heated water than fossil fueled plants (see table

1).

All steam electric plants produce large amounts of waste heat as a result of the very low level of efficiency now achieved in the generation of electricity. About two-thirds of the heat cannot be turned into energy; rather, it must be discharged into the air or water as waste heat (Fabricant and Hallman, 1971).

Presently, the amount of water used for cooling power plants is about 120 billion gallons a day, or about 10% of the average runoff of water in the continental US. Cooling water requirements are expected to increase to 200 billion gallons per day by 1980 and 600 billion gallons per day by the year 2000, the equivalent of 50% of the average daily runoff of water in the continental US (excluding Alaska) (Fabricant and Hallman, 1971).

Thermal discharges can affect drastically aquatic life and water quality, e.g., density, viscosity and gas solubility (Fabricant and Hallman, 1971).

The Federal Water Pollution Control Administration has declared that waters above 93 degrees Fahrenheit are essentially uninhabitable for all fishes in the US except certain southern species. Many US rivers already reach a temperature of 80 degrees F. or more through natural heating alone. Since the waste heat from a single 1000 megawatts power plant is expected to raise the temperature of a river carrying a flow of 3000 cubic feet per second by 10 degrees, and since a number of industrial and power plants are likely to be constructed on the banks of a single river, it is obvious that many US waters will become uninhabitable (Clark, 1969).

Fish, as poikilotherms ("cold blooded"), are particularly sensitive to changes in the thermal environment. Most of the effects of temperature stem from the impact on the rate of

metabolism, which is sped up by heat. Generally speaking, the metabolic rate doubles with each increase of 10 degrees F. Since a speedup of metabolism increases the animal's need for oxygen, the rate of respiration must rise. At elevated temperatures a fish's respiratory difficulties are compounded by the fact that the hemoglobin of its blood has a reduced affinity for oxygen and therefore becomes less efficient in delivering oxygen to the tissues (Clark, 1969).

The temperature of water has pronounced effects on appetite, digestion and growth in fish. Young carp digest food 4 times as rapidly at 70 degrees F. as they do at 50 degrees . In general, aquatic animals tend to raise their swimming speed and to show more spontaneous movements as the temperature rises (Clark, 1969).

Temperature plays a critical role in the reproduction of aquatic animals. Some species of fish spawn during the fall as temperatures drop; many more spawn in the spring. The rising temperature induces a seasonal development of their gonads and then at a critical point triggers the female's deposit of her eggs in the water. The triggering is particularly dramatic in estuarine shellfish, which spawn within a few hours after the water temperature reaches the critical level. However, there are critical temperatures below which fish will not reproduce (Clark, 1969).

Temperature affects the longevity of fish as well as their reproduction. Fish, by some process not yet understood, are able to acclimate themselves to a temperature shift that is modest and not too sudden (Clark, 1969).

So far, there have been a number of recorded fish kills by thermal pollution in US waters. One kill occurred in the summer of 1963 when a large number of menhaden acclimated to temperatures

In the 30's became trapped in effluent water at 23 to 25 degrees F. during the testing of a new power plant on the Cape Cod Canal (Clark, 1969). Two large fish kills have been reported on the Hudson since Consolidated Edison's Nuclear Unit No. 1 was placed in service in 1963. In all, about 270000 fish - white perch and striped bass - were killed. Other smaller kills have been reported in New York State (Fabricant and Hallman, 1971).

Pollution by sewage is a contributing factor to the deleterious effects of thermal pollution on the fauna. Increases in water temperature also increase algae growth, particularly in a nutrient rich area near a source of sewage or industrial waste; speed the eutrophication process in waterways; and trigger excessive growth, decreasing water flow and increasing siltation. Higher temperatures can also create conditions enabling bacteria in domestic sewage to multiply rapidly (Fabricant and Hallman, 1971).

The dissipation of heat can be facilitated in various ways by controlling the passage of cooling water through condensers. The prevailing practise is to pump the water once through the condensing unit. The heated effluent is then discharged through a channel into the body of water from which it was taken. There the effluent, since it is warmer and consequently lighter than the receiving water, spreads in a plume over the surface and is carried off in the directions of the prevailing surface currents (Clark, 1969).

Various strategies have been devised to make the discharge water safe for aquatic life:

- Cooling ponds: for the 1000 megawatts plant of the future a lake with a surface area of 1000 to 2000 acres would be required. (A 2000 acres lake would be 1 mile wide and 3 miles long)

(Clark, 1969). Although cooling ponds are the cheapest cooling systems (SIP, 1970), they are very inefficient in their land use.

- Evaporative towers: In evaporative towers, the heated water mixes with air and is cooled largely by evaporation. A substantial amount of the water is lost to the atmosphere by this process (SIP, 1970). The towers for a 1000 megawatts power plant would eject some 20000 to 25000 gallons of evaporated water a minute, an amount that would be the equivalent of a daily rainfall of an inch on an area of 2 square miles. Further, on cold days such a discharge would condense into a thick ice over the area in the vicinity of the plant (Clark, 1969).

- Dry towers: the dry type of cooling tower can be compared to a giant automobile radiator. Thus, there is no evaporation of the water in dry towers (SIP, 1970). However, the "dry" system is 2.5 to 3 times as expensive as the "wet" system, and to date no such towers have been used on a large power station (Clark, 1969).

In *Calvert Cliffs Coordinating Committee v. AEC*, the Court ordered the AEC to give more complete attention to the environment in its internal review process (Anonymous, 1972). This landmark case was principally brought about by opposition to the effects the heated effluent water from the nuclear power plant would have had on the biotic communities of Chesapeake Bay (Rasmann, 1972).

CHEMICAL POLLUTION

Chemicals such as chlorine are added to the water used in steam electric plants to protect the machinery. Biocides are added to protect from the buildup of slime in the condenser. Various other compounds are added to control the acidity of the cooling process water. At present, all of these additives are not

being recovered but rather released into the nearest body of water (SIPI,1970).

TRANSMISSION LINES

Approximately 100 acres are required for 1 mile of transmission lines; the farther away an electric station is from the consumers of power, the more land is removed from other uses. Yet the closer a power plant is to the consumers, the greater the chances of harmful exposure of large numbers of people to the various pollutants by these plants (SIPI,1970).

Currently there are about 300000 miles of electric power transmission lines in service throughout the country, which occupy about 4 million acres of land. Only 2400 miles (0.008%) of these lines are underground. It is estimated that by 1990, 200000 additional miles will be required, bringing the total to 7 million acres of land for right of way, or more than 11000 square miles (the area of the state of Connecticut is 5100 square miles) (Fabricant and Mallman,1971).

NUCLEAR POWER PLANTS

UNIQUE FEATURES

Nuclear power offers certain environmental and resource conservation benefits: it eliminates air pollutants released by combustion of fossil fuels, and breeder reactors (projected for service in the 1980's) which produce more nuclear fuel than they consume, offer a possible means for substantially extending the life of nuclear fuel supplies and conserving fossil fuels for power, as well as for other purposes. However the lightwater burner reactors now in use, and to be used increasingly in the

next 15 years, consume only about 0.6% to 1.2% of the potential energy in uranium ores, whereas breeders are expected to use from 60 to 90% of uranium processed from ore (Fabricant and Hallman, 1971).

Naturally occurring uranium contains 99.29% U-238, 0.71% U-235, and 0.0058% U-234 (Selby and Yeast, 1966). Lightwater burner reactors use only a fraction of the potential energy contained in uranium ore, that of U-235. It has been estimated that the expanded use of current reactors would exhaust the economically extractable reserves of U-235 within the next 20 to 30 years (Fabricant and Hallman, 1971).

In a nuclear reactor, the following reaction occurs:
slow neutron $w \rightarrow U^{235} \rightarrow$ fission fragments + 2.5 neutrons (on the average) + prompt gamma rays.

The fission fragments then decay to fission products, beta particles (electrons) and delayed gamma rays.

From an environmental standpoint nuclear reactors are unique in their emission of ionizing radiation and discharge of radioactive wastes.

RADIATION HAZARDS

In the case of ionizing radiation, it is generally accepted that there is no threshold (SICR, 1979). The Federal Radiation Council establishes the limits on nuclear radiation that the US population may be exposed to from peaceful atomic energy activities. Most people assume that these standards, set by a responsible body, have a wide margin of safety built into the permissible dosage. Unfortunately this is not true. If the population of this country did receive the present maximum allowable radiation dosage there would be, conservatively speaking,

24000 additional cases of leukemia and cancer each year (Gofman and Tanplin, 1971).

Exposure to radiation can have basically two effects on humans:

1. Somatic damage, or direct damage to body tissues other than reproductive cells, which may cause various forms of cancer (e.g., leukemia, bone cancer and thyroid cancer), shortening of the life span, and damage to unborn children (Fabricant and Hallman, 1971).

2. Genetic damage, i.e. damage to reproductive cells, resulting in mutations (Fabricant and Hallman, 1971).

Estimates have been made of the total number of deaths which might result from exposure to radiation (see table 2).

RADIOACTIVE WASTES

Under present US regulations, the allowable release of radioactive materials into coolant water will be 2200 Curies per year (Lovenstein, 1971).

Many aquatic organisms concentrate radioactive elements. Oysters for example have been observed to concentrate zinc-65, a common fission product, by a factor of 250000 over its level in the surrounding water, and cobalt-60 by a factor of 1 million. Certain edible seaweeds concentrate iodine-131. Other typical radionuclides which may be avidly incorporated by aquatic organisms are tritium, chromium-51, iron-59, manganese-54, as well as the familiar cesium-137 and strontium-90 (Lovenstein, 1971).

Strontium-90 closely resembles normal calcium, an important component of all living cells, and which in animals appears especially in milk and bones (SPOEL, 1969).

Cesium-137 is chemically similar to potassium, a common constituent of all living cells (SPOFI,1969).

Iodine-131 has the same chemical behavior as non radioactive iodine, and like the normal element becomes concentrated in the thyroid, where it is incorporated into the iodine containing hormone thyroxin (SPOFI,1969).

Tritium, the radioactive form of hydrogen, behaves like hydrogen and can become part of all living tissues (SPOFI,1969).

However, the direct discharge of radioactive materials accounts for less than one hundred millionth of the total radioactive wastes which are stored in tanks as corrosive liquids that will boil for more than 100 years, or incorporated into glassy materials and stored in abandoned salt mines. It is estimated that by 1980, ten trillion Curies of accumulated wastes will be stored, of which one trillion will be strontium-90. Although precautions are taken to prevent contamination by these lethal and long lived poisons, a number of storage tanks have already developed leaks (Lowenstein,1971).

In 1965, four of the tanks at the Hanford Atomic Products Operation had sprung leaks of varying severity, through the corrosive action of their hot radioactive content (Hovick,1970).

It is inevitable that some of these radio-isotopes will find their way into the world's waters and the hydrosphere (Lowenstein,1971).

MAJOR ACCIDENTS

A major risk associated with nuclear plants is the possibility of a reactor accident. In 1961, three reactor staff members were killed by radiation and an explosion of steam in an experimental AEC reactor owing to mismanagement of a single

control rod. In 1957, a plutonium production reactor in England malfunctioned, all reactor safeguards failed, and radioactive fission products (approximately 20000 Curies of Iodine-131) went up the stack and were spewed over a 400 mile area, contaminating milk and vegetables (Fabricant and Hallman, 1971).

An atomic explosion is not possible in current lightwater reactors, but a malfunction of the reactor with a simultaneous failure of safeguards could result in fuel meltdown (Fabricant and Hallman, 1971). In a 1000 megawatts power reactor, the radioactive material released to the environment would approximate that released in the explosion of a 50 megatons bomb (SIPI, 1970). Even if the nuclear fission is shut down promptly upon failure of cooling, built up radioactivity in the fuel continues to generate heat at a sufficient rate to melt the fuel (Fabricant and Hallman, 1971). For a reactor of 1000 megawatts or more, molten fuel would breach not only the reactor containment structures in the present designs, but would melt through the structure and steel casing, and down into the earth. This would be a serious occurrence, for many radioactive wastes ordinarily trapped within the fuel are gases. At this point, at least, the gaseous portion of the radioactive wastes would be released to the outside air (Novick, 1969).

EAST BREEDER REACTORS

Nuclear breeding is achieved with the neutrons released by nuclear fission (see equation above). One of the neutrons must trigger another fission to maintain the nuclear chain reaction, some neutrons are non productively lost, and the remainder are available to breed new fissionable atoms. The fertile raw

materials for breeder reactors are thorium-232, which is transmuted into uranium-233, and uranium-238, which is transmuted into plutonium-239 (Seaborg and Bloom, 1970).

There are two different breeder systems: the thermal breeder, employing slow neutrons, operates best on the Th-232 - U-233 cycle. The fast breeder, employing more energetic neutrons, operates best on the U-238 - Pu-239 cycle (Seaborg and Bloom, 1970).

In the US and other countries, decisions were made rather early that a fast breeder reactor cooled with liquid metal was the most attractive concept to pursue. This concept is known as the liquid-metal cooled fast breeder reactor (LMFBR). A serious alternative effort is being pursued, chiefly by the utility companies to develop the technology of a gas cooled fast breeder reactor using pressurized helium as the coolant (Seaborg and Bloom, 1970).

The potential for a serious reactor accident resulting in widespread dispersion of radioactive wastes is higher in some types of breeder reactors than in the light water reactors used today: an explosive accident is possible if a cooling duct becomes plugged. The latter is precisely what happened to Detroit's Enrico Fermi Power Plant in 1960. The reactor was an advanced LMFBR. A piece of metal blocked the liquid sodium coolant, causing partial melting of a few fuel assemblies. Some radioactive gas escaped within the plant, although none was detected outside the building. While they analyzed the possibilities, the operating staff hesitated for a month to probe for the source of trouble and scope of damage fearing that an explosion might be triggered because of the distorted fuel configuration that resulted from the meltdown (Fabricant and

Hallinan,1971).

Another characteristic of the LMFBR, is the use of sodium as a coolant. Since sodium is opaque, provision must be made for the maintenance and the refueling of the reactor without benefit of visual observation. Sodium is of course highly reactive chemically, and it becomes intensely radioactive when it is exposed to neutrons. Hence the sodium must be kept out of contact with the air or water, and radiation shielding must be used to protect workers who are near sodium that has been through the core and blanket of an operating reactor (Seaborg and Bloom,1971).

THE PROBLEM OF PLUTONIUM

If the LMFBR is developed and implemented according to AEC projections, then by the year 1980 commercial plutonium production will be 50 tons annually, and in excess of 100 tons by the year 2000 (Geesaman,1971).

Pu-239 is an alpha emitter with a half-life of 24000 years, hence its activity is undiminished in human time scales. Plutonium is a fuel that is toxic beyond human experience. One microgram injected intradermally in mice has caused local cancer. A similar amount injected in the blood system of dogs has induced a substantial incidence of bone cancer because of the element's affinity for bone tissue. It is fortunate that the body maintains a relatively effective barrier against the entry of plutonium into the blood system (Geesaman,1971).

Recently, the Natural Resources Defense Council (NRDC) has petitioned the AEC to tighten radiation exposure standards pertaining to plutonium by a factor of 115000. The petition argues that particles of plutonium inhaled in the lung deliver

much higher doses of radiation to immediately surrounding tissue than to the lung as a whole, and that it is these local doses which should be considered in setting radiation standards (Anonymous, Apr. 1974).

RELIABILITY OF NUCLEAR

POWER PLANTS

Nationally, seventeen civilian nuclear power plants and one military plant, at Hanford, Washington, had been completed by the end of 1968. Of these, five had been shut down by that time as impractical or unsafe; a sixth, the Fermi reactor, was never made to operate properly and finally suffered an accident that took it out of service (see above); a seventh, the Humbolt plant, has operated within allowable radiation release limits only by reducing power output. The remainder have had various degrees of difficulty, and another was shut down in 1969 (SIPI, 1970).

The outlook has been similar in New England. In 1973, of the five major plants that can distribute electricity into the New England power grid, none was running at full capacity and one was idle (Langner, 1973).

As a final note on the reliability of nuclear power plants, the San Onofre nuclear power plant, which is near the Western White House, was shut down due to an accident just before President Nixon praised it on television (Anonymous, Jan. 1974).

Louis H. Doddis, vice-chairman of Con Ed has calculated that as of October 1972, nuclear power plants were delivering only 81% of the power they would have produced operating at full capacity all of the time; coal and oil burning plants, by contrast, delivered 75% of their maximum output (Anonymous, Apr. 1974).

NUCLEAR POWER ANDTHE PEOPLE

The existing utility rate structure and method for calculating returns provide strong economic incentive for utilities to promote nuclear power. The high capital cost of nuclear plants is included in the utility's rate base, which increases its allowable revenues (Fabricant and Hallman, 1971).

Ever since the Salvert Cliffs case, the USAEC has carefully avoided assessing the environmental impact of its programs:

- Under the Atomic Energy Act of 1954, the AEC has the basic responsibility for regulating the location, as well as safety of radioactive emissions from major nuclear facilities in a manner which protects "the health and safety of the public". At the same time, the AEC has the responsibility for promoting the development of atomic energy for peaceful, military and industrial purposes. Until recently, it also was responsible for establishing radiation exposure and emission standards governing virtually all man made sources of radioactivity (Fabricant and Hallman, 1971).

- The AEC has consistently taken the position that no state or local government should have the right to establish stricter standards for radiation exposure emissions from major nuclear facilities than are set by the Federal Government, or to regulate reactor safety. Recently, this position has been challenged by several states which have imposed limits on radioactive emissions from nuclear power plants which are stricter than the AEC requirements (Fabricant and Hallman, 1971).

- The Price-Anderson Act was pushed through Congress in 1957

(currently in effect until 1977) shortly after the AEC's Accident Report was released. Under this act the liability of the utilities and the reactor manufacturers in the case of an accident is limited to a maximum of \$560 million, - \$473 million of which will be paid by the Federal Government. This is only 33 of the maximum \$7 billion estimated in the AEC's outdated 1957 Accident Report. When this measure was being considered by Congress in 1965, several reactor manufacturers and utilities testified that they would probably abandon the nuclear power business if the limitation on liability was dropped (Fabricant and Hallman, 1971).

- The AEC has showed an ambiguous attitude towards siting nuclear power plants near densely populated urban areas (Fabricant and Hallman, 1971).

- The AEC refuses to inform the public fully as to the risks and all possible consequences of an accident involving the large reactors now in service (Fabricant and Hallman, 1971).

- The AEC has failed to set radiation exposure and emission levels specifically for nuclear power plants and reprocessing facilities (Fabricant and Hallman, 1971).

- The AEC's recent decision to essentially terminate safety research and development in lightwater reactors and to shift responsibility in this area to industry which historically has not made any substantial effort to carry out such research and development (Fabricant and Hallman, 1971).

A few specific examples of the AEC's lack of concern for the public's health and welfare, follow:

- The AEC had planned to ship radioactive wastes by truck from its Shoreham, Long Island nuclear power plant, to a reprocessing facility in upstate New York. In its draft SIS, the AEC had

calculated population exposure to radioactivity along the trucking route by using a standard calculation of 330 people per square mile, although the density in Manhattan, through which the trucks must pass, runs as high as 8000 per square mile, thereby greatly increasing the risk to the population as a whole (Anonymous, Nov. 1972).

- The AEC allowed Commonwealth Edison, a Chicago based utility company, to purchase land on which to site a nuclear power plant without first having issued an EIS (Anonymous, Jan. 1973).

- In December 1972, the AEC issued the draft form of a report entitled WASH-1250: "The safety of nuclear power reactors and related facilities". This report purports to be a complete and candid review of the nuclear fuel cycle. However, safeguards, diversions, and plutonium toxicity are not even discussed (Abrahamson, 1973)!

CONCLUSIONS

In 1974, \$320 million in private and Federal development will be spent on the LMERB: 20% of the entire national budget devoted to energy options. Yet, little or no attention has been paid to energy utilization and conservation options (Rose, 1974).

In 1973, in Sweden, a national parliament hesitated for the first time to rush into a hazardous nuclear future, and showed a willingness to listen to the serious arguments about the global risks of large nuclear power development (Gillberg, 1973).

While the US is the most industrialized nation of the world, the infant mortality and age specific death rates are 1.5 those of a number of countries such as Sweden, and the average life expectancy is 4 years less (Templin, 1971).

As R. Rapoport wrote: "... the AEC and its allies in industry have totalitarized their hold over nuclear power. They probably have more freedom to pollute than any other power source in the country. The AEC finances, licences, regulates and polices itself. Other governmental agencies involved in the sampling or monitoring of radiation pollution are often forced to rely on inadequate AEC data, or are themselves funded and controlled by the AEC" (Rapoport, 1970).

Clearly, this state of affairs must be stopped. The AEC should transfer the full regulatory authority regarding licensing, safety, public health, and environmental impact of nuclear facilities to the Environmental Protection Agency. Further, the Federal Price-Anderson Act of 1957 should be repealed to make liable the owners and suppliers of nuclear power facilities and nuclear reprocessors for harm caused by nuclear accident or radiation (Fabricant and Gallman, 1971).

Instead of spending the majority of the Federal budget on the development of hazardous, unreliable and inefficient technologies, the emphasis should be placed on energy conservation. In 1973, only \$5.75 million were spent on the development of the highly efficient magnetohydrodynamic power generation method (see table 1) (Edelson, 1975). Further funding of this project, as well as the development other environmentally sound energy sources (e.g., solar energy) is necessary.

In the past the US government has been infatuated with the development of new technologies for their own sake. However, looking into the future, the US should set an example to the world, and particularly to developing nations, of efficient energy use and conservation; and not cast the image of an economic giant crippled by the wanton destruction of its

environment.

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Richard Daifuku
44 Buwell Street
Boston, Massachusetts 02215

Dear Mr. Daifuku:

Thank you for your letter of April 11, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received and a copy of the Final Statement is enclosed for your information. AEC staff responses to your specific comments are also enclosed. More detailed information concerning your comments and concerns on Plutonium Toxicity is presented in Section 4.7 and Appendix II.G of the Final Statement.

Your concerns on thermal pollution were discussed in Section 4.2 and Appendix 4.H of the Draft Statement and are also discussed in the Final Statement. Your concerns regarding nuclear plant reliability were not discussed in the Draft Statement. One purpose of the LMFBR Program is to demonstrate LMFBR plant reliability, to an extent beyond that presently known. This information will be obtained in part from the LMFBR Demonstration Plant Project, which is discussed in the Final Statement under Section 3.5.

Your interest in the LMFBR Program and comments on the Draft Statement are appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

Enclosure 1

AEC Staff Response to Specific Comments by Mr. Richard Daifuku1. Comment (page 11):

"It was claimed that '... the direct discharge of radioactive materials accounts for less than one hundred millionth of the total radioactive wastes which are stored in tanks as corrosive liquids that will boil for more than 100 years...' Then quantities of radioactivity stored by 1980 were presented and references to early tank leaks at Hanford were cited. It was then stated that "It is inevitable that some of these radioisotopes will find their way into the world's hydrosphere."

Response:

Most of the waste (in terms of curies) will originate at fuel reprocessing plants as liquid high-level waste. Current Federal regulations require that this liquid waste be converted to a solid material within five years after separation in the fuel reprocessing step. Technical aspects of the Hanford waste tank leaks are for the most part unrelated to the question of commercial high-level waste management. When short-term liquid storage is part of the commercial waste management plan, corrosion resistant alloys will be used for the primary containment barriers (tanks) and more than one barrier will be used (e.g., tanks installed in lined vaults). The probability of leaks will thus be very low; the probability that a sizeable leak could go undetected will also be very low (the leak will be trapped and detected in the vault) and these factors combined with the short-term storage (5 years or less) make the probability of uncontrolled large leaks extremely small. Analyses of possible paths to the hydrosphere for radioisotopes from waste management operations have not shown any instance where a serious public health hazard resulted.

2. Comment (page 11):

"A major risk associated with nuclear plants is the possibility of a reactor accident."

Response:

All civilian power reactors must undergo an extensive safety review by the AEC. The general safety requirements which must be met are set forth in the text of the Final Statement in Section 4.2.7.3. Through a defense in depth approach, the risk of a reactor accident is reduced to acceptable levels. The experience of the SL-1 accident and all other reactor accidents, such as the Fermi meltdown incident, has been factored into the design and construction of both LWRs and future LMFBRs. It may

be pointed out again here that no member of the general public has been killed or injured as a result of a reactor accident.

3. Comment (pages 11-12):

"In 1961, three reactor staff members were killed by radiation and an explosion of steam in an experimental AEC reactor owing to mismanagement of a single control rod. In 1957, a plutonium production reactor in England malfunctioned, all reactor safeguards failed, and radioactive fission products (approximately 20,000 curies of Iodine-131) went up the stack and were spread over a 400 mile area, contaminating milk and vegetables. The latter [explosive accident with coolant duct plugged] is precisely what happened to Detroit's Enrico Fermi Power Plant in 1966. The San Onofre nuclear power plant, which is near the Western White House, was shut down due to an accident just before President Nixon praised it on television."

Response:

In the San Onofre and Fermi examples cited, no significant amounts of radioactive material were released from the containment. The San Onofre "accident" was a minor malfunction which the plant was designed to accommodate and resulted in very little effect on operation. The Fermi incident is discussed in more detail in the response to Comment 8 and in the text in Sections 4.2.7.5 and 4.2.7, Annex C. It should also be noted that the British reactor was an air-cooled reactor using metallic fuel, completely different from present or planned U.S. nuclear power plants with respect to potential for fission product release. SL-1, an early prototype military reactor, experienced a malfunction of a type which would not be possible in any current power reactor.

4. Comment (page 12):

"An atomic explosion is not possible in current lightwater reactors, but a malfunction of the reactor with simultaneous failure of safeguards could result in a fuel meltdown."

Response:

Simultaneous failure of several safeguards and multiple reactor system malfunctions would have to occur to significantly damage an LMFBR reactor core. The multiplicity of lines of defense in current nuclear power plants is so great as to make this probability vanishingly small. Capabilities to achieve comparable or improved levels of safety are addressed in Sections 4.2.7.4 and 4.2.7.5 in the Final Statement. The

accident cited is addressed in Section 4.2.7.

5. Comment (page 12):

"In a 1000 megawatts power reactor, the radioactive material released to the environment would approximate that released in the explosion of a 50 megaton bomb."

Response:

All reactors are built with many barriers to the release of fission products to the environment. These barriers are the nuclear fuel, its cladding, the reactor vessel and primary cooling system, and the plant containment building. The possibility for escape through all of these barriers is extremely remote, so remote as to constitute an insignificant risk. In any event, a release of radioactive material approximated by that produced in a 50 megaton bomb would simply not be possible.

6. Comment (page 12):

"Even if the nuclear fission is shut down promptly upon failure of cooling, built up radioactivity in the fuel continues to generate heat at a sufficient rate to melt the fuel. For a reactor of 1000 megawatts or more, molten fuel would breach not only the reactor containment structures in the present designs, but would melt through the structure and steel casing, and down into the earth. This would be a serious occurrence, for many radioactive wastes ordinarily trapped within the fuel are gases. At this point, at least, the gaseous portion of the radioactive wastes would be released to the outside air."

Response:

The possibility of enough molten fuel reaching the bottom of the reactor vessel to breach it is very remote because of the many safety features, inherent and designed. If, however, it is arbitrarily assumed that normal coolant is lost, and that all safety features fail, including all decay heat removal systems, and that no emergency measures were taken to provide cooling, it would be possible that molten material would eventually escape into the ground. The number of simultaneous major failures which must be assumed however put this event far outside reasonable consideration.

7. Comment (page 13):

"The potential for a serious reactor accident resulting in widespread dispersion of radioactive wastes is higher in some types of breeder reactors than in light water reactors used today... ."

Response:

There are many inherent features in the LMFBR that reduce the potential for certain types of accidents as compared to light water reactors. These features include the large margin from boiling in the coolant (500-600°F), low pressure of the system, and the thermal capacity of the coolant (see Section 4.2.7.4 of the Final Statement). Both LWRs and LMFBRs have design features to prevent the occurrence of accidents and to mitigate accident consequences if one should occur. The potential for a serious reactor accident in either type of system is considered extremely small.

8. Comment (page 13):

"... an explosive accident is possible if a cooling duct becomes plugged. The latter is precisely what happened to Detroit's Enrico Fermi Power Plant in 1966. The reactor was an advanced LMFBR. A piece of metal blocked the liquid sodium coolant, causing partial melting of a few fuel assemblies. Some radioactive gas escaped within the plant, although none was detected outside the building. While they analyzed the possibilities, the operating staff hesitated for a month to probe for the source of trouble and scope of damage fearing that an explosion might be triggered because of the distorted fuel configuration that resulted from the meltdown (Fabricant and Hallman, 1971)."

Response:

Extensive work has been performed on the interaction between molten fuel and sodium coolant at the high temperatures associated with partial coolant blockage. This work has shown that although there would be some transfer of energy from the fuel to the coolant which might lead to partial vaporization of the coolant and some increased pressure in the coolant duct, the extent and rate of this energy transfer would not be of such magnitude as to characterize it as an explosion. In the case of Fermi, coolant blockage was followed by fuel melting and a consequent decrease in energy production rate. Although there was some uncertainty following the partial meltdown as to the best way to proceed with analysis of the incident, the possibility of an explosion was not a major concern. See Section 4.2.7, Annex C for a more complete discussion of the Fermi incident.

Future LMFBRs will be designed to prevent blockage of coolant channels in the core through the use of strainers and other engineering features (see Section 4.2.7.4); experiments and analyses (cited in Section 4.2.7.6.4) have shown that even for large flow blockages, on the order of 80-90% of the total coolant flow through a subassembly, only very minor temperature rises will result, as cross flow of coolant between fuel pins in a subassembly will remove sufficient heat to prevent excessive overheating or flow instability.

9. Comment (page 19):

"Emphasis should be placed on energy conservation and on the development of environmentally sound energy sources."

Response:

The AEC agrees that a national effort on energy conservation is necessary, as discussed in Section 6C of the Final Statement. However, while recognizing that conservation measures have recently had an important impact resulting in reduced energy usage, it is also realized that the extent by which conservation measures may alter future energy demand or growth rates is at this time uncertain. It would therefore appear that energy conservation alone, despite its necessity, should not be relied on to completely offset those factors which lead to increased energy usage. It is in this context that we believe the development of all environmentally sound energy sources is necessary along with conservation practices. These sources, such as solar energy, should be developed to their full potential, and the AEC, NASA, NSF and other government agencies are already supporting work in these areas (see Section 6). However, for the several reasons discussed in the Final Statement, it does not appear that our energy requirements can be satisfied (even assuming a successful conservation program) without the availability of and contribution from several energy sources, including the LMFBR. It is therefore felt that failure to develop the LMFBR would lead to our being unable to meet projected energy demands.

3900 Cashion Pl.
Oklahoma City, Okla. 73112
Monday, April 15, 1974

Director,
Environmental Impact Review Board
for the Liquid Metal Fast Breeder Reactor
Atomic Energy Commission
Washington, D.C. 20545

Dear Sir,

My husband and I would like to submit the following papers to be entered into the Environmental Impact Statement in opposition to the liquid metal fast breeder reactor. Along with our statements, prepared separately and in two separate folders, I am also sending along literature derogatory to the LMFBR, also material illustrating the hazards of the proliferating use of plutonium, which is the chief fuel of the fast breeder reactors.

Some of this material is of national concern and some pertains to our local situation in Oklahoma. Outside of some of the local inspection reports, I have not included material put out by the A.E.C. since that is available to you already.

We have the gravest concerns about the safety of the fast breeder reactors, and cannot too strongly urge our government to not proceed with their development and use. There are safer and saner forms of energy that can be developed- one might be our 300 to 1000 year supply of coal.

With deepest concern,

Ilene H. Younghein
Gaylord A. Younghein
Ilene H. and Gaylord A. Younghein

Background Material Opposing the Liquid Metal
Fast Breeder Reactor and the Plutonium Economy

to be entered into the environmental impact
statement against the LMFBR

April 15, 1974
Ilene and Gaylord Younghein
3900 Cashion Pl.
Oklahoma City, Okla, 73112
405-946-6368

1. Letter dated March 18, 1974 from Barry Smirnoff (Hudson Institute) to (addressee omitted) concerning current LWR's.
2. Unknown source, information concerning Fuel Facilities (General Electric Company, Kerr-McGee Corporation (Cimarron Facility), Green Bay X-Ray Service, Inc., Green Bay, Wisconsin.
3. Letter from Kerr-McGee Nuclear Corporation, March 7, 1974 to Mr. R. G. Page, Chief of Materials and Plant Protection Branch, Directorate of Licensing, USAEC, Washington, D. C., and a return letter from R. G. Page of the USAEC to Kerr-McGee Nuclear Corporation, Mr. W. J. Skelley, Director Regulations and Control, Kerr-McGee Center, Oklahoma City, Oklahoma on February 14, 1974, concerning physical security of Cimarron Facility.
4. Not Man Apart, April 1974.
 - (a) "Marianas Trench Linked To A-Plants"
 - (b) "Green Thumbs Vs. Fast Breeders"
5. "Science Conquers All," Johns Hopkins Magazine, November 1973.
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33. Reply letter to Mr. and Mrs. Gaylord Younghein's letter of October 9, 1973. Letter from James G. Keppler, Regional Director, Directorate of Regulatory Operations, Region III, letter dated January 11, 1974.

34. Material obtained from Public Records from Guthrie Library:
- (a) Letter dated March 12, 1973 from Richard Chitwood to W. I. Skelley Director of Regulation and Control, re: Environmental Report for Cimarron Plutonium Plant.
 - (b) AEC Inspection Report dated February 12-16, 1973, re" Liquid Effluent, Part III, Plutonium Plant, from AEC Inspection Report June 18-22, 1973, Cimarron Facility.
 - (c) March 7, 1973 letter to Directorate of Regulatory Operations, AEC N Notification of an Incident, from G. H. Bedinger, G. W. Roy, and R. H. Engelken.
 - (d) Letter fro Kerr-McGee, dated April 17, 1973 to AEC Richard B. Chitwood, Chief, Technical Support Branch, Directorate of Licensing, originator George R. Parks, Executive Vice President
 - (e) Letter from R. B. Chitwood, Chief, to Kerr-McGee, Attention: George Parks.
 - (f) Letter from R. G. Page, Materials Plant Protection Branch, to Kerr-McGee, attention: Mr. Morgan Moore.
 - (g) Letter from AEC, Frank Malone, Chief, Admonistrative Services Branch, Office of Administration.
 - (h) Letter from W. J. Skelley to AEC.
 - (i) Guthrie Daily Leader, Friday, March 9, 1973. Kerr-McGee Reports Minor Fire.
 - (j) Letter to Parker S. Dunn, Vice President, Nuclear Operations, Kerr-McGee from Harold L. Price, Director Of Regulations.

QUAKER HILL ROAD, GROTON, CONNECTICUT, N.Y. 06220 • TELEX 137342 • 914 733-1111

Addressee Omitted Highland NY.

16 March 1974

In response to your request for my position concerning nuclear power plants, the fundamental characteristic of the existing nuclear industry is its immaturity. By this I mean that the nuclear industry has not yet become economically, technically, or politically mature and cannot be considered viable without extensive external support from public and private institutions.

An example of the nuclear industry's economic immaturity is the historical fact of persistent increases in nuclear power plant capital costs, from about \$125/kwe in the early 1960's to \$600-700 now. This precipitous cost escalation suggests that nuclear reactor technology has not reached its economic learning curve, as every other technology does when it matures to the extent that operating experience accumulates and unit costs begin to decrease (in real terms). Consequently, until the nuclear industry can build and operate reactors so that unit costs begin to decrease, the industry's economic maturity will not be achieved. Moreover, until the industry can self-insure against extraordinary (catastrophic) accidents, thereby precluding the necessity of Federal Price-Anderson indemnification, economic maturity will not be attained.

The industry's technical immaturity is indicated by the broad spectrum of so-called expert opinion concerning reactor safety and other nuclear-specific issues which have great significance for public health and safety, as well as for environmental quality. Obviously, computer codes resulting in theoretical confirmation of adequate function of the emergency core cooling systems does not suffice to prove the actual adequacy of ECCS function in an accident situation.

Early reports of the Rasmussen safety study indicate that the probability of a serious accident is 10^{-6} to 10^{-7} ; a recent New York Times Magazine piece by Ralph Lapp suggests that two factors of 10^{-3} constitute Rasmussen's overall probability estimate of one in a million. One of these factors, however, reflects a purely theoretical estimate of ECCS failure probability of 10^{-3} , which could be quite wrong. As a result, if we believe Rasmussen's other estimated factor, the serious accident probability per reactor-year could be anywhere between 10^{-3} and 10^{-7} . The high estimate translates into one accident per year after the year 2000 if 1000 reactors are around by then. (Another example of technical immaturity, together with AEC miscalculation, is the boondoggle of placing radioactive wastes in bedded salt in Kansas.)

Political immaturity in the nuclear industry relates, in part, to the miserable job of public relations which has been done. Evidently the industry did not feel that the public was sufficiently intelligent to understand that the nuclear reactor program was highly experimental but that many safeguards were being implemented (but not enough); or the industry realized that it could not persuade, hence tried to snow and evade. The result has been that pockets of nuclear dissenters have become quite adept at penetrating the nuclear industry's snow-job and educating enough of the public that the industry is sitting up and taking notice.

Recently, both Craig Hosmer and Chet Holifield, oldtimers on the Joint Committee on Atomic Energy, have announced that they are retiring from the House of Representatives. Congressional nuclear politics will become quite volatile without the presence of these two intensely pro-nuclear men, and the nuclear industry's political immaturity may eventually do it in during the next few years, especially if LOFT and other critical experiments are unsuccessful.

Summarizing, my belief is that the nuclear industry is basically immature across the spectrum of economic, technical, and political factors which affect decision-making and policy-making relating to nuclear power plants.

Any community considering the desirability of becoming a site for a nuclear power plant should understand that it will become the home of an experimental, complex, possibly dangerous, machine which provides both benefits (taxes, electricity) and costs (safety and environmental hazards, security) and one which is, to repeat, intrinsically experimental. The community should attempt to balance the costs against the benefits, not only for itself but for the larger affected community in which it finds itself, while keeping in mind that the technological machine it considers providing a home for is far from being perfected.

Signed by Barry Smeernoff
Staff Specialist

Regards,

Barry Smeernoff

FUEL FACILITIESGeneral Electric Company (MFRP)

Inspections were conducted on nine days between March 5 and 19 to review cold run and test activities. The integrated plant cold run has been delayed further as a result of tests carried out on the UNH Calcliner-Airveyor System following recent modifications. Issuance of the Operating License is not expected until July or August 1974.

Kerr-McGee Corporation (Cimarron Facility)

The licensee informed RO:III by telephone on February 28 that the February monthly plutonium physical inventory showed a significant material unaccounted for (MUF) loss quantity. As a result, Kerr-McGee stopped fuel fabrication work and initiated a new inventory on March 1. The reinventory, which was conducted from March 1 through 11, resulted in finding most of the plutonium MUF.

Inspections were conducted on March 1 through 13 to observe the reinventory and to review the implementation of the licensee's physical security program. No significant deficiencies were identified. Four samples of plutonium nitrate solutions representing the scrap inventory were taken by RO for evaluation at Los Alamos. The unaccounted for plutonium is not considered significant for the operation involved and is believed to be in the process piping systems. Based on the results of the licensee's reinventory and the RO inspection findings, the licensee was permitted to resume production operations.

Green Bay X-Ray Service, Inc., Green Bay, Wisconsin

In response to the Commission's Order of February 19, imposing civil penalties of \$5000, the licensee responded on February 28, offering to pay \$2500, but requesting a hearing on seven of the alleged violations on which the remaining \$2500 civil penalties were assessed. This matter is under review by RO.

KERR-MCGEE NUCLEAR CORPORATION

KERR-MCGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

March 7, 1974

Mr. R. G. Page, Chief
Materials and Plant Protection Branch
Directorate of Licensing
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Page:

Please refer to your letter of February 14 requesting that we submit a reply to the items numbered 1 and 2 by March 1, 1974.

Our reply has taken the form of a substantial revision to the security plan. A revised plan for License SNM-928 is attached. You will also find the request for certain exceptions to the requirements of 10 CFR 73 addressed in a separately attached Appendix. We do not believe that the request for exception should be released to the public in accordance with 10 CFR 2.790(d).

Please let me know if you have additional comments.

Sincerely yours,

W. J. Shelley, Director
Regulation and Control

WJS:m1

Attachment

0459

Kerr-McGee Nuclear Corporation

- 2 -

FEB 14 1974

We have established that the enclosures to your letters of January 5, 1974 and January 25, 1974 contain information of a type specified in 10 CFR 2.790(d). Accordingly, pursuant to Section 2.790(d), your security plans are deemed to be commercial or financial information within the meaning of 10 CFR 9.5(a)(4) and shall be subject to disclosure only in accordance with the provisions of 10 CFR 9.10. For similar reasons, we are withholding the enclosures to this letter from public disclosure.

Sincerely,

R. G. Page, Chief
Materials and Plant Protection
Branch
Directorate of Licensing

Enclosures:

1. Additional Questions on
Kerr-McGee Pu Physical
Protection Plan
2. Additional Questions on
Kerr-McGee U Physical
Protection Plan

*Not Man Apart**Apr. 1974**For fun!*

April 1974

New Research:**Marianas Trench
Linked to A-plants****In Those Days
They Worried About
The "America Syndrome"**

Researchers at the Brookhovel National Laboratories have recently discovered evidence suggesting that the Marianas Trench — the deepest hole in the ocean's floor — may have been caused by a meltdown of a prehistoric light-water reactor.

Scientists have so far been unable to determine whether the reactor was of the boiling-water or pressurized-water variety.

Contacted for comment at her cozy house-trailer, "Bide-a-wee," AEC Chairman Dixy Ray Gunn said, "why sure they had a meltdown. They tried to build a reactor down there on the bottom side of the earth, and the lid simply fell off. Dummies."

The UN's International Atomic Energy Agency released the following statement early this morning:

"The alleged discovery of a nuclear history to the geologic origins of the Marianas Trench marine formation is the product of untrustworthy pseudo-scientists who didn't go to an AEC-accredited university and seldom take baths."

Senator Tedward Kenney, in a speech on the Senate floor, called for emergency legislation to fund a new agency of the federal government to study the new findings and determine what link, if any, exists between the major oil companies and the Trench.

Gulf Oil was rumored to be dispatching a

team of researchers to the site to determine if it will be feasible to mine the radioactive residue at the bottom of the Trench. Vice President Elmer Curie joked with reporters, "The stuff's nearly as potent now as it ever was."

The Center for Atlantis Studies, in a related press release, confined their comments to one sentence: "We told you so." A call was placed to Friends of the Earth's office in San Francisco for comment, but all this reporter could get from the person who answered the phone was hysterical laughter.

Fair Is the Wind From France**Green Thumbs
Vs.
Fast Breeders**

Thursday last month, I went to the information meeting of "Les Amis de la Terre," hoping I would get good advice for my gardening. I entered a rather small room where people were excitedly discussing the plans for a new action. They were heatedly accusing mysterious entities called "EDF" and "CEA" of hushing-up the seriousness of the situations. Puzzling words like "millirems," "periods," "transuranian alpha-emitters" were exchanged. Taking advantage of a lull in the discussion, I asked:

"What are you guys talking about?"

"Breeders, fast breeders."

And the abstruse discussion went on. These crazy people were so engrossed in their "breeders" that it was useless to try extracting from them any tip about gardening; they were forget-

ting "la Terre!" So I left, trying to figure out by myself what they were so excited about.

Breeders? Breeders? Fast ones?? Maybe a bonanza for the cattle business? But I suddenly remembered that Les Amis de la Terre are worried by overpopulation and that they translated and published an American book called "La Bombe P." So I decided to ask "Le Planning Familial," a nice group which gave contraceptive information to my girl friend. They probably are also interested in overpopulation, and surely they are more accessible than these high-brow ecologists at Les Amis.

A short-haired young lady in blue jeans greeted me at "Le Planning Familial." Well, they are overworked, the government has cut their funds, life is hard in Pompidoulian France for groups fighting for more freedom. But, yes, my question is important. Fast breeders are surely a big menace. Something must be done.

The young lady, who has some knowledge of human biology, helped me to guess what the problem is about. Breeders, fast ones . . . probably a kind of mutant who breeds faster than ordinary human beings . . . bad . . . very bad. Moreover they engender things with very long periods . . . probably poor females, even more handicapped than their normal sisters! Great excitement at "Le Planning Familial."

The story went to the ears of journalists. What a scoop for them! Five-centimeter headlines on the front pages: "Fast Breeding Mutants! Beware!" Latent racist feelings arose, pushing our beloved Minister of the Interior and his police into organizing a nationwide mutant-hunt: cars stopped on the roads by search patrols, compulsory blood-tests, third-degree questioning . . . Everybody a suspect! 1984!

Today, a friend who works in a lab told me something from which I gather that there may be some connection between "breeders" and nuclear energy. Maybe I made a mistake? But do not tell anyone. I might very well end up in jail if "they" discover that I am at the origin of all this fuss!

Jules Sibiragou (p.c.c. Pierre Samuel)

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20543

FEB 14 1974

Kerr-McGee Nuclear Corporation
ATTN: Mr. W. J. Shelley, Director
Regulation and Control
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Gentlemen:

We have reviewed your January 5, 1974 submittal for the physical protection of the plutonium plant and your January 26, 1974 submittal for the physical protection of the uranium plant located at the Cimarron Facility.

Our review identified a number of requirements of 10 CFR 73.50, 73.60, 73.70, and 73.71 which are not adequately addressed in your security plans. During a plant visit by Dr. Frank A. Costanzi on February 5-8, 1974, these items were discussed and explained in detail with representatives of your staff. These items are listed in Enclosures 1 and 2 using the format of Enclosure 4 of our general letter sent to licensees on November 26, 1973. Enclosure 1 contains our comments and questions concerning the plutonium security plan; Enclosure 2 pertains to the uranium plant security plan.

We request that you submit your reply to the items in Enclosures 1 and 2 by March 1, 1974. Please submit your reply for each security plan as a separate enclosure. It is imperative that we receive your reply by this date so that we may complete our review of your security plan by March 6, 1974. If we do not receive your reply by March 1, 1974, it may be necessary for us to supplement your security plans with amendments to your licenses.

In your reply, any request for an exception from a specific requirement in the regulations must be submitted separately from the security plan. A detailed justification must be presented for each such request. An exception request must be prepared in a manner suitable for public disclosure; however, the details of alternative methods of protection should be submitted as an enclosure so that they may be withheld from public disclosure.

From Johns Hopkins Magazine

SCIENCE CONQUERS ALL

Some cheerful rules for research
in a world where anything that can
go wrong will...

This manuscript, found in the Johns Hopkins Medical School office of Laure Aurelian, Ph.D., is of unknown provenance. All Dr. Aurelian will say is, "It's been around for a long time. But a bunch of us who believe in cynicism did glorify it a bit."

First Law of Experiment: In any field of scientific endeavor, anything that can go wrong will go wrong.

Corollary 1: Everything goes wrong at one time.

Corollary 2: If there is a possibility of several things going wrong, the one that will go wrong is the one that will do the most damage.

Corollary 3: Left to themselves, things will always go from bad to worse.

Corollary 4: Experiments must be reproducible; they should fail in the same way.

Corollary 5: Nature always sides with the hidden flaw.

Corollary 6: If everything seems to be going well, you have overlooked something.

Second Law: It is usually impractical to worry beforehand about interference; if you have none, someone will supply some for you.

Corollary 1: Information necessitating a change in design will be conveyed to the designer after, and only after, the plans are complete.

Corollary 2: In simple cases, presenting one obvious right way vs. one obvious wrong way, it is often wiser to choose the wrong way so as to expedite subsequent revisions.

Corollary 3: The more innocuous a modification appears to be, the further its influence will extend and the more plans will have to be redrawn.

Third Law: In any collection of data, the figures that are obviously correct, beyond all need of checking, contain the errors.

Corollary 1: No one whom you ask for help will see the error.

Corollary 2: Any nagging intruder who stops by with unsought advice will spot it immediately.

Fourth Law: If in any problem you find yourself doing an immense amount of work, the answer can be obtained by simple inspection.

The following rules have been formulated for the use of those new to the field of research:

1. Build no mechanism simply if a way can be found to make it complex and wonderful.

2. A record of data is useful; it indicates that you have been busy.

3. Before studying a subject, first understand it thoroughly.

4. Do not believe in luck; rely on it.

5. Always leave room, when writing a report, to add an explanation if it does not work (Rule of the Way Out).

6. Use the most recent developments in the field of interpretation of experimental data:

a. Items such as Finagle's Constant and the more subtle Bougerre Factor (pronounced "bugger") are loosely grouped, in mathematics, under constant variables, or if you prefer, variable constants.

b. Finagle's Constant, a multiplier of the zero-order term, may be characterized as changing the universe to fit the equation.

c. The Bougerre Factor is characterized as changing the equation to fit the universe. It is also known as the "Soothing Factor"; mathematically similar to the damping factor, it has the characteristic of dropping the subject under discussion to zero importance.

d. A combination of the two, the Diddle Coefficient, is characterized as changing things so that universe and equation appear to fit without requiring a change in either. [9]

A Grim Fairy Tale — Or Is It?

By ILENE YOUNGHEIN

In the country of Newlandia lived a most amazing people. They loved moving around, hither and yon, to and fro, crisscrossing the countryside, through the air, on the water, under the water, over hill and dale, even though tunnels in the ground, until no mole was safe in his hole.

Many, in their joy of moving, took their houses with them like snails. Their mobiles were powered by black gloil — a substance that had been accumulating in the deep regions of the earth for eons — dating back before there were Newlanders, or anybody else. Primitives thought the gloil was a nuisance until the Newlanders came along and DISCOVERED it, and DISCOVER it they did.

The old Newlanders were known to be thrifty, hardworking, simple folk, but with the great gloil windfall the people began to change. Not only did they build mobiles to take them hither and yon, up and down, over and under, but they built machines to do their work and even contraptions to entertain them. So, besides going to and fro they learned to push buttons, pull levers, and spend hours watching the magic picture box.

But, alas, something was amiss in the land. The Newlanders became fat and bored and started moving around all the more frantically — using up their gloil in tremendous glunks.

One day a wise man, from the Middle of the East, came to the kingdom and announced to the king and his court that the gloil was depleting and that the Newlanders would have to make do with less. The magic picture box carried the dire news to the remotest area of the country. For the first time in a generation, the Newlanders stopped. They looked at their fat bellies, shriveled muscles, and mechanical slaves and panic reigned.

While rumors flowed back and forth like the tides, there arrived at the palace gates Georgia Dee Beam, the Wizardess from the West. She arrived with a grand retinue of worthy advisors, two pets, a Siberian Greyhound and a smoodle, her house — like a snail — and a mysterious lead lined glass box borne very carefully by four black clothes bearers.

She was granted an audience by Good King Richard II himself. "What do you want, Georgia?" he said. "My Lord," replied the Wizardess, "in this lead-lined glass box, I have a most miraculous substance called satonium. Satonium is the fuel of the rapid multiplier reactor, and it is truly amazing. The more you burn, the more you have — works on the principal of perpetual motion, you know. With this stuff, the Newlanders can come and go, push buttons, pull levers, and watch the magic picture box to their hearts' content..."

The king and his council were overjoyed at the wonderful news. Servants

were ordered to go to the coffers and bring back five and a half billion gold duckets to dump at the Wizardess's feet. Good King Richard II handed down a decree that she go and develop the rapid multiplier reactors and fill them with the amazing satonium. The news was broadcast far and wide, on the magic picture box and happiness again reigned throughout the land.

But amid all the rejoicing, the Wizardess turned serious. "There is one thing I forgot to mention," she confessed. "The Wicked Witch of the Atolls has put a curse on the satonium. She is very angry because we stole it from her while she was busy making bombs with it. A speck the size of flea's dandruff can give anyone breathing it a fatal dread disease; what's more, it can continue killing people for 200,000 years. An amount the size of your Christmas turkey could kill everyone in the land. You must be extremely careful and never, never allow any of it to get out. Only top experts should be employed to handle it — people who never make mistakes."

But the king and his council and the Newlanders were so busy celebrating and rushing to and fro and turning the billboard lights on again that they paid no attention. "We trust you, Georgia, to do a good job," they said.

So, the Wizardess from the West gathered together all of the top perfectional scientists in the land, men from Lost Alamost, Oak Rim, the Madhattan Project, Prince Town, Orderance Labs, Mitters and Califects, and they all went busily to work building the rapid multipliers and filling them with satonium fuel.

Of course, as you might expect, there were some hysterical peasants who had misgivings about the whole thing. These prophets with their long hair, flowing beards, and faded patched trousers, pedaled their twocycles out of the woods and descended on the palace.

"We think you are making a dreadful mistake," they pleaded.

"You alarmists are very backward about going forward," yelled the king as he slammed the gates on their departing twocycles.

Well, dear reader, I guess you can imagine what happened. Everything went along well in Newlandia for awhile. But after some time, they became careless. Dullites from the hinterland were hired. One day a Dullite was reading the "Fogpatch" comic strip instead of watching the rapid multiplier, when the satonium in the rapid multiplier began multiplying too rapidly. It all melted down in a dreadful mess and the satonium got OUT.

Newlandia is still there, sparsely covered with odd looking plants, but there are no people, no birds, no animals, not even any snakes. Maybe in about 200,000 years another Columbus will come along and discover it.

from The Nuclear Power Rebellion
by Richard Lewis
Editor, Bulletin of Atomic Scientists

1

Another Kind of Fire

The Committee has noted with concern in the past year the increased public opposition, not a little of it wholly unreasoning, to the construction of all electrical generating sources and their transmission systems.

—Report of the Joint Committee on Atomic Energy, United States Congress, 1970

From the altitude where airliners pass over the region, the Endless Mountains of northeastern Pennsylvania are configured like the folds of a carpet pushed inward from its edge. The rounded ridges and shallow valleys run in parallel from the southwestern to the northeastern horizons. The view from aloft supports a theory that the mountains were formed by forces exerted against the continental margins of North America by sea-floor spreading, as magma from the earth's mantle was extruded from the mid-Atlantic Ocean rift.

Through this northerly region of Appalachia flows the north branch of the Susquehanna River. Along its east bank, 1300 acres of level farmland near the village of Meshoppen in Wyoming County were staked out in 1967 for a historic development. On this site, the Pennsylvania Electric Company, a subsidiary of General Public Utilities Corporation, proposed to build an advanced type of atomic-power plant in partnership with the Atomics International Division of North American Rockwell Corporation and the United States Atomic Energy Commission. The proposed plant

would demonstrate for the first time the commercial application of the Liquid Metal Fast Breeder Reactor to electric-power production. A second-generation fission reactor which the AEC had developed at a cost approaching a half-billion dollars to supplant its light-water reactor, then coming into widespread use, the "breeder" was the product of a makeshift national energy policy based on the expectation that, early in the twenty-first century, advanced fission reactors would be producing half of the nation's electrical energy and eventually would replace coal, oil, and gas to become the principal energy source.

In fuel efficiency and economy, the Liquid Metal Fast Breeder Reactor (LMFBR) would be as far ahead of the first light-water reactor put into commercial demonstration in 1957 at Shippingport, Pennsylvania, as that device was ahead of Enrico Fermi's Chicago Pile No. 1, where the first controlled nuclear chain reaction was achieved on December 2, 1942.

A nuclear reactor is another kind of fire—a source of heat. Instead of coal, oil, or gas, the light-water reactor developed in the United States "burns" the fissionable fuel uranium-235. The heat of the fissioning atoms boils water and makes steam to run turbine generators. But electric utilities using these reactors face rising fuel costs because uranium-235 is very limited in nature. It amounts to only 0.7 per cent of natural uranium.

With breeder reactors, however, the picture is brighter. The fast breeder can tap up to 75 per cent of the energy in natural uranium—a hundred times more than the light-water reactors can utilize. Breeders do this by transmuting the bulk of natural uranium, which is not fissionable, into fissionable plutonium-239, which does not exist in nature. In theory, the breeder reactor can "breed" three atoms of plutonium-239 for every two atoms of uranium-235 undergoing fission in the fuel rods. Hence it is capable of breeding more fuel than it consumes.

With the breeder reactor, the nuclear-power industry could look forward to the extension of an economical fuel supply from decades to millennia. The breeder thus becomes the device which a

growing nuclear-power establishment can employ to become a principal supplier of energy in the United States and the world.

A Rising of Skeptics

In proposing to build the first demonstration breeder in the Endless Mountains, the utility did not anticipate the reaction of some of the residents. The communities in Wyoming County resemble those of New England in some ways. White-painted frame houses, unpretentious and neat, are predominant. A considerable degree of economic homogeneity is suggested by the lack of conspicuous affluence or poverty. In this part of Pennsylvania, on the border of the great anthracite coal-mining region, as in New England, one encounters a highly articulate skepticism that has questioned the impact of every technological innovation since the electric light.

Possibly because the summers are pleasant and the autumns are long and warm, with mountains illuminated by glorious foliage of red and gold, the natives take great satisfaction in the natural surroundings that they have begun to refer to as their environment. They display a special concern for the preservation of a style of uncrowded country and village life in which the devices of modern technology can be used without altering or intruding coarsely on the rustic scene.

It was inevitable that some of the residents would consider the construction of a large nuclear-power demonstration plant, still in an experimental stage of design, as an intrusion and a threat in an area where no need for it existed. Five hundred megawatts was more than five times the demand for electricity in the region. Who needed that much? The answer was obvious and unacceptable to some people. Not Wyoming County or even the centers of nearby Scranton and Wilkes-Barre. This was power for the future, serving the Northeastern industrial complex. It had no relation to the needs of Wyoming County, and its environmental impact was considered only by the people who lived there.

It was by no means an overnight development. As early as 1962, the blueprint for the Meshoppen breeder and its sister demonstrators had been drawn in the AEC's report to President John F. Kennedy. It said, in part, "... we estimate that by A.D. 2000, nuclear power would be assuming the total increase in electrical-energy production. . . . We have crudely estimated that by the century's end, nuclear installations might actually be generating approximately half of the total electric energy in the country."^{1*} The report, which in the words of Chairman Glenn T. Seaborg represented a "new and hard look at the role of nuclear power in our economy," urged the development of the breeder reactor to exploit "the vast energy resources latent" in uranium-238 and thorium.

Some of the people who began to feel concern about the plans of Pennsylvania Electric Company, Atomics International, and the AEC for Wyoming County had never heard of this report, were not aware of industry claims of greatly increased power requirements for the twenty-first century, and were not impressed by the AEC's visions of the atomic future. The demonstrator served interests remote in space and in time, interests which were guarded by mountain walls and distance from any accidental release of massive radiation from a new type of nuclear reactor. And it served these interests, it seemed, at the expense of the security of a small, dispersed population which the nuclear-energy planners considered evacuable in the "unlikely event" (as they were always saying) of a nuclear emergency.

What kind of an emergency would that be? Some people believed that nuclear reactors could blow up, like bombs. And they were right—about fast reactors, fueled with plutonium. Under certain conditions, breeders running on plutonium could blow up and spew deadly radioactive poisons all over the countryside. Or they could be sabotaged or struck by missiles with the same effect.

In a report on "Public Health Factors in Reactor Site Selection," the United States Public Health Service had commented:

* Numbered reference notes begin on p. 299.

Population density is an important factor to consider in selecting optimum reactor sites. Based on data available to the public, release rates of radioactive air and water contaminants from power reactors during normal operations have been quite low. However, in the unlikely event of a reactor accident, relatively large quantities of radioactive materials could be released to the environment. This necessitates locating reactors in areas with low population densities or close to populations of high mobility who could be moved in a short time period.²

While the population of Wyoming County could not be described as "highly mobile," the road network in the county would enable most people to flee a massive release of radiation from a reactor at Meshoppen, if they were warned in time. How the urban populations of Scranton and Wilkes-Barre within a radius of thirty miles would fare might be regarded with less optimism. But Wyoming County clearly met the Public Health Service criteria for population density. The county seat, Tunkhannock, has a population of 2100 and a traffic light.

A Committee Is Formed

One evening in the autumn of 1969, Mrs. Joan Daniels, a housewife and mother who worked part time in the county library at Tunkhannock, was driving home from a Quaker meeting at Wilkes-Barre, when she decided that something ought to be done about the Meshoppen breeder. She turned to her friend and remarked, "I'd like to do something about that."

Mrs. Daniels recalled (even after two years) that her friend had responded without any hesitation, "All right. I'll help."

"That's the frame of mind you get into at a Quaker meeting," Mrs. Daniels related. So began an organization called the Citizens Committee for Environmental Concern, which in 1969 opened its campaign to block the construction of the 500-megawatt LMFBR at Meshoppen.

Within twelve months, the committee had recruited members in Luzerne and Lackawanna counties, had entered into an extended

dialogue with state legislators and with representatives in Congress, had brought a two-months series of seminars on atomic energy to the Tunkhannock High School auditorium, and had gathered six thousand names to a petition asking county, state, and federal officials to prevent the construction of the Meshoppen breeder. The committee was influential in motivating State Representative Franklin L. Kury of Sunbury to introduce a bill in the 1970 Pennsylvania legislature outlawing the building of breeder reactors in that state. The Kury bill did not survive—but it was a beginning.

By the spring of 1970, the proliferation of conventional, light-water reactors in Pennsylvania—a coal-producing state—had aroused concern among environmental groups in Pittsburgh and Philadelphia. According to the State Director of Radiological Health, Thomas M. Gerusky, Pennsylvania had more nuclear reactors in operation, in construction, or in the planning stages than any other state. In view of the rising concern about the Meshoppen breeder emanating from Tunkhannock, and the publicity attending Representative Kury's bill, the State Senate appointed a Select Committee to "see what all the hullabaloo is about." Public hearings were held at the State Capitol in Harrisburg during the summer and fall of 1970.

The Hullabaloo

The anatomy of a hullabaloo is least likely to be perceived at legislative hearings where, too often, ideas are drowned in rhetoric. One frosty night in January 1971, I attended a meeting of the Citizens Committee for Environmental Concern at the United States Department of Agriculture regional office in Tunkhannock. It was there that the nature of the hullabaloo became apparent. The snow-draped mountains gleamed softly under the bright stars like sheeted forms, and the snow crunched crisply in the parking lot, where automobiles, trucks, and station wagons drew up to bear witness to the potential mobility of the population in the event of a nuclear catastrophe.

About a dozen men and women were seated around a polished table, talking informally and all at once. The aroma of percolating coffee filled the room. What could these "country people" do to frustrate the design of an Establishment in which the government was formally allied with the private electric-power industry and its industrial suppliers? When the Limited Test Ban Treaty was debated in the United States Senate in 1963, some scientists expressed regret that the mysteries of the nuclear age were so arcane that only an intellectual elite, an atomic priesthood, was capable of understanding and passing judgment on questions of nuclear policy. Advancing nuclear technology was disenfranchising the people.

However reasonable this opinion may have appeared in 1963, there was no basis for it in Wyoming County in 1970. After a year of study, lectures, seminars, and discussion, members of the Citizens Committee for Environmental Concern had acquired a firm grasp of the technical issues of nuclear power and its safety problems. Indeed, I found that the folk of the Endless Mountains had a more sophisticated understanding of the hazards of radiation contamination and fuel-core overheating than most of their elected representatives. They could see clearly enough the propaganda, half-truths, and inconsistencies in the promotional matter purveyed by both the AEC and the industry to persuade residents of the area that fission reactors were safe, clean, wholesome devices for power production.

Mrs. Daniels had become co-chairman of the committee with Dr. Bryan Lee, Jr., a veterinarian. Mrs. Daniels, with the efficiency of a librarian, had assembled a prodigious file of atomic-energy and environmental information. With the forbearance of her husband, Sidney, she set up a library of her own in the bedroom of their home.

Members of the Citizens Committee were people who vote carefully at elections, pay their taxes, perform useful work in the community, help each other in times of stress, offer their children as much higher education as the children will take, and are concerned about the future of their community, nation, and humanity.

So much was obvious to any neutral observer. Committee members included Bryan Lee, Jr.'s father, Bryan, Sr., a dentist and county commissioner; Spencer Burr, the former county treasurer; Virginia Sheret, a retired United States Army dietician; Francis Heisler, the mayor of nearby Factoryville; Davis R. Hobbs, an attorney; Victor Capucci, Jr., and William Ohme, businessmen of Mchoopany; Tom Shelburne and Gus DiStadio of UHF television station WNEP, which had devoted public-service programming to the reactor issue; and two well-informed and public-spirited housewives, Mrs. Angela Rinehimer and Mrs. Betty Tewksbury.

The Challenge

The discussion that evening at Tunkhannock revealed the basic conflict between a concerned citizenry and a technical establishment. The citizens questioned the right of an establishment to impose upon them a new technology affecting their health and safety without their consent. Here was the basis of public intervention into the plans of a powerful new force—the Atomic Industrial Establishment—to install an advanced atomic-power system, based on a plutonium-fuel cycle of great potential hazard, throughout the country. Wyoming County residents had been alerted early to this development. Some of them reacted by asserting the right to be heard of the demos—in which the collective wisdom of a democratic society must reside. It was a challenge which the Establishment's technical elite would evade or resist as long as it could.

An important issue plaguing the citizens, not only in Wyoming County, Pennsylvania, but also in Maryland and Michigan, Wisconsin and California, Minnesota and Colorado, was the credibility of the Establishment. "There is so much contradictory evidence about the effects of these reactors among scientists at the highest level that we don't know what to believe," one of the housewives said. "They rattle around in their academic armor and they arrive at diametrically opposed conclusions from the same data. Scientists are supposed to be honest. How can they be, when they are

working for a company or a government agency and depending on it for a living?"

Bryan Lee, Jr., said: "Maybe they could operate the plant safely, but a whole series of such plants could be hazardous. I think the way we all feel is . . . we just don't want to live near one."

Gus DiStadio questioned the AEC's radiation standards:

Do you think any human being has the right to set a radiation standard for me? To determine how much radiation I should get? I have to accept the natural radiation background that God gave me, but I don't accept man-made radiation. As a species, we have evolved with a certain radiation background. What happens to our species when more radiation is added? Can they tell us that?

Others spoke of their fears of sabotage against a nuclear-power plant. One had written to Defense Secretary Melvin R. Laird asking how vulnerable reactors are to sabotage or to a missile attack that would loose massive radiation from the reactor core over the countryside. The inquiry had received a reply: There were no measures to protect nuclear-power plants per se from a missile attack.

Discussion followed on that point. Should nuclear reactors, especially those in the East, within range of submarine-launched ballistic missiles, be built underground, like missile silos? Who in the government considered such contingencies? No one knew.

Several mothers said that "propaganda" had been distributed to school children purporting to "educate" the children, and through them their parents, about the advantages of atomic energy. One of the pamphlets brought home by the children had been prepared by the AEC's Division of Technical Information, to tell all about nuclear energy and the good things the friendly, workaday atom could do for everybody. The mothers said they feared the children were being indoctrinated to accept radiation hazards, or the AEC's view of them, as the natural order of things. One of the pamphlets prepared by an industrial firm described radioactive nu-

clear waste as "goop." Everybody knew what "goop" was—nothing to worry about.

In the initial stages of its campaign against the project, the Citizens Committee found their state and Congressional representatives attentive. But the span of attention turned out to be brief. As the committee persisted in demanding answers and action from their elected representatives, the responses of these officials became more formalized and terse. Members of the committee said that utility public-relations people who had initially catered to inquiries became increasingly indifferent and remote as the inquiries became more challenging.

"They regard us as a bunch of country people who are in over our heads," said Bryan Lee, Jr. "It happens to be true. We *are* a bunch of country people, but we think that after a year of study, after a year of listening to some of the most brilliant scientists in the country on the subject, we have learned something about nuclear technology. We've had some of the best nuclear scientists and engineers from Penn State over here to lecture. We know enough at least to ask questions and to know when we're not getting the right answers."

The Hearing in Harrisburg

The Citizens Committee for Environmental Concern had raised the question of the consent of the electorate to exposure to the risks of nuclear-power facilities at the State Senate Select Committee hearing on atomic-power plants in Pennsylvania during the summer and fall of 1970. The hearing was clearly a political response to the concerns of citizens' groups in Philadelphia and Pittsburgh, as well as in Wyoming County, and to the concerns of the state's massive coal industry.

In its formal statement to the Senate Select Committee, the Citizens Committee for Environmental Concern asserted:

We cannot condone the logic which advocates siting a reactor of any type in a low-population area at a time when it is considered

far too great a risk if sited in a highly populated area. We further submit that the risk we would be expected to tolerate is an indignity upon the rights of every citizen of the United States.

Lee, Jr., raised the consent issue in his testimony as a witness before the Select Committee:

What if the people don't want . . . nuclear generators? What if we don't want fuel-reprocessing plants [which also emit radioactive waste] in our state? What if the people prefer to receive their electricity from hydroelectric facilities in Canada that would have no environmental impact on anyone and which are assets to the development of that country? What if the people prefer increased research into the production and transmission of electricity from harnessing the energy of the tides and the sun? What if fusion power seems much more acceptable? If funds should be allocated for earnest research into the control of sulfur dioxide or for the development of magnetohydrodynamic power? We submit that the power industry needs to be washed and hung on a line. It needs to be gotten out in the open for the public's inspection."

An Unfriendly Giant

The controversy over the Meshoppen breeder revealed to the Citizens Committee the existence of an Atomic Industrial Establishment which somehow had the power to invade their environment and, from their point of view, threaten their security without their consent. The Establishment had first appeared in Pennsylvania in 1957 when the Shippingport pressurized-water reactor was developed as a joint demonstration project of a commercial atomic-power plant by the AEC, the Westinghouse Electric Company, and the Duquesne Light Company. A second commercial plant, built by the General Electric Company for the Commonwealth Edison Company of Chicago at Morris, Illinois, became operable in 1959. The following year, the Yankee Atomic Electric Company's pressurized-water reactor, built by Westinghouse, had gone on line at Rowe, Massachusetts. The Consumers Power Company started up a General Electric boiling-water reactor in 1962 at Big Rock, Michigan. In the same year Consolidated Edi-

son Company began operating its first pressurized-water reactor, manufactured by Babcock and Wilcox, at Indian Point near Buchanan, New York. In 1963 the Pacific Gas and Electric Company's General Electric boiling-water reactor went into service in Humboldt Bay, California.

The trend toward nuclear power accelerated in the second half of the 1960s. By 1971 there were 21 operating light-water nuclear reactors in commercial service in the United States; 56 more were in construction, and 37 were on order—a total of 114, with an electrical-energy potential of 92,135,800 kilowatts. When the new generation of fast-breeder reactors appeared on the public horizon in 1967, the nuclear industry had shown promise of becoming a giant—an unfriendly giant from the viewpoint of people concerned about its environmental impact. Privately owned investor utilities and their industrial suppliers formed the economic base of the new Establishment, with the AEC acting sometimes as its agent and at other times as its management. Eventually, the Congressional Joint Committee on Atomic Energy became its board of directors.

The threat of the new breeder reactor to public health came early into focus in Pennsylvania where it was explored in the Senate Select Committee investigation into nuclear-reactor safety at public hearings between August and October 1970. Two safety issues were discussed at these hearings: first, preventing the fuel core of the reactor from becoming so overheated that it would melt, destroy its container, and eject radioactive debris over the surrounding area—a problem particularly menacing in the breeder reactor, which used plutonium in its fuel assembly, the most hazardous, perhaps, of all radioactive materials; and second, the hazard of radioactivity released during routine operation of the plant or during an emergency that did not result in a meltdown.

The likelihood of the fuel core becoming hot enough to melt through its containment had been studied for years. Several estimates of the magnitude of the disaster resulting from a meltdown

had emerged, all indicating that the radiation effect would be analogous to the detonation of a nuclear bomb near an inhabited area. How likely was such an accident?

Bryan Lee, Jr., recalled for the State Senate Select Committee the meltdown of the Enrico Fermi experimental fast-breeder reactor, a forerunner of the larger one which the Establishment wanted to construct and demonstrate at Meshoppen. Fermi I, as the reactor was called, was a joint project of the AEC and the Detroit Edison Company. It was built in 1963 at Lagoona Beach, Michigan, and operated at low power for several years. In 1966, the liquid-sodium coolant was blocked and the core overheated and partially melted. There was no significant release of radioactivity, however, according to the AEC.

"It took almost a year to find out what triggered the accident, but eventually it was discovered," Lee, Jr., testified.

By inserting a specially designed periscope into the interior of the reactor, a piece of crumpled metal about eight inches long was discovered. This piece of metal was part of one of three zirconium plates, which had been fastened to the cone at the bottom of the reactor to guide the sodium flow. These plates were not part of the original design and had been hurriedly added at the last moment, ironically as an extra safety measure. Because it was a last-minute, hurry-up job, it was never shown in the plans or work drawings submitted, so that no one in the plant at the time of the accident even knew of their existence. A former employee who had retired but was still employed as a consultant finally remembered the incident and was able to enlighten everyone. What happened was due to vibration and pressure. One of the plates had torn loose and blocked the flow of liquid-sodium coolant. Without the coolant, part of the fuel melted down. A great concern is that when this happens in a fast reactor, the fuel can then recool, become a critical mass, and set off an explosion which could rupture the core of the reactor and release large amounts of radioactivity to the air. Fortunately, this did not happen in this case, perhaps because the reactor was running at only a fraction of its potential power at the time of the accident.

Dresden II Incident

A lesser-known accident, which was not made public at the time it happened, occurred June 5, 1970, in the boiling-water reactor of Commonwealth Edison Company's Dresden II plant, southwest of Chicago. The reactor was being tested at 75 per cent of its power when a spurious signal in the pressure-control system altered the steam flow to the turbine. A series of malfunctions then followed and resulted in a massive discharge of steam and water into the reactor dry well. Radioactive iodine, which can cause cancer of the thyroid, became concentrated in the well to a hundred times the maximum permissible level. Radioactivity in the gas coming out of the smokestack increased from 10,000 to 25,000 microcuries per second for about thirty minutes and then subsided to the lower level. Although temperatures and pressures jumped in the reactor core, plant operators were able to control them, and the reactor was shut down until August 8, 1970.

The AEC reported a year later that no *significant* amount of radioactivity had been released to the environment.³ Subsequently, I met with engineering and public-relations personnel of Commonwealth Edison and asked why no public announcement of the incident had been made earlier. The answer was that because the unit was in a testing phase, no one thought it was necessary. How many other instances which illustrate that accidents can and do happen in the "older" generation of nuclear plants have been withheld from the public?

The danger in this kind of incident is a rupture in the cooling system allowing the water that circulates around and cools the bundles of uranium-dioxide fuel elements to drain out. Without cooling water, normal operating temperature of about 315 degrees centigrade zooms to 1800 degrees in less than a minute. This is the melting point of the zirconium alloy in which the uranium is encased.

A backup emergency core-cooling system for light-water reactors to prevent a meltdown and the dispersal of massive radioac-

tivity outside the plant has been in development for several years. At this writing, none has proved acceptable to the AEC. A principal difficulty is that steam pressure building up inside an overheating reactor vessel prevents cooling water from rushing in promptly enough to avert melting temperature. Yet, such a system is the only emergency measure that could prevent a meltdown in the event of a catastrophic breakdown in the cooling system. So far, no emergency core-cooling system has even been attempted for the fast breeder, which is cooled by liquid sodium.

In a report on nuclear-reactor safety in July 1971, the Union of Concerned Scientists of Cambridge, Massachusetts, stated that in the event a light-water reactor lost its cooling water, "the reactor core would be expected to melt down and breach all the containment structures, very likely releasing some appreciable fraction of its fission product inventory. The resulting catastrophe and loss of life might well exceed anything this nation has seen in time of peace." This organization and other critics of the AEC's reactor-safety efforts contended that until an emergency core-cooling system can be devised—one that will satisfy all conditions—nuclear-reactor construction should be stopped.

That proposal was made directly to the Select Committee of the Pennsylvania Senate by an AEC scientist, Dr. John W. Gofman, a nuclear chemist and a physician on the staff of the AEC's Lawrence Radiation Laboratory at Livermore, California. A compact man in his fifties, with a predilection for sandals and an Elizabethan beard that lent him the mien of a Renaissance savant, Gofman suggested at the hearing that the Pennsylvania legislature consider a five-year moratorium on the planning, construction, and operation of new atomic-power plants built above ground.

The reasons, he said, were that nuclear electric power has been developed "with the most grave failure of appreciation of the radiation hazard to the population" and that it represents "an anti-democratic disfranchisement" of citizens in several respects. It exposes them to hazards without their consent and also threatens them with property loss without compensation.

During his testimony, Gofman produced a copy of his Home-

owners Insurance Policy, issued by the Hartford Insurance Group. The clause entitled "nuclear exclusion" stated: "This policy does not insure against loss by nuclear reactor or nuclear radiation or radioactive contamination, whether controlled or uncontrolled or due to any act or condition incident to any of the foregoing. . . ."

"I urge every Pennsylvanian to examine his home-owner's insurance," Gofman urged, "and ask himself whether he likes the risk to his life, whether he enjoys disfranchisement for an enterprise about which the insurance industry is too skeptical ever to risk dollars."

In its famous report on the consequences of a reactor disaster coded WASH-740, the AEC's Brookhaven National Laboratory estimated that a serious accident in a reactor smaller than the one proposed at Meshoppen could inflict \$7 billion in losses in a populous region.

"The individual lucky enough to escape with his life from such an accident," Gofman said, "stands to recover a maximum of seven cents on each dollar lost."

This inadequate amount of nuclear-disaster insurance protection, he explained, is provided under the Price-Anderson Act of 1957 which limits total liability to \$582 million for any single nuclear-plant disaster. Through three pools, private insurance companies provide the reactor licensee with \$84-million worth of property insurance and \$82-million worth of liability insurance for one location. For liability in excess of \$82 million, the AEC would indemnify the licensee up to \$500 million. In the case of a natural disaster, such as that inflicted on Louisiana and Florida by Hurricane Betsy in 1965, the maximum liability allowable under the Price-Anderson Act would not cover the damage. The Pennsylvania Insurance Commissioner, George F. Reed, testified on this point before the Select Committee. According to one estimate, insurance loss from Hurricane Betsy amounted to \$715 million; another estimate cited losses of \$1.2 billion in Louisiana alone.

In a disaster to a nuclear-power plant costing \$500 million—the estimated cost of the Meshoppen breeder—the allowance of Price-Anderson insurance to the utility and the government's un-

derwriting of the utility's liability appeared grossly inadequate. In citing the insurance situation, Gofman had made a telling point for the citizens' groups. Many of the members had not been aware that private insurance companies would not assume liability for nuclear accidents without government subsidy. It confirmed their worst fears about the nuclear risk.

A Plutonium Economy

Dr. Gofman was emphatic in his testimony about the hazards of the breeder reactor. The individual, he said, is threatened by the plutonium fuel which the fast breeder creates.

Plutonium in the form of plutonium-oxide particles is one of the most powerful lung-cancer producers known. Release of any plutonium on the surface of the earth irreversibly increases lung-cancer hazards for generations to come—for periods measured in hundreds of thousands of years.

It was unbelievable that serious consideration was being given to an above-ground, fast-breeder reactor in Wyoming County, he continued;

This is not only a potential disaster for Wyoming County, but for a large part of the eastern seaboard. One millionth of a gram of plutonium is the order of the amount required to produce lung cancer. Any—just any—mishap in handling the ton quantities of plutonium associated with fast-breeder reactors can compromise the future of countless generations of humans.

Wave of the Future

In the fall of 1970, the Meshoppen breeder was being considered by the AEC as one of three breeder-demonstration plants. A total of seventy utilities and utility groups were involved in the over-all program, divided into three groups, each clustered around a manufacturer. Participating in the Meshoppen breeder, with the Pennsylvania Electric Company as proposed operator and Atomics International as constructor, were sixteen other utilities and the

Tennessee Valley Authority. A group consisting of the General Electric Company as constructor and of Consolidated Edison, with six other New York State utilities banded together as the Empire State Atomic Development Associates, as operator, was involved in a second breeder-demonstration project. Another twenty-three power utilities, including Swedish and Swiss interests, were participating in the design study. The third group, clustered around Westinghouse, of twenty-nine electric utilities and the Bonneville Power Administration, was considering a fast-breeder site on the AEC's Hanford reservation near Hanford, Washington. The initial planning contemplated that the Meshoppen breeder would start operating in 1977, the other two in 1979 and 1981, but the order was not determined.

The AEC had determined that the Liquid Metal Fast Breeder Reactor was its highest-priority civilian power program. This made the breeder the highest-priority power device in the United States, since no other agency of government was engaged in any significant development of new sources of power. By reasons of this default, the AEC had become a self-appointed Energy Agency and its energy policy, such as it was, became the national one.

Studies of breeder-reactor construction were going on throughout the power industry as a result of this policy. The electric-utility groups involved in the three breeder-demonstration projects, represented about a quarter of the installed, electrical generating capacity in the United States. These utilities looked ahead to the magic year 2000, when all of their wishful expectations would materialize. According to the Edison Electric Institute, nuclear power would then be producing 57 per cent of all electrical energy in America. By the turn of the twenty-first century, the nation's energy requirements would be six times those of 1970, when nuclear energy was providing barely 1 per cent of the nation's electricity. The breeder was the only economical way the industry knew to capture this fabulous future market.

Radiation Emissions

While the radiation hazards of nuclear processes had been argued for a quarter of a century, it was not until the advent of the Meshoppen breeder proposal that the safety of this type of reactor became a public concern—in spite of the fact that the breeder had been in development for twenty years. On this issue, the Pennsylvania Senate Committee hearings provided a more extensive public forum for debate than had the hearings of the Congressional Joint Committee on Atomic Energy on the environmental effects of producing nuclear electric power the year before. The state hearings called upon scientists who were critics of the AEC's radiation-protection policies for expert testimony; the Congressional hearings ignored them.

In a Joint Committee session, Senator George D. Aiken of Vermont had inquired about "the degree of danger to people living in the vicinity" of a breeder, addressing the query to Milton Shaw, the AEC's forceful, gung-ho director of the Division of Reactor Development and Technology, who had been pushing breeder development hard in the agency's laboratories. Radiating reassurance, Shaw replied: "To me, the degree of danger is such that I will live next door to any one of them with my family." ⁴ Dr. Gofman, who had another view of the radiation hazard, was not called to these hearings, although he had organized a biomedical program at the Livermore laboratory to evaluate the impact of radioactivity released upon man in the biosphere.

A year later, at the Pennsylvania hearings, Herman Dieckamp, president of Atomics International, echoed Shaw's conviction:

I can say unequivocally with respect to radiation that our plant is so designed that the radiation exposure to the public from normal operation is negligible. At the site boundary, the exposure is only a fraction of that which comes with frequent air travel, living at high altitudes, having medical or dental X-rays, living in a stone or brick house, or even watching television. . . . Opposition to nuclear

plants on the grounds they present a radiation hazard simply is unfounded.

Of the seventeen commercial power reactors licensed for operation in the United States at that time, he said, none has been responsible for radiation-exposure injuries to the general public.

That contention was challenged by a persistent critic of the AEC, Dr. Ernest J. Sternglass, a radiological physicist at the University of Pittsburgh who also testified at the Pennsylvania hearings—though not before the Joint Committee. He presented data purporting to show a correlation between a rapid rise in radioactive gases released from the Dresden I plant of Commonwealth Edison, southwest of Chicago, and an increase in infant mortality at the same time in the vicinity. Dr. Sternglass cited public-health records in Illinois showing that from 1964 to 1966, the period of the high gas emissions, infant mortality increased 141 per cent in Grundy County, where the reactor is located; 140 per cent in Livingston County, adjacent on the south; and 43 per cent in Kankakee County, adjacent on the southeast. The AEC and the Illinois Department of Public Health branded the Sternglass correlation preposterous. But no other explanation was advanced by either agency to account for sudden infant mortality changes in the three counties near Dresden I.

Another challenge to the AEC-industry position on radiation from nuclear reactors came from Dr. Gofman, who told the Pennsylvania Senate Committee that the AEC's standards of permissible radiation could result in 32,000 cancer deaths a year in the United States. He and Arthur R. Tamplin, an associate at the Livermore laboratory, had called for a tenfold reduction in allowable radiation emissions from nuclear plants.

The AEC radiation standards were defended at the Select Committee hearing by Dr. Lauriston S. Taylor, president of the National Council on Radiation Protection and Measurements, which recommended the standards. Taylor insisted that the standards were perfectly safe. It was unlikely that the limit of permissible radiation would be reached by a reactor, he said, but in the event

they were, the most pessimistic estimate of fatalities from the radiation would be only eighty-five persons.⁵

Perceptions might vary about the eighty-five persons. To statisticians, they were an abstraction of little consequence. To critics of radiation policy, they were victims of a propitiatory human sacrifice. The question of radiation safety was to become the most bitterly contested aspect of reactor safety. The Atomic Industrial Establishment took the position that a little radiation was harmless, from a clinical viewpoint. Gofman, Tamplin, and Sternglass maintained that even a little radiation was statistically deadly.

Reducing permissible radiation emissions from nuclear-power plants was not an engineering problem, but an economic one. The emissions could be reduced tenfold if the utilities wanted to spend the money to do so. But according to the AEC's official position, it wasn't necessary. There was, admittedly, some risk in the radiation that escaped up the chimney in the exhaust gases from the plants, or in the water used to cool the condensers, or during periods when the fuel rods were changed. But one must take risks for the benefit of cheap power. From the Establishment's point of view, the benefits far outweighed the risks—except for people living immediately downwind of a big nuclear-power plant.

The Trojan Horse

In the 1970 hearings on atomic-power plants by the Pennsylvania Select Committee—the first public forum on the safety issues in the rising struggle between citizens and the AEC—each side was thoroughly polarized on the questions of plant safety and radiation hazards. Supported by scientist critics of the AEC, notably Gofman, Tamplin, and Sternglass, the concerned citizens regarded the proliferation of nuclear-power plants as hazards of health and property. Supported by the AEC, the Establishment insisted that atomic energy was the key to the future of civilization. The numbers of concerned citizens in the state were small and the organizations tended to act independently of each other. But they were powerful because the questions they raised and the warnings

they issued, abetted by the AEC's amazingly clumsy counterpropaganda, worried many thousands of people.

What was happening in Pennsylvania also was occurring spontaneously in a dozen other states in the East, the Midwest, and the West. Citizens in small groups were contesting atomic-power plants all over the country. But the basis of it was opposition, not to technology per se, but to the imposition of a new and hazardous technology without consent and without an acceptable definition of its real dangers. The issue was one of consent.

Beyond the issues of plant safety and radiation hazard, there was a third. Quite apart from the State Senate hearings, it was raised by Representative Dan Flood of Wilkes-Barre, when he attacked the siting of nuclear-power reactors on or near the east coast as a "Trojan Horse" in national defense. They would be easy targets for missiles launched from ships or submarines off the coast. He asserted that a hit would have the effect of detonating a nuclear bomb, emitting huge doses of radiation over a wide area.

The Pennsylvania Congressman cited a section of the AEC's reactor-licensing code stating that an applicant is not required to provide design features or other measures "for the specific purpose of protection against the effects of attacks and destructive acts, including sabotage, by an enemy of the United States." Citing also a letter of September 23, 1970, from the Department of Defense stating that no specific countermeasures are taken to prevent an attack on nuclear plants as such, he said:

Now, in the face of all this, we learn that Pennsylvania has been selected to have an enormous, first-of-its-kind, experimental, fast-breeder reactor on the Susquehanna River at Meshoppen, thirty-five miles north of my office in Wilkes-Barre. This nuclear experiment is to have as its fissionable core a ton and a half of plutonium. If sabotaged and explosively compressed, which I am assured can be accomplished in a variety of ways, this neighborhood gem will instantly become a huge and incomparably dirty atomic bomb.

The resulting permanent poisoning of the Susquehanna watershed from New York State to the mouth of Chesapeake Bay would probably eliminate the large and heavily populated section of the United States as a habitable region.

The first demonstration Liquid Metal Fast Breeder Reactor did not come to Meshoppen, after all. It was designated for another part of Appalachia, in the forested, mountain wilderness of Tennessee. There, the wave of the future was destined to break late in the 1970s, far from the "madding crowd" of environmentalists.

There was a rebellion against atomic energy in the land. It was a protest unprecedented in the history of technology.

on the basis of self-reliance, i.e., with minimum reference to and dependence on assistance from DC. It was felt that a study of this theme should be carried out, involving leading economists and natural scientists from East, West, North and South, to analyze the situation on the premise that little or no assistance will be forthcoming from the rich countries, and that the future salvation of LDC, therefore, lies in planning together on the basis of maximum cooperation in the use of their own resources and through joint undertakings in all fields.

Resources for Development. It was felt that there are no absolute shortages of human, physical and financial resources for applying science and technology to development. There is rather a need of social organization to promote the efficient utilization of existing resources.

A strong case can be made for a study in the near future to identify and suggest measures that would remove constraints on the development and utilization of human resources.

Mechanisms of Cooperation between Developing Countries. It was noted that there are imperative needs for LDC to enter into forms of cooperation with other developing countries to further economic development, particularly the application of science and technology toward that end. Such cooperation, however, is sometimes difficult to achieve, the preponderant links still being between DC and LDC. One of the major reasons for this is the comparative lack of financial resources to support cooperation between LDC. Scientists are urged to contribute ideas to bodies, such as the U.N. Development Program (UNDP), which are prepared to devote financial resources to study such cooperation between the LDC.

Professional Norms of Scientific and Technical Communities. Educational and research establishments in LDC have been modeled upon those in the metropolitan countries. The new needs of development are recognized, but established traditions and attachment to DC institutions, tending to encourage pure rather than applied science, make changes difficult. The incentive and reward systems—now geared toward excellence in basic research in sciences rather than to the development and application of technology to fields of importance for development—need to be changed. Both basic and applied research have to be relevant to national requirements as identified jointly by scientists, planners and the users of research.

The prime responsibility to effect the required change remains with the scientific leadership in the LDC. But the international scientific community should lend support to actions in LDC aimed at bringing such changes about, and help to educate and influence their colleagues in both LDC and DC in this regard.

Role of Scientists in Promoting the Self-reliant

Development of LDC. Parallel to the influence which the scientific community has exercised on disarmament questions, scientists need to exert pressure, particularly on governments, by means of person to person contacts through scientific societies, the press and parliaments, in both the DC and the LDC, for the development of the welfare and self-reliance of the latter countries.

Radioactive Pollution of Environment

Need for Fission. The future needs for fission power depend on the growth of energy consumption worldwide, the distribution of that growth between rich and poor countries, the size of electricity's role in the total energy budget, and the magnitude and time scale for development of alternative energy sources. Growth of energy use is most badly needed in the poor countries, where nuclear power is at a disadvantage because of the small scale and dispersed character of present needs. Fusion, solar and geothermal energy are major sources potentially achievable and able to reduce reliance on fission on a time scale of 20 to 50 years, while cleaner technologies for burning fossil fuels have some promise for the interim.

Need for Breeder Reactors. Continued reliance on non-breeder fission reactors for the next 30 to 50 years would require the use of expensive low-grade uranium ores if fission grows as its promoters have projected.* However, the cost of nuclear-generated electricity is so insensitive to the price of uranium, even in non-breeder reactors, that no drastic increase in electricity cost would result from the use of the expensive and abundant ores in light water reactors or gas-cooled reactors.** Available data indicate that it is not necessary, on the grounds of a worldwide uranium shortage, to deploy breeder reactors in the next 30 to 50 years. (It must be noted that this conclusion was not unanimous.)

Routine Emissions. It is technically possible and desirable to reduce routine emissions of radioactivity from nuclear reactors and fuel reprocessing plants to levels such that the radiation exposure to members of the public from all such sources is less than one percent of the average "natural background." The greatest technical and regulatory vigilance will be required to assure that the technical potential for such low emissions is achieved, in practice, everywhere in the world. Establishment of a world-

*Although low-grade uranium ore—tri-uranium octoxide, U_3O_8 —cost \$15 per kilogram in 1973, it is estimated that it will cost \$35 per kilogram in the year 2000 and \$100 per kilogram in 2020.

**It is estimated that the increase in electricity cost would be about 0.5 mills per kilowatt hour electrical in the year 2000 and 1.5 to 3 mills per kilowatt hour electrical in 2020. These cost increases compare to an average delivered cost of electricity of 20 mills per kilowatt-hour electrical in the United States in 1970.

Kerr-McGee

Kerr-McGee

Kerr-McGee

Chemical Spill
Treated Minor,
Of Common Type.

By Jim Reid

Kerr-McGee Corp. has received a clean bill of health from the Atomic Energy Commission following an investigation of a minor leak of nuclear material at its Cimarron facility near Crescent, Okla. The Oklahoman learned Friday.

James Donaghue, a representative of the AEC's Radiological and Environmental Protection Branch in Chicago, said the Aug. 18 incident was "no big deal."

Donaghue and two other AEC representatives, K. M. Ridgeway and John A. Flinn, conducted an inspection of the Kerr-McGee plant last week.

Relict Material Made

The plant mixes enriched uranium dioxide and ammonia to form a powder that is compressed into pellets that go into fuel rods for nuclear reactors used for generating electricity.

The operation produces plutonium nitrate, a radioactive material with a half-life of 24,100 years. It is a by-product of the process that causes it to condense in 55-gallon drums.

After the solidification process, the drums containing the plutonium nitrate are hauled off by an AEC-licensed disposal agent to a licensed burial site.

Waste from the Cimarron Facility is buried at either of two AEC installations at Sheffield, Ill., or Morehead, Ky.

Contamination Slight

Donaghue said that on Aug. 18 a small amount of the plutonium nitrate leaked from one of the 55-gallon drums onto the floor of a small truck where it was stored prior to burial.

"There had apparently been a breakdown in the solidifying agent," he said.

Donaghue said there was no contamination of plant workers or of the environment. The contamination was contained in a small area, which was decontaminated according to AEC regulations.

"There was no emission off the site," he said.

In instances of this kind, Donaghue said, it is not necessary for the company to make a report to the

Atom Plant Passes Test

Continued From Page One
pany is required to document the incident, along with decontamination efforts, for review by AEC personnel during routine inspections.

Donaghue said Kerr-McGee complied with that rule.

He said leakages and spills of radioactive materials are "fairly common" around such facilities as the Kerr-McGee plant when containers rupture.

"But as long as the contamination is contained on the plant site there is no danger," Donaghue said.

He said the Cimarron Facility has had several such leaks — or spills —

since it went into operation in early 1965.

All of the incidents are on record in the public document section of the public library at Gettysburg, along with inspection reports, Donaghue said.

Jim Allen, supervisor of the Chicago AEC branch, put to rest any fears that the plutonium nitrate produced at the Kerr-McGee plant could cause a nuclear explosion.

He said extra precautions are taken to keep the nuclear waste in small containers "so it won't go critical."

"We're satisfied that Kerr-McGee took adequate precautions in the area

contaminated by the leak," he said. "However, we are still evaluating the information obtained during the inspection."

Allen said there will probably be a couple of instances where Kerr-McGee did not comply with AEC regulations.

"These are no reason to the leak of Aug. 18, or the of a record-keeping violation," he explained.

He said the violations were minor and not subject to penalties.

The maximum fine for a serious violation of AEC rules is a \$5,000 fine, Allen said.

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BIOLOGIC EFFECTS OF NUCLEAR POWER

by J.K. Frenkel, M.D.
Department of Pathology, University of Kansas Medical Center

Radiation effects. Nuclear radiation can be compared to exceedingly small machine gun bullets shooting off electrons from atoms which are left charged or ionized or in a very reactive state (free radicals). When this occurs within cells, the ionized chemicals, such as enzymes, rearrange, killing or damaging the cells. Particularly subtle is a chemical change, or mutation in chromosomes, carriers of the genetic code, which may manifest itself by the development of cancers or may lead to inherited, genetic defects in succeeding generations with potentially cumulative effects. Depending on the radiation intensity, fewer or larger numbers of cells are damaged and killed. Cell death usually takes place at the next attempted cell division. Mutations become apparent after an interval of years, after the damaged cells have multiplied.

For external radiation, a roentgen or R defines the amount of ionization and serves as a unit of measurement. About 600R to the whole body are fatal to man and domestic animals. About 500-600R results in serious illness producing prolonged sterility. About 100-600R results in radiation illness and premature aging. About 10-100R doubles the mutation rate leading to cancer or genetic defects.

5R per year is the occupational "allowable dose," for radiation workers over 18 years of age. This means that for time-consuming jobs in a radiation area, work has to be done by a succession of people. In some repair jobs, all the available welders were exposed to a maximum 5R, making them unavailable if a similar need arose in the same year. 0.5R per year is the "maximal individually allowable dose," from industrial irradiation to the general public, including children and fetuses, and 0.17R per year is the current legal average that may be delivered to the population average with a permissible variation up to 0.5R.

The allowable dose is sometimes misunderstood to be innocuous. However, it is not reasonable to assume a "threshold" by which, for example, .49R was okay and .51R was harmful. Actually, due to the delay in mutations becoming evident, the effects of low-level irradiations are difficult to measure. As a general guideline, one can extrapolate radiation effects. If on the average a million radiation "bullets" produce cancer in 10% of animals or man, 100,000 will produce 1 cancer in 1%, 10,000 in .1%, 1,000 in .01%, etc. Radiation effects are related to "bullet" hits, and it does not make much difference whether these occur in one or in many individuals. There is repair of some of the radiation damage, but also evidence from studies in Hiroshima and Nagasaki that straight extrapolation from high doses to predict effects of low doses may underestimate the incidence of cancer in a mixed human population. At higher doses, some of the cells that would have become cancerous died; but at low doses they survived to transform into cancer. There is evidence also of greater sensi-

tivity of children and fetuses to a given amount of radiation. Some geneticists regard the allowable dose to increase the prevalent mutation rate by about 10% in adults, but by 25% in fetuses, as indicated by the occurrence of leukemia and cancer during childhood. Some of these estimates have been derived from studying the effects of diagnostic X-rays where a diagnostic benefit is involved; this certainly indicates that similar small doses without medical benefits should not be disregarded. Post-reproductive adults would not need to be concerned about genetic defects.

Internally deposited radiation, inhaled, ingested or introduced into wounds, presents special problems due to the fact that vital cells may be directly irradiated from isotopes deposited nearby. Particularly the short-range alpha and beta particles, which from the outside might cause only a skin burn, can directly affect the blood-forming bone marrow if deposited in the bone, or the thyroid if deposited there. Their radioactivity is expended over a short distance, producing a path of intense ionization. They probably kill most of the cells near them, and turn some into cancer cells. Recalling that there are about 30 fission product elements, these are distributed in the body in a variety of ways characteristic of the element: calcium, strontium, barium—to the bone; iodine—to the thyroid gland; and the rare earth elements—to bone marrow, liver and spleen. Inhaled uranium is excreted by the kidneys. Characteristics of solubility and absorption, and concentration within the food chain play an important role. For example, insoluble plutonium, when eaten, is largely excreted. When inhaled, it remains in the lung where it acts as one of the most toxic materials known to man. By weight, it is 10 times as toxic as radium. One-millionth of a gram can produce cancer, and about 10 to 100 millionth of a gram, death from hemorrhage, edema and fibrosis (scarring), all from intense radiation. Soluble plutonium hexfluoride is deposited in the bone, irradiating the marrow cavity and producing loss of blood cells and osteosarcoma (in dogs, rats). In general, bone deposition is more effective in children and young animals than in adults.

The delay in onset of leukemia is 5-10 years after accumulating the radiation exposure, and for other cancers 10-20 years. For this reason, we cannot expect to see these effects as yet. But we need only recall the uranium miners where in spite of what were considered adequate precautions in the 1950's and 60's, 67 excess lung cancers were recorded up to 1968, a rate four times as high as in other metal miners; about 500 more are expected to occur. Or consider the radium dial painters who pointed their brushes with their tongues, absorbing significant amounts of radium, and some of whom developed leukemia in 5-10 years, bone cancer in 5-15 years.

Human aspects. Although the scientific and military aspects of the U.S. nuclear program were conducted with a high degree of caution and with carefully selected personnel, a number of fatal laboratory and industrial accidents occurred. With the expanding nuclear technology, inevitably precautions will be fewer, people less highly selected, and fission products and plutonium

will escape. Probably there are not enough people capable of the constant rigorous watchfulness required for the job. A 115,000 gallon leak from storage containers in Hanford, Washington went undetected for 7 weeks; accidentally discharged fission products in Broomfield, Colorado appeared in the municipal water supply, a plutonium oxide over the countryside, are just known beginnings. Most accidents are covered up at first, then described as unimportant, or as "safe."

The first demonstration breeder, the Enrico Fermi reactor, is shut down after a near meltdown. And there are no published figures about sabotage and theft losses. But if we are to increase nuclear energy production 100-fold as planned, it is inevitable that spills, accidental releases, plutonium fires, traffic accidents involving nuclear materials, and clandestine thefts will occur more frequently. With the 24,000 year half-life of plutonium created in ton amounts, and its 10 millionth gram toxicity, we are headed for unprecedented trouble. Alvin Weinberg, former director of the Oak Ridge National Laboratory said, "We nuclear people have made a Faustian compact with society: we offer... an inexhaustible energy source... tainted with potential side-effects that, if uncontrolled, could spell disaster." We are changing our national commitment, therefore, from promoting "the general welfare and securing the blessings of liberty to ourselves and our posterity," as stated in the Preamble of the Constitution, towards a commitment to greater dangers and control in support of nuclear industrialization. Should this change in commitment not be preceded by a full Congressional hearing and a national debate? Nothing less is worthy of the bicentennial celebration.

FURTHER READING:

Recent volumes of Science, Bulletin of the Atomic Scientists, Health Physics, Radiation Research:
Alice Stewart: An epidemiologist takes a look at radiation risks. Dept. of HEW, Publ. No. 73-8024;
Effects on populations of exposure to low levels of ionizing radiation. National Academy of Science, November 1972; includes glossary;
The Nuclear Fuel Cycle. Union of Concerned Scientists (P.O. Box 289, MIT Branch Station), Cambridge, Mass. 02139.

Mid-America Coalition for Energy Alternatives Newsletter

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- ☐ Here is my \$3 membership in MACEA (includes MACEA newsletter)
- ☐ I would like to subscribe to the newsletter alone, here is my \$3 subscription
- ☐ Please send me a packet of literature for more information on energy issues, for which I enclose \$1
- ☐ Here is my additional contribution of _____ to MACEA

(Due to our lobbying status memberships and contributions are not tax-deductible, which means you get more action for your money.)

WHAT WE'VE BEEN DOING:

MACEA-K.C. members have had a very busy month. We have delayed the publication of the newsletter because we wished to include a report on the Atomic Industrial Forum.

Several of our members have participated in energy panel discussions at area churches. A two day energy symposium at Shawnee Mission South High School involved four of us rotating with representatives from the Environmental Protection Agency, Standard Oil, and Kansas City Power and Light. Ron Henricks has been talking to Kiwanis and Jaycees in St. Joseph and Clinton.

The committee on methane digestion from waste met twice with the Mid-America Regional Council to urge inclusion of methane and sludge recovery in the regional water treatment plans. They also met with Senator Symington's staff, Representative Bolling and Mayor Charles Wheeler of Kansas City.

An important activity this month was planning for, gaining admission to, and reporting on the Atomic Industrial Forum Conference on Nuclear Power and the Public. A press conference was held prior to the AIF Conference in which we voiced our objection to the press being excluded and presented our comments on the topics to be discussed. We also issued a press release further elaborating our position, and it was sent to many newspapers in our two-state area. The Kansas City Star, Sunday, March 3, carried a report on the press release.

Partly due to the coverage of our concerns in Sunday's Kansas City Star and interest expressed by others in the press, Diane Tegtmeier was allowed to cover the conference. A brief report of the proceedings appears in another article. A more detailed report and copies of several key speeches given at the conference are available from MACEA for the cost of duplication.

Statewide meetings are being planned for Kansas and Missouri during April and May. Area groups will be receiving information soon.

The MACEA newsletter should not be a report only from Kansas City. We would like to regularly feature articles concerning activities in each area we represent. Since we have not been receiving such articles we are asking that area leaders take the responsibility of writing or obtaining a brief article about what your groups have done, learned or will do and then send it to the MACEA editors before the 5th of each month. David and Kay Reiswig, 4515 N.E. Kelsey Rd., K.C., Mo. 64116 are the newsletter editors, so send them the materials. Let us know who you have talked to, what legislators you have seen and what their response has been. Share your ideas and experiences with us.

HELP NEEDED

MACEA needs replacements for treasurer Laura Brannon who is leaving the area in April, and secretary Becky Burcham who is leaving the area in May. If you are interested in one of these positions or know someone who might be interested, please call the MACEA office at 531-8711 or Diane Tegtmeier at 362-8596. Volunteers need to live in the Kansas City area.

FOR FURTHER READING:

1. "Plutonium and the 'Hot Particle Problem': Environmental Group Proposes a Draconian Answer," Science, Vol. 183, No. 4127 pp. 834-835.
2. "Floating Nuclear Plants: Power from the Assembly Line," Science, Vol. 183, No. 4129, pp. 1063-1065.

Allen L. Hammond

PUBLIC ISSUES

BREEDER REACTORS: MARVEL OR MENACE?

The case for rethinking a national commitment that could be a national disaster

AT ONE TIME, Americans obtained ample energy with a technology no more sophisticated than an ax. Now we depend increasingly on electricity generated in central power stations—most of them fueled by coal, with its side effects of air pollution and strip-mine damage. The U.S. also has twenty-five uranium-fueled nuclear power plants; many more are under construction. But neither coal nor uranium can supply our energy needs indefinitely. Uranium particularly is in short supply; according to the Atomic Energy Commission, reserves of this fuel will run low within twenty or thirty years. Ultimately we will have to develop other fuels and still more sophisticated technologies to power our industries and light our homes. Worse, the U.S. demand for electric power is likely to double twice by 1990, creating a genuine energy crisis.

How we should marshal our resources to meet our energy needs is a controversial subject. Some years ago, the Atomic Energy Commission decided unilaterally that our highest priority should be the breeder reactor, a new and complex type of nuclear reactor that will burn plutonium instead of uranium. The breeder has the almost magic ability to produce, or "breed," more nuclear fuel than it consumes, and it will, the AEC claims, provide cheap, abundant electric power with less pollution than uranium-fueled reactors. By the year 2000, the AEC plans to have in operation more than 500 breeder reactors, representing a quarter of this country's electrical generating capacity.

In contrast, the breeder's critics argue that it will lead to unprecedented environmental hazards. Far from being an ideal solution to the energy dilemma, they believe, the breeder may well be the worst of the alternatives at hand. Physicist and Nobel laureate Hannes Alfvén claims

that with this technology, "a total poisoning of the planet is possible." Even some thoughtful proponents of the breeder have pointed out that large-scale use of these reactors will pose novel difficulties arising from their production of vast amounts of radioactive plutonium, a long-lived and extremely lethal material. There is a "moral responsibility" to face up to such potential dangers, says Alvin Weinberg, director of the AEC's Oak Ridge National Laboratory. Given the dangers, one might reasonably ask why we do not devote more resources to cleaning up fossil fuels (coal, oil) and to developing less hazardous sources of energy, such as nuclear fusion, solar energy, or geothermal energy, instead of building breeder reactors.

AT ISSUE HERE is the way in which we as a society are to make decisions about our technological future. As in the struggle over the supersonic transport, the traditional methods for making these decisions are inadequate; the conventional framework for judgment is not broad enough to encompass widely differing visions of what America should be. The rejection of the SST, in part for environmental reasons, was a healthy precedent. But it was only a skirmish; we didn't really need that airplane. The real battle in technology assessment lies ahead; it concerns future energy systems. Here the stakes will be higher—we do need energy—and the risks of a hasty or ill-considered commitment will be far more serious.

The AEC's program to commercialize breeder technology already has considerable momentum. By 1980 the agency and its Congressional sponsor, the Joint Committee on Atomic Energy, plan to spend more than \$2 billion in federal funds on developing the breeder, more than is being spent for research on all other types of energy together. In a message to Congress in June 1971, President Nixon called the breeder

"our best hope for meeting the nation's growing demand for economical clean energy." The utility industry has pledged more than \$230 million to help build a demonstration power plant powered by a breeder reactor; construction is scheduled to start late next year.

Unfortunately, none of this headlong activity was preceded by any serious study of energy resources or any open debate on the merits and disadvantages of various methods of generating power. In fact, the government still lacks any overall national policy for energy. Because the AEC has preempted the field—simultaneously developing and promoting the use of nuclear energy for twenty-five years—the AEC's point of view has become *de facto* national policy.

Alaska's Senator Mike Gravel has repeatedly attacked the breeder program on the Senate floor, but thus far his lonely battle has been unsuccessful. What may prove to be a more effective move is a lawsuit filed against the AEC by the Scientists' Institute for Public Information (SIPI), a group headed by biologist Barry Commoner and anthropologist Margaret Mead. The SIPI lawsuit seeks to compel the AEC to file an environmental impact statement on the breeder program, which the AEC has refused to do. As the plaintiffs see it, the National Environmental Protection Act requires a detailed statement assessing not only the breeder's long-range consequences but also the possible alternatives to this new nuclear technology. The AEC, with White House backing, claims that it need only prepare such statements on a plant-by-plant, piecemeal basis. With the help of an anti-environmentalist federal district judge in Washington, D.C., where the suit was filed, the government won the first round in late March 1972. The legal action then moved to the Court of Appeals, which has previously overruled the judge in several environmental cases. As of November, a decision on the case was pending.

Dr. Hammond, a physicist and writer, is currently research news editor of Science, the journal of the American Association for the Advancement of Science.

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years. If AEC projections for the commercial use of breeders prove correct, these reactors will be producing as much as 80,000 kilograms of plutonium a year by the end of the century.

Such large quantities of plutonium, according to the AEC point of view, represent a distinct benefit to mankind. As fuel in a nuclear reactor, for example, a pound of plutonium can produce as much energy as three million pounds of coal. By using plutonium instead of fissionable uranium as a nuclear fuel, we will extend our energy resources and obviate the need for costly separation facilities to process the uranium. As a result, the AEC claims, plutonium constitutes an almost inexhaustible fuel.

But plutonium is also among the most toxic substances known to man. Experiments have shown that trace amounts induce lung cancer in animals. Federal health standards recommend no more than 0.6 microgram (about twenty billionths of an ounce) as the total amount to which a human body should be exposed. Because plutonium combines readily with oxygen, there is a substantial fire hazard wherever this material is used. The critical mass of plutonium, the amount that could cause a nuclear explosion, is only a few kilograms, thus requiring unusual care in handling, storing, and shipping to prevent such quantities from coming together. Not the least of the problems posed by plutonium is its radioactivity; the radioactive half-life, or decay period, of plutonium is about 24,000 years, so that the contamination of an environment with plutonium by whatever means would be essentially permanent. Both the projected scope of plutonium usage—what former AEC chairman Glenn Seaborg has optimistically described as the "plutonium economy of the future"—and the hazards associated with this valuable yet dangerous material make the debate over the merits of the breeder a significant one.

THE AEC IS CONFIDENT that dependence on plutonium fuel will present no irremediable difficulties; its top officials are apparently unwavering in their belief that the breeder is the best solution to our energy problems. But this conviction and the AEC's case for the breeder seem to depend on the tacit assumption

that some form of nuclear energy is inevitable. In essence, the AEC's arguments are threefold: (1) we must have the breeder and have it quickly, if we are to continue to enjoy the benefits of nuclear energy; (2) breeders will make available abundant and inexpensive electric power; and (3) the plutonium problems notwithstanding, the AEC claims that the breeder will pollute less than other sources of energy.

The first argument is essentially a scarcity argument. AEC estimates of commercially recoverable uranium indicate a shortage of nuclear fuel before the end of the century if breeders are not built. Because it will take fifteen to twenty years to develop breeder reactors and perfect them to the point of commercial acceptability, the AEC reasons, it is urgent to move ahead rapidly if the energy crisis is to be staved off. There is indeed no question that, in the long run, breeder reactors will be necessary if we continue to use nuclear fission as a source of energy. But there is disagreement about whether we have fifteen or fifty years before this necessity must be faced and choices made. The AEC's estimates of uranium assume, for example, that no new discoveries of uranium ore will be made, that no more drilling (to verify suspected deposits) will be done, and that no uranium will be imported from Canada and Australia, where most of the free world's reserves of this mineral are located. Independent studies of uranium reserves have questioned the AEC's findings and have indicated that sufficient domestic supplies of high-grade ore exist to fuel the growing nuclear industry through at least the year 2020 without recourse to breeders. The point is not that breeders should never be built but that, if these independent studies are correct, there is no justification for a crash program to develop breeders. We have enough time to make an informed and rational choice.

WHAT ABOUT the argument that breeder reactors have economic advantages as a source of power? Even the AEC no longer believes, as it once did, that breeders will make electricity "too cheap to meter." But the AEC does claim, as justification for federal investment in breeders, that the introduction of this technology

might save as much as \$20 billion in the nation's power bill over a fifty-year period. Several nuclear experts who have looked closely at the design to which the AEC is committed are dubious that the breeder will in fact perform as economically as claimed. A recent study by Resources for the Future, a reputable nonprofit group in Washington, D.C., indicates that the breeder is likely to be a far more expensive source of electricity than present nuclear power plants. The relative attractiveness of the breeder will also depend in part on the effort and money expended to develop and improve other sources of energy.

The AEC's third argument is an environmental one: breeders will eliminate the air pollution that fossil fuel plants would cause; they will reduce waste heat and thermal pollution compared to present types of nuclear power plants; and they will further reduce the release of trace amounts of radioactivity into the environment. These are substantial advantages, taken one reactor or power plant at a time, but they do not give the entire picture. The large number of breeder reactors that the AEC envisions will make the issues of reactor safety, the transport of nuclear fuel, and the disposal of the radioactive waste products of reactors much more serious questions than they are at present.

Reactor safety, for example, is not something that can be absolutely guaranteed. Nuclear power plants are probably among the most carefully engineered and rigidly regulated structures in the world. Allowances are made even for unlikely events: near airports, these plants must be designed to withstand an airplane crash without releasing substantial amounts of radioactivity. But even the most conservatively designed and carefully run industrial facilities do have accidents.* The possibility of unforeseen natural disasters, war, or sabotage cannot be ruled out. While the chances of a serious nuclear acci-

* Since January, the safety of existing nuclear power plants has been challenged in hearings at Bethesda, Maryland, by members of the Union of Concerned Scientists, a Boston group, and by some of the AEC's own safety experts. The AEC has admitted that reductions in power output of up to 20 percent may be required in several such plants. Because of their greater complexity, breeder reactors may have still more difficult problems.

 

It may be that breeder reactors are the best or even the only feasible source of energy for mankind. It may be that the complexities associated with large inventories of plutonium are part of the price of living in a technological society. But it would be well to be sure before the enterprise is too far advanced and the cost of error too high. We must free ourselves from the narrow vision of the past and ask for a reassessment of energy problems in a forum accessible to a wider range of interests than ever before. The call for a comprehensive national policy on energy is now fashionable, but we have not yet begun to reallocate the resources and acquire the information that could provide a basis for such a policy. It is long past time that we did. □

The SIPI suit asks, in effect, that the federal government put its national energy policy on a rational and explicit basis so that Congress and interested citizens can have a say in its formulation. It is a modest but nonetheless revolutionary request, and if successful it may provide the information needed for a proper assessment of the breeder program.

IS THE BREEDER another irresponsible high adventure in technology along the lines of the SST? Or is it, as the AEC claims, the only feasible alternative we have? Before we examine the arguments for these conflicting points of view, we need to know something about how breeder reactors work and how they differ from the type of nuclear power plant that is now being built around the country.

Nuclear reactors exploit the process of nuclear fission—the splitting of the atom. The heat produced in this process is in turn used to generate electricity in nuclear power plants. Only a few natural substances readily undergo fission, however, and the most common of these, uranium-235, constitutes less than 1 percent of the uranium found in nature. Commercially recoverable reserves of fissionable materials are limited; hence nuclear reactor fuel will eventually be in short supply—exactly when depends on the extent of the deposits of high-grade uranium ore. A possible solution to this impending shortage is to have nuclear reactors artificially breed new fuel for themselves by converting “fertile” materials, such as the more plentiful uranium-238 and the element thorium, into fissionable materials such as plutonium; for this reason the breeding process has been of interest since the early days of nuclear energy.

Nuclear reactors of the kind now being installed in power plants breed small amounts of new fuel, but the conversion process is relatively inefficient, producing only about sixty atoms of plutonium for every 100 atoms of uranium consumed. Breeder reactors, as their name implies, are more efficient at the conversion process and produce more nuclear fuel than they consume. The resulting plutonium can be used as a fissionable fuel in a breeder to produce still more plutonium, thus doubling the plutonium on hand about every ten

dent may be exceedingly small at a given plant, the net probability will be considerably increased when several thousand breeder reactors are in operation.

At regular intervals, nuclear reactors must be refueled and the fission waste products and plutonium removed and shipped to a fuel reprocessing plant. The radioactive waste is then to be shipped to a depository for long-term storage, while the plutonium is refabricated into reactor fuel and shipped back to a nuclear power plant. Transportation accidents occur with predictable frequency; railway cars, for example, are derailed about once every million miles. By the year 2000, there will be as many as 600 shipments of highly radioactive fuel per week, so that we can expect a certain number of accidents in which radiation is released. This number will probably be very small, but that is not the point—there will be some accidents. One is forced, as with the possibility of reactor accidents, to make unpleasant decisions about what risk, in terms of human exposure to radiation and contamination of the environment, we are prepared to tolerate as the price for power from the breeder.

Long-term storage of radioactive wastes is a problem the AEC has still not adequately solved. According to current projections, more than ten million gallons (or their solid equivalent) of such wastes will have accumulated by the end of the century. These toxic materials must be cared for over many thousands of years. We shall have to build or find repositories that, like the pyramids, will outlast our present culture as monuments to our use of nuclear energy.

TO BE SURE, technological problems are amenable to solution, at least in theory. But the same cannot be said for the social problems created by technology and human nature. Airplane hijacking is one example. The diversion of plutonium to illegal purposes may well be another. Plutonium is extremely valuable as nuclear fuel and is worth about \$10,000 per kilogram—comparable to the wholesale price of heroin and about ten times the value of gold. Given this incentive and the relative ease of truck hijacking or of stealing in small amounts from industrial stockpiles, it seems likely that a black

market for plutonium will develop, an assessment with which the AEC's own experts agree. Moreover, it takes only a few kilograms of plutonium for an atomic bomb, and the know-how to construct such a bomb is readily available. One can imagine, without too much difficulty, an extremist group of the future demanding an enormous price in return for not blowing up New York City. Even without bombs, the public health and national security hazards of a clandestine plutonium market will be considerable.

Despite a distinct resemblance to science fiction, these are not hypothetical problems. The AEC is aware of the difficulties that a "plutonium economy" will bring and is seeking ways to avoid or ameliorate them, although the agency has not always been candid with the American public about these problems and their consequences for the future. It is also fair to say that, while AEC spokesmen often talk about including the environmental and social costs of fossil fuels in their price tag, they have not seen fit to apply the same reasoning to the breeder.

Hence our central dilemma: the future of nuclear energy depends on breeders, yet the widespread use of this technology may pose unacceptable costs in environmental damage, health hazards, and social chaos.

WHAT ALTERNATIVES to the breeder do we have—or might we have if we committed as many resources to their development as to the breeder? In the short run it would be to our advantage as a society to decrease our use of electric energy if we can, but there is no easy way to legislate the ever-rising demand for power. Improvements in the way we use fossil fuels are possible and may represent a good social investment for the immediate future, but fossil-fuel reserves will run out eventually, probably within a few centuries.

On a longer time scale the only sources of energy for mankind will be nuclear fission (i.e., the breeder), nuclear fusion, solar energy, and geothermal energy. Methods of capturing sunlight and converting this energy to heat or electricity look promising, but it is uncertain how much these methods will cost. Similar statements can be made about the prospects of tapping the geothermal

THE CASE AGAINST THE FAST BREEDER REACTOR

AMORY B. LOVINS

An Anti-Nuclear Establishment View

In the opinion of the Friends of the Earth and some other environmental organizations, the most critical environmental problem facing the nation is nuclear power—especially the proliferation of it through fast breeder reactors. In this article, the author, a physicist, gives a detailed and documented account of FOE's opposition to breeder technology. The article is based on the FOE statement presented to the Joint Committee on Atomic Energy at a public hearing Sept. 8, 1972.

The proposed liquid metal fast breeder reactor demonstration plant at Oak Ridge, Tenn., looks like a bad bargain for the taxpayer. The memorandum of understanding already executed by the Atomic Energy Commission, the Tennessee Valley Authority, the Commonwealth Edison Company and two corporations representing the industry (Breeder Reactor Corporation and Project Management Corporation)—lays these obligations on the AEC:

- pay \$422 million outright, and to bear the sole responsibility for trying to raise the money to meet any cost overruns,
 - pay back (and, if desired, to dismantle and decommission) the plant if the TVA doesn't want it after five years, and
 - indemnify the other four parties against all claims and liabilities.
- The obligations of Commonwealth Edison and of the TVA, on the other hand, are limited to their very small utility contributions plus \$2 million from which they can subtract their preparatory expenses and the value of any services they supplied.

The President's Energy Message to Congress, June 1971, specified: "Industry should play the major role in [demonstration projects] . . . but the government can help by providing technical leadership and by sharing a portion of the risk for costly demonstration plants." Yet this plan has been abandoned for the government, through the AEC, is now going to assume three-fifths or more of the cost and all of the risk. The utilities' contribution of a quarter of a billion dollars (the limit of their liability for the project) sounds like a lot of money.

The notes that the investor-owned electric utilities have a total valuation of \$105 billion (1971), and have already committed themselves (in orders outstanding at the start of 1972) to \$31 billion for

new light-water reactors and to \$127 billion for the fuel and operating budgets to run them. Compared with these staggering investments, the utilities' token contribution of \$250-odd million for a supposedly revolutionary project of "proven feasibility" bespeaks a reluctance that should give this committee (JCAE) pause.

The AEC is trying to accept on the taxpayers' behalf an open-ended commitment to escalating costs and unlimited indemnities, while the utilities are buttering their bread on all six sides. Approving such a lopsided arrangement would not meet this committee's duty of safeguarding the public interest. No other body can perform this duty instead.

Under the proposed contract, the public will have no way of knowing what the five participants are doing, and the detailed management of the project, funded mainly by the Treasury, will pass forever out of public control. Annual or even weekly hearings before this committee could not repair the public damage wrought by a defective contract. Principles of sound management demand, therefore, that the Joint Committee on Atomic Energy insure that the Congress

- either increase the directness of public control over the project or lessen Treasury funding of it, so that commercial participation in its support and in its administration are made commensurate;

- require that all board meetings of the Project Management Corporation (PMC) and the Breeder Reactor Corporation (BRC) be minuted, other administrative actions be properly recorded, and all these records be made currently available to the public;

- appoint a nonexecutive watchdog committee of both technical and lay members of the public, free of connection with the nuclear community and required to relay continuously to the public all in-

formation about the progress of the project. Such a function can not be reliably performed by the AEC as now constituted.

An Intolerable Threat

There are major defects from which a demonstration plant would suffer which, if multiplied by the more than 2,600 commercial fast breeders the AEC proposes to build by the year 2020, would produce an intolerable threat to the health, safety and security of this or any other nation.

It is important to bear clearly in mind some of the differences in design between liquid metal fast breeder reactors (LMFBRs) and the light-water reactors (LWRs) now in commercial service. The power density of the proposed demonstration breeder (roughly one-third commercial size) is to be 400 kilowatts per liter—some 12 times that of large commercial LWRs going on line in the past few years. This immense heat flux is to be removed by molten sodium metal flowing through the core (roughly two cubic meters) at a rate of at least five cubic meters per second. The sodium, which is violently reactive with air or water, is to emerge intensely radioactive and heated to about 1000 degrees F. It is opaque (so that all adjustments and maintenance must rely on hard-to-develop instruments [1, p. 1173] rather than on direct inspection), and it freezes unless kept at nearly the boiling point of water.

The core of the reactor contains not 100-odd kilograms (as in a LWR) but roughly a *ton* of plutonium-239—a radiological poison so toxic that if properly reduced and dispersed, a ton of it would far more than suffice to give lung cancer to everyone on earth. "[T]he quantitative relationship between plutonium dose and cancer induction at low dose levels," says the AEC, "has not been determined" [2, p. E1126].

The plutonium inventory in fast breeders is not dilute but concentrated, and constitutes several hundred times the critical mass. Meltdown or local compression of the core could cause accidental reassembly into critical configurations, and thus a violent explosion. Furthermore, any fast breeder reactor is inherently less stable and harder to control than a thermal reactor [2, p. E1119]. The AEC notes: "Among the more severe hypothetical accidents [3] are reactivity insertions . . . leading to events which could damage the core before the . . . inherent shutdown phenomena or normal control actions take effect" [2, p. E868] and possibly "resulting in the release of fission products from the reactor [2, p. E820]. Somewhat less severe accidents "may lead to various degrees of core melting and disruption, and corresponding releases of fission products and plutonium from the fuel" [2, p. E868]. Such effects can be mitigated if "safety features operate . . . as designed" [2, p. E871]—yet "malfunction of the automatic control systems can reasonably be expected to occur within the lifetime of the demonstration plant" [2, p. E866].

The AEC's projected breeder economy for 2020 entails 100 railway cars daily loaded with 800 metal-cooled casks of spent fuel on the way from reprocessing plants. The high capital cost of holding up the contained plutonium may lead the AEC to shorten the usual pre-shipment cooling period from the present 150 days to 30 days—increasing the activity from the fuel of one 1000-Mw breeder at some half-a-billion curies [2, p. E8]. Shipping casks designed to withstand a 30-foot fall or a 30-minute fire may not do so well with a 31-foot fall or a 31-minute fire; and the consequences of a ruptured fuel cask could be immense. A 1968 AEC study [4] states that "it is virtually impossible to design a package to survive any possible accident."

The AEC's attitude toward fast-breeder safety is that these problems—containing sodium and fission products, preventing flow blockage or sodium voiding, inhibiting fuel-pin failure propagation, controlling criticality accidents, controlling reactivity excursions, removing post-accident decay heat, preventing fuel-transport and fuel-loading accidents—are all "amendable to engineering solution" [2, p. E8]. We think this view reflects a basic error—that confusing the way things are with the way one would like them to be. This distinction is clearly drawn by Hannes Alfvén, the Swedish Nobel laureate in physics [5]:

The reactor constructors claim that they have devoted more effort to safety problems than any other technologists have. This is true. From the beginning they have paid much attention to safety and they have been remarkably clever in devising safety precautions. This is perhaps pathetic, but it is not relevant. If a problem is too difficult to solve, one cannot claim that it is solved by pointing to all the efforts made to solve it.

The technologists claim that if everything works according to their blueprints, fission energy will be a safe and very attractive solution to the energy needs of the world. This may be correct. Hence, they consider all objections to be due to "ignorance," "viciousness," "hysteria." This is not correct. The real issue is whether their blueprints will work in the real world and not only in a "technological paradise."

Accident Potential

Neither the Joint Committee nor any other human institution is able, or will ever be able, to forestall all acts of God. The needed guarantees simply cannot be given, not because it is not technically possible but because it is not humanly possible. The dozens major contractors now performing some of the tasks and subtasks for the breeder R&D program are doubtless very competent, but they are human. Human error is inevitable and with risks of magnitude—intolerable. Professor Alfvén concludes:

It is difficult to see how a satisfactory answer can be given. But if it cannot, we have to conclude that fission energy does not represent an acceptable solution to the energy problem. . . . In general, the breeders are more dangerous [than present reactors], and current plans to develop breeders should be revised [3].

The accident potential of fast breeders offers an unprecedented scope for the sort of catastrophe

averted only by good luck in such accidents as the Detroit fast reactor meltdown in 1966. The lessons of that near escape seem not to have been learned. In 1971 at the same reactor, for example, seven pints of pump lubricant were accidentally poured into primary sodium [1, p. 1199]; on May 20, 1970 at the same reactor, 200 pounds of radioactive sodium leaked out and reacted with water. As for other reactors, an industrial system in which plant drinking fountains can be accidentally connected to a radioactive waste tank [6], in which the core of a large boiling-water reactor can be twice uncovered during an uncontrolled oscillation of coolant level [7], in which common-mode failure can prevent the shutdown of a reactor during an emergency (SCRAM) [8], or in which 63 out of 191 valves can fail to operate on test [9] is plainly not perfect.

Without needing to multiply all-too-plentiful examples, we should go further than saying mistakes have been made. As the AEC staff wrote to this committee [1, p. 107]:

...the utilities, reactor plant suppliers, architect engineers, constructors, and equipment vendors... must demonstrate their capabilities to bring into operation the light water reactors prior to undertaking a more complex and difficult breeder reactor program.

ECCS Hearings

The AEC's Bethesda hearings on emergency core-cooling systems provide ample evidence that the nuclear community has not performed this task. Moreover, the Bethesda hearings must reveal to any disinterested observer a dangerous bankruptcy of the regulatory process that has not only continued to license hazardous reactors, but has tried to conceal news of the hazards from the public. An Atomic Energy Commission that can not produce safe light-water reactors has no business trying to produce fast breeder reactors, just as people who can not build safe cars should not try to build aircraft.

Largely because the AEC has not been candid about present reactor safety problems, we are unable to trust the AEC's assessment of breeder safety, even were it not to depend on human fallibility in every stage of design, construction, operation and maintenance. "Safety" rests on little empiricism. The director of the AEC's Division of Reactor Development and Technology, Milton Shaw, recently told this committee that "It is important to recognize that the information obtained from semiscale tests (and from other principal parts of the Nuclear Safety program) is not directly applicable to larger systems except through analytical models intended to describe the course of hypothetical accidents" [1, p. 1221]. The Bethesda record shows how flawed such models can be. "The analysis of postulated accidents," says the AEC, "involves numerous assumptions which are difficult to quantify" [2, p. E1026].

The AEC's public vacillations give little cause for confidence in safety estimates. Shaw assured this committee in February 1972 in the strongest terms that the Lyons, Kansas, salt mine proposed for high-level waste storage would be "completely safe" and proof against all intrusion by water [1, p. 1233]. Yet in the March-April issue of *Technology Review*, the director of the Kansas Geological Survey pointed out that the salt beds are "a bit like a piece of Swiss cheese, and the possibility for entrance and circulation of fluids is great"—a fact known since 180,000 gallons of water mysteriously disappeared down a hole the previous summer.

Elastic Standards

Recently, the AEC has decided that rupture of reactor pressure vessels is not, after all, incredible. Radiation exposure standards long held to be safe have been suddenly reduced by as much as two orders of magnitude. As reactor sizes have quadrupled in less than a decade [1, p. 1133], supposedly impossible types of fuel-rod failure have just been discovered in several working reactors, to the consternation of the industry. The AEC's notions of the safe and standards of the credible seem too elastic to be infallible.

Just as human error will always make it impossible to prevent serious accidents as fast breeders proliferate—and as necessarily less-skilled operators take over from their unsuccessful teachers—human fallibility will make it forever impossible to prevent the plutonium economy from posing a grave threat to national security and world peace. The inventory of fissile plutonium recovered from light-water reactors, if the AEC has its way, will increase in the United States from less than 1 metric ton now to 45 in 1980 [1, p. 1230], 170 in 1985 [1, p. 1234], and—with the advent of the breeder economy—to thousands of tons early in the next century. (The present price is about \$10 million per ton.) Thus within a generation we should see the basic raw material for thousands of Nagasaki-sized bombs being shipped around the country every day.

We find this a chilling prospect. We cannot comprehend how the AEC can be so naive as to rely on any system of safeguards to prevent the diversion, sometime, somewhere, of a few kilograms of plutonium to a private bomb factory [10]. Safeguards administered by mightier bodies than the AEC have failed to halt bank robberies, aircraft hijackings and the black market in heroin. The incentive to steal and sell fissile plutonium will be much higher, and so will the stakes [11].

No amount of electricity is worth the risk that some criminal maniac will be afforded dozens of chances daily to acquire the only thing he now lacks to make his own atomic bomb. This problem, like that of operating safety, has no practical solution: it may be soluble on paper, but it is not soluble by fallible men.

The third main problem in this category of "fallibility problems" restricts the development not only of breeder reactors but also of all fission technology. Unlike safety and plutonium security, however, it is first a moral problem, and is likely to be deferred because its consequences are felt less by us than by the unborn, who do not vote or own shares. We refer to the unsolved problem of high-level waste isolation—how to deal with some 150 billion curies of long-lived breeder waste three decades hence [12].

Waste Storage

The AEC's waste policy provides that wastes be solidified and placed in a federal repository, but these repositories are no more satisfactory in the long run than any other temporary solution yet proposed. As the director of the AEC's Division of Waste Management and Transportation has said: "[N]one of the suggested long-term solutions to the problem of permanent disposal of high-level radioactive waste is technically or economically feasible today" [13].

No amount of careful supervision of the burial of wastes will help if there is no place to bury them. Many thoughtful scientists now question the wisdom of creating wastes genetically dangerous on a time-scale on which human institutions are fragile. Nor will fallible men ever be able to guarantee that a given method of storage is absolutely safe for the needed millennia. The problem is one of which we have had no experience, and no responsible geologist, however expert, will ever be able to give the sort of guarantee required.

Even the low-plutonium wastes from light-water reactors are intractable if one operates enough reactors. In 30 years, the inventory of cesium-137 from such reactors will, on AEC projections, be about 15 billion curies. The International Commission on Radiological Protection limiting body burden for this isotope is 0.3 millionths of a curie (for the general population). Thus if only one part in 100 million of the accumulated cesium-137 escaped and were evenly distributed, it would suffice to meet the limiting body burden for an entire U.S. population of 300 million. In 100 years, the cesium-137's activity would have lessened by only a factor of ten.

Unacceptable Risks

If any of the three concerns we have voiced is valid—and we think there is a widespread feeling in the independent scientific community that all three are valid—then it follows that the social risks of the breeder economy are unacceptable and cannot be incurred. The AEC has evaded honest discussion of these three problems, assuring us instead that all are or will be solved—but providing no evidence of it. We can no longer take such bland assurances on faith, and this committee should not

do so either. We are sure that if this committee's faith in the AEC proves stronger than its desire to protect the public interest, its statements and voting record will be very critically examined when the faults of the AEC's schizophrenic regulatory-cum-promotional process lead to their logical conclusion.

Breeder Economics

The economic justification for committing the United States to this program—to a capital investment of several billion dollars now and some half a trillion dollars over the next three decades—appears to rest in the two so-called "cost-benefit analyses" prepared by the AEC [14]. Cost-benefit analysis is a complex and often useful science whose rigorous criteria, unfortunately, these studies do not satisfy. They seem, as the Council on Environmental Quality said of NEPA's impact statements, to have been "written to justify decisions already made, rather than to provide a mechanism for critical review. Consideration of alternatives often is inadequate."

We urge this committee to subject the AEC calculations to critical independent examination before relying on documents that are a waste of the taxpayers' money and the reader's time. The more glaring deficiencies of the AEC "analyses" include the use of a 7 per cent discount rate rather than the standard 10 per cent, thus inflating the "benefits" by a factor of four (indeed, an interest rate well over 10 per cent would be more appropriate for a speculative project); ignoring most environmental and some safety costs; ignoring accidents; and underestimating capital costs. Sensitivity analysis is grossly inadequate.

More generally, it is an abuse of economics to pretend to do a cost-benefit analysis for any technology 50 years ahead, even a well-known technology; with a technology that does not yet exist, the exercise can only be called fraudulent.

Fuel Shortage

A reason commonly given for a crash program to develop fast breeder reactors is an imminent shortage of sufficiently cheap uranium. But the price of electricity from light-water reactors would rise only about 0.075 mills per kilowatt hour for each \$1/lb rise in the price of yellowcake. This effect is so small, especially in the light of uncertainties about capital costs, for example, that utilities could tolerate a very considerable rise in the uranium price, perhaps a factor of three to ten. If this is not true—if nuclear utilities will go out of business (due to the competition of coal) if they have to pay more than \$10/lb for their yellowcake—they will also go out of business if they ever have to bear any of the external (i.e., larcenous) costs that society now covers for them, such as the cost of uranium miners' lung cancer, of disposing of mill or reprocessing wastes, of isolating high-level

wastes, of somatic damage, of insurance against nuclear accidents, or of paying for their own R&D or capital support. So heavy are these hidden and seemingly perpetual subsidies that it is at best disingenuous of the AEC to suggest that "development of nuclear power has taken place in the highly competitive utility market place" [1, p. 1094]. But for its many extraordinary privileges, nuclear power would never have got off the ground—a fact of which those who pay the bills should be more aware.

Uranium Scare

The AEC's uranium scare does not appear to be wholehearted nor of long standing, and is contradicted by optimism in the uranium industry. As former AEC chairman Glenn T. Seaborg pointed out [15]:

The full extent of our uranium resources is not yet well known. Exploration has been under way for only about 25 years, and resources are increasing as exploration continues.

It is unfortunate that most AEC estimates of reserves merely extrapolate past production rather than using the estimation techniques standard in economic geology. The results of this error are especially misleading because the domestic uranium market is so soft that producers are seldom bothering to prove suspected reserves. Elementary calculations tend not to support the AEC's claims that we need breeders now to avoid "the economic penalty of utilizing our lower grade uranium ores in the LWR fuel cycle" [2, p. E1121]—or at least they suggest that it is far cheaper to live with the "penalty."

Perhaps the most fundamental flaw in the AEC's cost-benefit analyses, if not in its entire program "to maximize exploitation of the energy latent in nuclear sources" [16], is its naive acceptance of projections showing continued rapid exponential growth in electric demand. As far as we can determine, the AEC has not made much of an effort to study critically who is supposed to use all this electricity for what purposes. The AEC's defense [2, p. E1117] to this charge is:

Increased usage of electricity has been projected in studies not only by the electric utility industry but also by industry associations (i.e., the same sources) and government agencies (viz. the FPC, a breeder-booster which essentially collated utility forecasts). . . . The AEC accepts as authoritative the consensus of the independent (sic) power projections developed by Federal agencies having that responsibility. The AEC, by developing technical options, is helping to meet these projected power requirements.

This buck-passing is lazy and unsatisfactory. We should like to propose to this committee the thesis—commonplace to physicists, though perhaps heretical to utilities—that our use of energy in this Nation is profligate; that such an energy crisis as we may have is one not of undersupply but of misdirection; that we certainly do not need 4 or 8 times as much energy (or electricity); and that if we had the political will to use our present technical know-

ledge, we could do a great deal more with less energy.

This is not the occasion to propose all the elements of a rational power policy. Yet we are dismayed to note that the AEC seems unable to supply a single reference to any study describing how to use less energy [2, p. E1109], even though at least two excellent papers [17] on the subject from Oak Ridge National Laboratory have appeared. The AEC does sympathetically admit [2, p. E904], however, that other agencies are now studying the subject in accordance with the thinking of "concerned citizens."

Each of the ORNL papers proposes workable ways to reduce our national energy budget substantially without reducing our standard of living. We hope such research will lessen the tendency of this committee to accept endless projected doublings with such facile remarks [1, p. 1209] as:

. . . the tremendous increase in the consumption of electrical energy relates to our total economy and to jobs in that economy. . . .

Or with the demonstrably false remark that the extra energy will be needed for recycling and various anti-pollution measures.

We propose instead a more careful attention to the distinction between demand and need, to the impact of promotional rates and practices, and to the logic of two remarks made recently to this committee by Shaw [1, pp. 1070, 1212]:

People have to think twice before they commit themselves to rapid electrical power growth.

The resolution of an imbalance between supply and demand requires either an increase in supply or a reduction in demand.

An Insane View

We believe that most projections of electrical growth, including those used by the AEC, reflect a fundamentally insane view of the role of energy in society, and cannot be met either in supply or in demand. This committee may wish to study the British example: the new chairman of the Central Electricity Generating Board (CEGB) astounded the Select Committee on Science and Technology in August 1972 by stating that the CEGB now expects U.K. electric demand to rise by only 3.5 to 5.0 per cent per year over the next decade, several percentage points lower than previously forecast. This change, mainly reflecting unexpected saturations, naturally upsets all sensitive cost-benefit studies.

We have suggested that nuclear fission is a dead-end technology in which we should cut our losses. It is a fair question what we should do instead, bearing in mind "the many unknowns concerning both the needs of this country . . . and the various options for best fulfilling those needs" [2, p. E754].

Other Energy Sources

Shaw has testified to this committee that "the scientific community is split" over alternative energy sources [1, p. 1106]. We think most of the split is between the AEC's employees and clients and others concerned with energy problems.

Here is the consensus as it looks from outside the AEC:

- We should devote at least as much effort to finding ways of using and wasting less energy as we should to finding more.

- Centralized electrification is inherently inefficient and should be discouraged wherever it is not essential.

- Nuclear fusion is worth an urgent close look. If activation products and tritium do not prove insuperable problems, fusion would probably be far preferable to fission. At least one of the several approaches now being made to controlled fusion will very probably succeed if we spend enough money on it. As Seaborg notes [15]:

As a result of successes of the past few years, scientists are now quite confident about their ability to achieve adequate confinement . . . and . . . temperatures. . . . [R]ecent progress in this program suggests that the scientific feasibility of [fusion] . . . may be demonstrated in the 1970s. The potential advantages of fusion power in terms of fuel reserves, compatibility with environmental quality, and technological applications are so impressive that the . . . Program should proceed as rapidly as technological progress permits.

We have, however, two reservations about fusion: First, one cannot guess, very convincingly, at its environmental impact until it is reduced to practice. Second, if fusion turns out to be fairly clean, it would certainly not teach us a needed discipline in the use of energy. The political problems inherent in trying not to discover global heat-limits empirically might prove insuperable. That said, if fusion is used, it is conceivable technically (though perhaps not politically) that its technology might be widely disseminated; and that the availability of the fuel to all nations equally, assuming they are given deuterium-extraction plants too, could help to remove a major source of tension in the world. Whether the rich countries would want to do that is another matter.

- Solar power is already exploitable on a small scale—and there are advantages to decentralized energy conversion—but large-scale photothermal conversion is still in the engineering stage. It can certainly be done; the question is how much it will cost. High capital cost may be offset in large part by free fuel, partly free distribution, and very low running and environmental costs. The AEC staff has told this committee [1, pp. 1089, 1093, 1100]:

There are a number of identified developmental areas that could be worked on if a sufficient priority were established. . . . [P]ossible improvements in solar cell performance and production techniques appear to be worthy of investigation. . . . Study of the economic trade-offs for [modular solar heat collectors] . . . appear[s] worthwhile. . . . [Such collectors, hooked to the steam cycle of a coal plant, could under reasonable engineering assumptions] produce power on a par with a coal plant.

In view of the apparently legitimate protests of most solar energy researchers that they are being starved for funds, the AEC position cited above is hard to reconcile with this statement [1, p. 1411]:

. . . in our opinion the [proposed] authorization of \$15 million for solar energy research and development is premature. We believe that priorities for energy research

and development programs should first be evaluated by the Commission, and by other interested agencies within the executive branch; and that the amounts authorized for such programs should generally accord with the views of these agencies as to the nature and level of effort of such work as they consider could be advantageously undertaken.

The land requirements of large-scale solar conversion are not excessive when compared with those of prolonged strip-mining. We should like to see a far heavier commitment to solar energy R&D—a technology we know will work, and to which we need to apply the ingenuity (and skill in liquid-metal engineering) now being wasted on fast breeders.

Even if solar power turned out to have a high capital cost reflected in higher energy prices, energy is now very inexpensive and should be far more costly. We could absorb a very substantial increase in energy price with little impact on the total economy.

- Geothermal power, carefully extracted, appears to be useful in certain regions, although it is not a general panacea. Much research remains to be done and should be well funded.

- Winds are locally useful on a small scale; tides and ocean currents are probably too expensive to harness; and hydropower has little room to expand.

- To get over any short-term problems, we urge the intelligent use of coal, with intensive effort to develop SO₂ and related control technologies, to refine and require reclamation techniques, and to improve underground mine safety. Strip mining should be prohibited wherever restoration is impossible; this includes most hilly areas.

There is no reason at all, save inertia, why coal should not substitute for nuclear power, which is presently only providing 3 per cent of U.S. electrical capacity. The AEC says [2, p. E906]:

Coal supplies appear to be sufficiently plentiful to provide for our electrical generation needs well beyond the next century, so that the choice between nuclear and fossil power generation will be made on economic considerations taking all costs . . . into account.

Our first line of defense against both depletion and pollution from energy conversion must be to use to the fullest what energy we have, and not to use it as wastefully as we now do. Many physicists estimate that a national energy saving of one-third or more should be attainable relatively painlessly within about a decade.

An unexpected benefit may flow from abandoning fission technology. We are not aware of any evidence that this technology, viewed as a whole and including all its capital and R&D inputs, is a net producer of energy; some evidence suggests the contrary. It is interesting that through 1970 (the last year for which we have data) there was no year in which the total electric production of all U.S. civilian nuclear power reactors exceeded the total electric consumption of the U.S. gaseous diffusion plants used to enrich uranium (both civilian and military). What kind of energy crisis is that?

We deplore a circularity that seems to govern

the AEC's choice of research priorities. The AEC wants to spend money on "promising nuclear technologies" even though its "role is not to promote one form of energy use over another" [2, p. E904]; the technologies funded most lavishly are those already furthest advanced because they have been funded best in the past; other (i.e., nonnuclear) technologies then become less well-advanced and are quietly abandoned, for

Actual deployment of any of the new energy options demonstrated and brought to the point of commercial usefulness will depend on the relative merits of each vis-a-vis other alternatives available at the time [2, p. E 756].

It is hard to see how, for example, solar technology can ever break into this sort of vicious circle unless this committee reverses its stated position on the overwhelming priority of the fast breeder. If this committee assumes, on the scantiest and least disinterested of evidence, that only fast breeders and fossil fuel can possibly be of use in this century, and if this committee then uses its considerable power to try to make that prophesy come true, then this Nation will have been deprived of fruitful options that may in the long run have ensured its survival. The public deserves a far wider choice over how their energy R&D money is to be spent than they can have from a committee that will give them any energy source as long as it is full of plutonium. A "limited, radioactive vision" is no longer good enough.

This committee's decision on fast breeders is as much a turning point for the nation as were the hearings on the two Atomic Energy Acts and on the 1965 renewal of Price-Anderson. In view of the gravity of the decision on breeders, today's hearings are premature—not only because we should not be talking about fast breeders until the 18-year-old structure of the AEC is overhauled, but also because, for no good reason we can see, this committee is participating in a needless stampede that effectively excludes public discussion of the most important issue ever to come before you.

Witnesses in this hearing should have had several months to prepare their testimony—not 16 days, which is a disservice and a discourtesy to the Nation. Notice of these hearings should have been publicized with all the machinery at this committee's disposal, not buried in a pile of press releases that very few people ever heard about. In this age of modern communication there are better ways to announce vital public hearings than relying on word of mouth.

These hearings should be recessed and reopened under conditions that the importance of their topic demands, with not token and hastily organized but very full and searching participation by a wide range of experts both within and outside the nuclear community. There seems to be an enormous rush to start building breeders at once, as though we had to be on the moon by next Wednesday; the AEC apparently thought it necessary to speed this "moonshot" on its way with a farcical and insulting

"environmental statement" that is under deserved attack today in the U.S. Court of Appeals.

But such blind haste is a silly and dangerous way to run any program. It does no credit to the promoters. We urge this committee to proceed instead with the wisdom, calm and balanced deliberation which the people of this Nation expect.

NOTES

1. Joint Committee on Atomic Energy Hearings, AEC Authorizing Legislation, FY 1973, Feb. 22-23, 1972 (Part 2, pp. 1063-1412).

2. Joint Committee on Atomic Energy Hearings, AEC Authorizing Legislation, FY 1973, Environmental Statements 1-8 (Part 5, vol. 1, pp. E1-E1143).

3. This discussion is concerned with design-basis accidents which the AEC is obliged to consider but which it considers unlikely. The hypothetical effects, however, are somewhat at variance with blanket assurances given elsewhere; for example, "[I]t is concluded that . . . the health and safety of the public would be protected from all potential radiation hazards" [2, p. E786].

4. "The Accident Experience of the USAEC in the Shipment of Radioactive Material," *Proceedings of the Second International Symposium on the Packaging and Transportation of Radioactive Material* (Washington, D.C.: AEC, 1968), p. 204.

5. Hannes Alfvén, "Energy and Environment," *Bulletin*, 28 (May 1972).

6. Atomic Energy Commission, *Reactor Operating Experiences* (ROE), 69-10.

7. ROE 71-2; compare *Nuclear Safety*, 12 (Sept.-Oct. 1971), 5.

8. ROE, 71-3.

9. ROE, 71-22.

10. AEC Division of Construction, "Directory of Shipping Containers for Radioactive Materials" (WASH-1145), October 1969; AEC Office of Safeguards and Materials Management, "Safeguards Systems Analysis of Nuclear Fuel Cycles" (WASH-1140), October 1, 1969. These reports assess the difficulty of the problem.

11. "Proceedings of AEC Symposium on Safeguards Research and Development, Los Alamos Scientific Laboratory," sponsored by AEC Office of Safeguards and Materials Management (WASH-1147), Oct. 27-29, 1969, p. 179.

12. "Siting of Fuel Reprocessing Plants and Waste Management Facilities," Oak Ridge National Laboratory, report 4451, UC-70 (1970), p. 3-58/9.

13. Frank K. Pittman, "Management of Commercial High-Level Radioactive Waste," paper presented at MIT course on Nuclear Fuel and Power Management, July 25, 1972.

14. AEC Division of Reactor Development and Technology, "Cost-Benefit Analysis of the U.S. Breeder Reactor Program," WASH-1126 (April 1969) and WASH-1184 (Jan. 1972). The Cochran report referred to is entitled "An Economic and Environmental Analysis of an Early U.S. Commitment to the Liquid Metal Fast Breeder Reactor," which is to be published by Resources for the Future. A good digest of the review draft appears in *Science*, 176 (April 28, 1972), 391.

15. Glenn T. Seaborg, Statement to U.S. Senate Committee on Interior and Insular Affairs, June 15, 1971 (serial 92-1, p. 110).

16. "Goals and Objectives of Federal Agencies in Fuels and Energy," Statement presented to U.S. Senate Committee on Interior and Insular Affairs, 1971 (serial 92-9, p. 14).

17. John C. Moyers, "The Value of Thermal Insulation in Residential Construction: Economics and the Conservation of Energy" (ORNL-NSF-EP-9), Dec. 1971; Eric Hirst, "Energy Consumption for Transportation in the U.S." (ORNL-NSF-EP-15), March 1972; Hirst, "Electric Utility Advertising and the Environment" (ORNL-NSF-EP-18), April 1972. See also the Hirst-Moyers summary paper on both transportation and space heating and cooling—testimony presented to U.S. House Subcommittee on Science, Research and Development, pursuant to hearings on energy research and development, June 1972. Harry Perry has prepared an excellent summary of many such sources: "Conservation of Energy," serial 92-18 for the U.S. Senate Committee on Interior and Insular Affairs, August 1972.

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NEWS RELEASE

Held for Thursday,
February 14, 1974.

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REPORT CONCLUDES PRESENT RADIATION
PROTECTION STANDARDS FOR
PLUTONIUM 100,000 TIMES TOO LAX
TO PROTECT PUBLIC

IN A MOVE WITH MAJOR IMPLICATIONS
FOR NUCLEAR INDUSTRY, NRDC PETITIONS
AEC AND EPA TO ESTABLISH NEW
LIMITS FOR PLUTONIUM

WASHINGTON, D.C. A report released today by the Natural Resources Defense Council concludes that existing radiation protection standards are grossly inadequate to protect the public from the high cancer risk posed by the release of plutonium from the nuclear power and weapons industries. The report recommends that current standards be lowered by a factor of 115,000.

Plutonium, perhaps the most potent respiratory carcinogen known, is produced in nuclear reactors. Atomic Energy Commission plans call for the increasing use of plutonium in the near future as reactor fuel, supplementing uranium. Total commercial production of plutonium in the United States is expected to reach 10 million pounds by the year 2000. A minute and unaccountable fraction of this inventory, an ounce and a half of plutonium, is the equivalent of 300 million lung cancer doses.

As a result of the report, the Natural Resources Defense Council (NRDC) today formally petitioned the AEC and the Environmental Protection Agency to set new radiation protection standards for plutonium that are more strict than present standards by a factor of 115,000. Both the AEC and EPA are responsible for setting standards which protect the public from radiation hazards.

*Ilene-
This may be
helpful to you.
Be sure your
attorney sees it,
particularly page 11
of the petition.
Regards -
Gus*

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The 50 page report, entitled "Radiation Protection for Hot Particles," was prepared by Drs. Arthur R. Tamplin and Thomas B. Cochran. In releasing their report, Tamplin and Cochran made the following statement:

"Our interpretation of the existing biological evidence leads us to believe that exposure to airborne particles of plutonium at the levels permitted by existing guidelines is extremely likely, indeed almost certain, to lead to lung cancer in the exposed individuals. Such exposures have occurred at the AEC's plutonium facility at Rocky Flats, Colorado. Moreover, it has been shown that the environment around the Rocky Flats facility has also been contaminated with plutonium from the facility. As a consequence members of the general public have also been exposed to this material.

"These exposures involved minute particles of plutonium oxide (PuO_2). These particles can become lodged in the deep respiratory tissue where, because they are insoluble, they remain fixed for a year or longer. During this time, they subject the surrounding lung tissue to an intense radiation dose. For this reason they are called hot particles -- that is, radiologically intense. While a single virus-sized particle of Pu-239 oxide in the lung of an average man will deliver a dose of only 0.3 millirem per year when averaged over the entire lung, the dosage to the tissue actually irradiated is 4,000,000 millirem per year. By comparison the same tissue would receive a dose of only 90 millirem due to natural background radiation. We believe that this highly non-uniform hot particle irradiation poses a unique cancer risk -- that, for the purposes of establishing radiation exposure standards for hot particles, the risk of cancer from a single hot particle in the lung should be considered equal to one chance in 2,000. As a result, we are proposing that, when hot particles are involved, the existing radiation standards governing plutonium exposure should be reduced by a factor of 115,000.

"Since 1967, two employees of the AEC, Donald P. Geesaman* and Arthur R. Tamplin have been trying through bureaucratic channels to persuade the AEC to modify their radiation standards for plutonium exposures when hot particles were involved. They argued, based upon an analysis of the existing biological data by Geesaman, that present standards were potentially very dangerous. Although the AEC has never been able to present a scientifically valid refutation of the Geesaman analysis during the intervening seven years, the agency has not moved to change its radiation standards. It would seem that the agency has been motivated largely by the hope that Geesaman was wrong - hope incidentally, that is shared by us because of the serious implications for already exposed individuals.

*Geesaman is now Associate Professor, School of Public Affairs, University of Minnesota, Minneapolis, Minnesota.

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"Nevertheless, seven years seems long enough. Since plutonium exposure is extant and since the nuclear power industry is presently expanding into plutonium recycle and promoting the fast breeder reactor, which breeds plutonium, we feel the time has long since passed when this hot particle problem can remain an unresolved issue in radiation standards."

Gus Speth, a spokesman for NRDC, said that his organization strongly opposes continuing with government plans to use plutonium as fuel in existing reactors and to develop the fast breeder reactor until the plutonium standards issue raised by the report is satisfactorily resolved. "We can't let the energy crisis blind us to the fact that plutonium poses unprecedented health risks. Simply put, plutonium is probably the most dangerous substance known. The AEC has been aware of the hot particle problem for several years, but has taken no action. And the economic impact of adequate plutonium standards has yet to be addressed. Despite these conditions, federal energy policies call for plutonium becoming a major energy resource in the near future. In light of the unresolved issues, current federal programs to commercialize plutonium are extremely premature."

Dr. Tamplin is a biophysicist presently on a one year leave of absence from the AEC's Lawrence Radiation Laboratory (LRL) in Livermore, California. In 1969, he along with his colleague at LRL, Dr. John W. Gofman, strongly criticized the AEC radiation exposure standards, saying that they were at least 10 times too high. Their critique precipitated a nationwide controversy and a two-year study by the National Academy of Sciences. The AEC subsequently reduced its exposure standard for light water reactors by a factor of 100, and the National Academy report, published in November, 1972, concluded that the existing exposure standards were unnecessarily high. Dr. Tamplin has lectured and published widely on nuclear power and radiation questions.

Dr. Cochran is a nuclear physicist who was formerly an AEC Health Physics Fellow. Before joining NRDC he spent two years as a Research Associate at Resources for the Future (RfF) in the Quality of the Environment Program. He is the author of The Liquid Metal Fast Breeder Reactor: An Economic and Environmental Critique, to be published by RfF next month.

NRDC is represented in its petition to the AEC and EPA by Anthony Z. Roisman, an environmental attorney who has represented citizen groups in several major nuclear power controversies.

NRDC is a national environmental membership organization with offices in Washington, D.C., New York, and Palo Alto, California.

Copies of Report Available

Printed copies of the Tamplin-Cochran report, "Radiation Standards for Hot Particles," are available from NRDC's Washington office for \$3.00 each.

TERRORIST THREAT SEEN

Scientist Warns of Bootleg A-Bombs

WASHINGTON (AP) — One terrorist with a softball-size supply of plutonium could build a nuclear bomb small enough to be transported in a car but deadly enough to kill tens of thousands of persons, a Senate panel was told Tuesday.

Dr. Theodore B. Taylor, a nuclear physicist, used the example to plead for tighter government safeguards on fissionable materials, especially as the United States increases production of nuclear power because of the energy shortage.

Taylor, chairman of the board of International Research and Technology Corp., said there is no evidence that plutonium has been stolen, although there have been unexplained disappearances of the material essential for a nuclear explosion.

Dr. Ralph Lapp, who was involved in the Manhattan Project for development of the atomic bomb, said some of Taylor's estimates are exaggerated.

"If it's that simple (to build a nuclear bomb) then the government

should do something about it," Lapp said.

The testimony was presented to a Senate Government Operations subcommittee which is considering a bill to reorganize the Atomic Energy Commission by transferring its developmental functions to a new Energy Research and Development Administration.

Sen. Abraham A. Ribicoff, D-Conn., subcommittee chairman, suggested it might be wise for the AEC to commission Taylor or some other expert to build such a crude atomic bomb, just to prove that it could be done.

Dr. Edward Radford of the Johns Hopkins University School of Hygiene said there is little doubt that the technology needed to build such a bomb is available in libraries.

Taylor said the information, nonnuclear materials

and equipment required to design the bomb are readily available. The explosive device could be built in a matter of weeks, he added.

Such a bomb could wipe out the U.S. Capitol or the World Trade Center in New York, he said.

The physicist said even smaller quantities of plutonium or uranium-233 could be used to kill thou-

sands simply by placing highly concentrated particles in a building's cooling system.

"The use of nuclear energy to generate electric power at rates now projected by the AEC would result in very large domestic and foreign flows of materials that can be used to make nuclear weapons," Taylor said.

*From Okla City Times or The
Daily Oklahoman, have lost
date, but think sometime in
March.*

Catch 24,400

(or, Plutonium Is My Favorite Element)

Roger Rapoport

There was a familiar ring to the fire alarm that sounded at 2:29 p.m. on May 11, 1969 at the Atomic Energy Commission (AEC) Rocky Flats plant, 16 miles upwind of central Denver. It signaled the latest in a series of over 200 fires that have occurred since the plant opened in 1953. But to hear the AEC tell it, Rocky Flats, which has the dangerous assignment of fabricating plutonium into nuclear triggers for hydrogen bombs and warheads, has built up an enviable safety record. Denverites who expressed concern about this latest accident were given a soothing, if somewhat evasive, official reply: "Rocky Flats ranks first in AEC facilities for safety and holds the fourth best all-time mark in American industry—2122 consecutive days (24,295,542 man-hours) without a disabling injury."

But all the press releases and National Safety Council plaques in Colorado didn't prevent plutonium from igniting spontaneously in the main production area on May 11. The flames leapt up inside the maze of glove boxes where plutonium is fabricated into parts for nuclear weapons. Tons of cellulose laminate shielding in the glove boxes fed the blaze, and it was nearly three hours before firemen brought the fire under control.

Days later Dow Chemical Co., which operates the plant for the AEC, reported that the fire had done \$45 million worth of damage and burned \$20 million worth of plutonium, enough to build about

Catch 24,400 (or, Plutonium Is My Favorite Element)

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77 Nagasaki-size atom bombs. But Dow and the AEC reassured increasingly nervous Colorado residents that no radiation had escaped from the safeguarded and specially constructed plant. Brandishing data compiled by the Colorado Department of Public Health and the U.S. Public Health Service, AEC spokesmen declared: "No appreciable amount of plutonium escaped from the building and no offsite contamination resulted from the fire."

This was supposed to be the last word. But for the over one million residents of Denver, it was the beginning of membership in the official AEC fairyland where accidents are infrequent, casualties unusual, pollution a forbidden word, and the graveyards carefully hidden from public view.

Since 1944 there have been 142 recorded atomic science fatalities, and cautious public health officials predict another 400 to 900 victims within the next 20 years. The conservatism in this estimate is clear when the facts are considered. In western towns, for instance, hundreds of thousands of tons of radioactive uranium mill wastes have been used as fill for construction sites and the radiation levels in some of the houses built on top of this waste are so high that residents are now being evacuated. AEC-sanctioned nuclear enterprises have contaminated the Colorado River, Lake Mead and the Great Salt Lake with radium; they have dumped radio-iodine into the Columbia River and released fission gases in Puerto Rico. They have seriously elevated iodine 131 levels in Utah milk and killed off deer and fish near Buffalo. And now two top experts predict that what the AEC regards as "allowable levels of radiation" could lead to as many as 32,000 extra cancer victims a year.

There are many reasons for this criminal irresponsibility. Most obvious is the fact that the AEC and its allies in industry have totalitarianized their hold over nuclear power. They probably have more freedom to pollute than any other power structure in the country. The AEC finances, licenses, regulates and polices itself. Other governmental agencies involved in the sampling or monitoring of radiation pollution are often forced to rely on inadequate AEC data, or are themselves funded (and controlled) by the AEC. Consultants for the atomic energy industry who work under AEC research grants crop up time and again as prime congressional witnesses proclaiming radiation is virtually harmless if kept below

*From
Ego-Catastrophe
ed. Ramparts May
San Fran. 1971*

V.8-46

Photograph by Carl Iwaski

he so-called "safe-threshold." And although atomic power reactors are so dangerous that insurance companies will not cover them (the public, through Congress, pays for \$500 million worth of insurance on each plant), when a state agency tries to set tough radiation standards for proposed nuclear power plants in its area, it is immediately sued by the AEC.

Not only does the AEC control the scientific talent involved in atomic power, it also determines which information about its activities reaches the public. It covers up mistakes with national security blankets, and suppresses reports, scientists and employees critical of its failures. Most Americans believe that there is no such thing as radiation pollution. In fact, many of the new environmentalists are little more than vaguely aware of this, the ultimate pollution. Look at the official Handbook for the Environmental Teach-In: more than 50 articles, over 360 pages, and not a single study of radiation hazards.

A catalogue of the environmental crises we face is dangerously incomplete without inclusion of the AEC and radiation pollution. Atomic energy, in fact, is the conservation issue stripped bare of the premature optimism some people now feel about our ability to stop

ecological damage. In the closed society that the AEC rules with an iron hand, there is no pretense of outside control.

Under the AEC's system of self-scrutiny, nuclear installations are free to contaminate both their workers and the public. The experience at Rocky Flats makes this clear. During the years the Colorado nuclear weapons production complex was being hailed as the safest of AEC plants, many workers there were being overexposed to plutonium. Plant officials refuse to say how many have died of cancer, but medical journal articles written by scientists employed at Rocky Flats admit that 325 workmen have been contaminated by radiation over the years. Between June 14, 1957 and October 28, 1958, there were 24 explosions, fires, plutonium spills and contamination incidents at the plant. According to congressional testimony, radioactive contamination has been found in the cafeteria, drinking fountains, sinks, laundered caps, shoes, drums, flasks, carts, lifts and saws—all these in the supposedly "cold" (non-radioactive) areas of the plant.

As in the case of the Santa Barbara oil disaster, technology to deal with accidents is almost non-existent. The AEC's solutions to the pollution it creates are almost pathetically inept. In 1968, for instance, a quantity of oil that had been contaminated by plutonium was scooped up, placed in a drum and trucked off from Rocky Flats to the official AEC burial grounds. En route, however, the drum began to leak, contaminating over a mile of highway. The AEC's solution was to repave the road. Unfortunately, plutonium's half-life of 24,400 years is a good deal longer than the full-life of asphalt, and many years from now, when the roadbed wears away, the hot plutonium will be exposed, to contaminate unborn generations.

After the May 11 fire, local scientists affiliated with the Colorado Committee for Environmental Information (CCEI) began to be skeptical of the Dow and AEC scientists. This independent group of college professors and privately-employed scientists asked the AEC to monitor Denver area soil for possible plutonium contamination from the fire.

In August 1969, Dow-AEC refused to make the plutonium soil samples. It explained to the CCEI that technical difficulties would make such a study inconclusive. So in the fall the CCEI's Dr. Edward Martell, a nuclear chemist with the National Center for

Atmospheric Research in Boulder, began conducting his own soil samples for plutonium. This former Pentagon specialist in nuclear weapons testing concluded his work in December 1969 and announced that highly lethal plutonium oxide from Rocky Flats had definitely spread out into metropolitan Denver during the May 11 holocaust. Martell found the highest plutonium contamination in areas east and southeast of the plant toward the Denver suburbs of Broomfield, Westminster and Arvada. High levels of plutonium were also found in Great Western Reservoir, part of the Broomfield water supply. The contamination of Denver ranged from 10 to 200 times higher than plutonium fallout deposited by all atomic bomb testing. And it was nearly 1000 times higher than the amount plant spokesmen said was being emitted.

The AEC and Dow sprang into action to try to counter Martell's facts. Bearing a cloak-and-dagger air, this counter-offensive began in early December when General Edward B. Giller, assistant AEC general manager for military application, learned that Martell was making independent soil samples and ordered the Rocky Flats staff to initiate similar work. Stanley Hammond, a chemist at Rocky Flats, even contacted Martell and asked for technical advice on how to make good soil samples for plutonium. Martell not only told him how to do it but sent some of his own soil samples over to Rocky Flats. The AEC study essentially corroborated Martell's data. As General Giller puts it: "So far we find his results are accurate, we don't disagree with his new data. As far as measurements, sampling techniques and knowledge of science we think Martell is a very competent scientist. Of course we question his interpretation of the new information. While it is true that some plutonium is escaping from the plant we don't believe it presents a significant health hazard to Denver." The AEC elaborated in a later press release: "Rocky Flats... has released trace amounts of plutonium.... However, these quantities have never shown a level of radioactivity in excess of the natural background radiation."

Background radiation is a favorite AEC game. Because the plutonium oxide particles from Rocky Flats emit dangerous alpha radiation, the agency tries to compare them with naturally occurring (background) particles that also emit alpha radiation. Dr.

Arthur R. Tamplin, an expert on the physiological effects of radiation and one of the few independent AEC scientists who have dared publicly to question the organization's dangerous nuclear mythology, explains what this means for Denver: "The Martell study shows about one trillion pure plutonium oxide particles [plutonium oxidizes in a fire] have escaped from Rocky Flats. These are very hot particles. You may only have to inhale 300 of them to double your risk of lung cancer. Inhaled plutonium oxide produces very intense alpha radiation dosage to lung tissue, thousands of times higher than the intensity for radioactive fallout particles and millions of times more intense than the dose from natural alpha radioactivity. An inhaled plutonium oxide particle stays in your lungs for an average of two years, emitting radiation that can destroy lung tissue. If the plutonium from the May 11 fire is being redistributed as Martell suggests, then it could increase the lung cancer rate for Denver by as much as 10 per cent. This could lead to as many as 2000 additional lung cancers in Denver."

Although Dr. Martell has already found a terrifying quantity of plutonium in Denver, he believes far more remains to be discovered. The Boulder scientist based his report on about 90 soil samples but believes hundreds more are necessary for a comprehensive insight into the extent of the contamination. He has urged that the federal government, independent of the AEC, launch a comprehensive soil sampling program in the Denver area.

Both federal and state agencies finally heeded Martell's call for a review of Rocky Flats, but their studies are neither comprehensive nor independent. President Nixon's top scientific advisory group, the Office of Science and Technology (OST), says it is now making an "independent analysis" of Rocky Flats contamination. Two AEC scientists from the agency's health and safety laboratory in New York have been taking 25 soil samples from sites in and around the plant. Results of these samples will be submitted to Dr. Hubert Heffner, deputy director of the OST, who says, "We have been assured [by the AEC] that this will be a comprehensive [sampling] program." Dr. Heffner plans to compare the AEC data with Martell's report and decide who is "more nearly right" in his measurements of contamination. While stating that he will not judge the

case until all the data is in, Dr. Heffner declares, "My supposition is that the health consequences created by the plant are not severe."

A second independent study of Rocky Flats contamination is being conducted by the Colorado State Department of Health. The agency collected soil samples at 25 locations around Rocky Flats and sent them to the U.S. Public Health Service (USPHS) Southwestern Radiological Health Laboratory for analysis. The Las Vegas-based lab monitors the AEC's Nevada test site and is funded by the AEC.

Rocky Flats is not an isolated example of AEC totalitarianism. There has been bad news before, and it is always euphemized by AEC publicists capable of first-rate fiction. In the official agency booklet "USAEC—What It Is, What It Does," for example, it is claimed that, "The AEC has an impressive safety record. For example, since the beginning of the atomic energy program in 1942 there have been only seven deaths from nuclear causes among atomic energy workers in the United States." But U.S. Public Health Service studies show that 142 uranium miners have already died because of radiation overdoses ranging as much as 500 times over the safe level. And Charles C. Johnson, Jr., head of the U.S. Consumer Protection and Environmental Health Service, says, "Of the 6000 men who have been uranium miners, an estimated 600 to 1100 will die of lung cancer within the next 20 years because of radiation exposure on the job."

AEC negligence has spread the hazards of uranium mines into homes in western mill towns, allowing more than 300,000 tons of uranium mill tailings (which emit the same radon gas that has led to high incidence of lung cancer in uranium mines) to be used as construction fill in little towns like Grand Junction, Colorado. And about 60 miles northeast of Grand Junction the AEC is showcasing Project Rulison, one of its latest schemes for the peaceful use of atomic energy. In September 1969, the AEC detonated a 40-kiloton underground nuclear explosion to free natural gas deposits. But now Project Rulison is a topic of debate among Colorado citizens because when the gas is flared, tritium and other radionuclides pollute the air. However, the AEC and its ally in the project, Austral Oil Co., have even more grandiose plans: they want to dilute the

radioactive gas that was freed (but contaminated) by the blast by mixing it with uncontaminated gas; then they want to pump it into customers' homes.

The citizens around Rulison have gone into court to stop radiation pollution in their area. But even if the AEC should lose this battle, it still has the wider war to think of. For it is hoping to electrify homes and businesses with nuclear power. At the moment, about 75 American atomic power plants are planned or under construction. It is these nuclear power plants that comprise the largest hazard of radiation for the future. The 15 plants already built don't give much cause for optimism, since those in Michigan, New Jersey and Minneapolis are currently shut down due to malfunction. As far back as 1957, one of the AEC's own studies suggested that a reactor built 30 miles from the nearest city could kill 3400 people, injure 43,000 and cause \$7 billion damage in a bad accident.

The AEC has a flock of experts devoted to studying radiation hazards. One of them is Dr. Wright Langham, a ranking AEC plutonium expert at Los Alamos, New Mexico. When American bombers accidentally dropped nuclear weapons on Palomares, Spain, it was Dr. Langham who rushed in to monitor plutonium contamination; he was subsequently awarded the Pentagon's Distinguished Service Medal in 1967 for his work. In a paper written for the Department of Health, Education and Welfare in 1968 on "The Problem of Large Area Plutonium Contamination," Dr. Langham says, "Plutonium is my favorite element. . . . The reputation of plutonium as a toxic material perhaps has contributed more than any other thing to my being supported in the modest though comfortable manner to which I have grown accustomed."

Scientists who formulate radiation protection standards say that safety is not the only consideration. For example, the International Commission on Radiological Protection reported: "At the present time, risk [health] considerations can at best play only a very general role in specific recommendations . . . and operational and administrative convenience must of necessity be of equal importance."

Despite the pressures to conform, two experts have started a crusade to stop the agency's radiation pollution. Charging that

currently allowable radiation pollution could cause as many as 32,000 extra cancer deaths each year, they are calling for a ten-fold reduction in present radiation exposure limits.

The insurgent scientists, Drs. John Gofman and Arthur Tamplin of the Biomedical Division of the AEC's Lawrence Radiation Lab at Livermore, are among the nation's leading experts on the medical effects of radiation. Both Gofman and Tamplin have had a continuing interest in radiation dangers throughout their professional lives, but Gofman's concern was hard-earned and dates back to 1941 when he was a Berkeley graduate student studying under then Assistant Professor of Chemistry Glenn Seaborg.

Gofman and Seaborg co-discovered uranium 233 and the young student was assigned to demonstrate that U233 was fissionable with neutrons. Such evidence would open up the world's thorium supply as a vast new source of atomic energy. Gofman was to bombard the virgin isotope with a one-gram radium-beryllium neutron source. A gram of radium-beryllium is deadly stuff, and is moved about inside lead containers. To protect himself, Gofman went to work building a small conveyor that would transport the hot neutron source up to the U233 by remote control. But Professor Seaborg was impatient. One day he dropped by and chided Gofman for being overly concerned with safety. "The war will be over before you get any [fission] measurements this way," he said.

So Dr. Seaborg came up with a better idea. Gofman remembers being instructed to tie a rope to the radium-beryllium source and connect it to a big stick. Like a fisherman he could cast the hot neutron source across the room to the U233 where the fission test could be conducted. Seaborg left the room and Gofman did precisely what he was told. The experiment succeeded; U233 was fissionable. Seaborg went on to win the Nobel Prize and become chairman of the AEC; Gofman received a disastrous overdose of radiation, at least 100 times the permissible exposure level. So far, Gofman has fortunately not experienced any ill effects from the overexposure.

In 1963, Gofman, by then a Ph.D., M.D. and Professor of Medical Physics at Berkeley, was hired to head a new AEC biomedical lab at Livermore that would be devoted to studying radiation's effect on man and his environment. The lab was established in part

to quell growing public concern about nuclear fallout, but after the Nuclear Test Ban Treaty was signed, the concern diminished and financial support for the lab waned.

As head of the Livermore Biomedical Lab and an associate director of the Lawrence Radiation Lab, Gofman hired biophysicist Tamplin. The tall, soft-spoken scientist pioneered the standard technique for measuring nuclear test fallout patterns, and with Gofman began to question the conventional AEC wisdom. At various symposiums the two men pointed out that AEC pet projects like nuclear excavation pose a grave health risk to the public. They also countered the official AEC theory of "acceptable levels of radiation" with the linear theory of radiation exposure which says that any radiation, no matter how slight, poses risks.

Indirectly, Gofman and Tamplin's crusade received a slight lift in early 1969 from University of Pittsburgh scientist Ernest Sternglass. In a widely quoted report, Sternglass charged that nuclear test fallout has caused 400,000 prenatal and infant mortalities. The AEC immediately asked Tamplin and several of his colleagues to do a critique of Sternglass' report. Tamplin agreed and presented a paper before an AEC Livermore symposium in April 1969 that declared Sternglass had overestimated the effects of fallout. Tamplin calculated that the fallout had caused only 4000 infant and prenatal mortalities, just one per cent of Sternglass' figure.

Tamplin proceeded to write up his report as an AEC technical paper. In August 1969 Tamplin's boss, Dr. John Totter, head of the AEC's Division of Biology and Medicine, tried to persuade Tamplin to delete a section from the paper. In a phone call on August 13, Totter and Spofford English, an assistant AEC general manager, tried to persuade Tamplin to criticize Sternglass but delete his risk estimate of 4000 infant and prenatal mortalities. Even though this was a mere fraction of the Sternglass estimate, the AEC executives did not want to lend any credence whatsoever to the Pittsburgh scientist's report. When Tamplin refused to accede to the telephone pressures from Washington, Totter wrote two letters reiterating his demand.

Tamplin ignored his AEC superiors and published the complete paper as a technical document. As AEC pressure on them built up, Gofman and Tamplin decided to fight back. In a San

Photograph by Baron Wolman
 Francisco speech in late October 1969, the two scientists publicly announced their call for a ten-fold cut in allowable radiation levels. Then in mid-November they reiterated their demand before the

U.S. Senate Public Works Subcommittee on Air and Water Pollution.

In December the AEC staff in Washington issued a nine-page critique of the California scientists' call for tougher radiation standards, and said there was nothing new in the Gofman-Tamplin paper, that the data was inconclusive and the report should have been published in a respectable, refereed scientific journal before it was released to Congress (this is the line the AEC has used unsuccessfully to try to persuade Tamplin to delete his risk estimate in the Sternglass critique). On this basis the AEC concluded there was no need for an official review of radiation protection standards.

But the Federal Radiation Council, which sets the nation's radiation protection standards, disagreed with the AEC. On January 28, 1970 the Council revealed that it was initiating an unprecedented review of radiation standards, as called for by Gofman and Tamplin. Instead of honoring Gofman and Tamplin, however, the scientific establishment snubbed them. On January 30, 1970 Phillip Abelson, editor of influential *Science* magazine, co-discoverer of neptunium and a charter member of the nuclear power fan club, rejected a Gofman-Tamplin paper on the need for tighter radiation standards. Then in early February, *Science* published a three-page critique of the Gofman-Tamplin work.

Thus we see what is required to get the nuclear power structure finally dragged into position for a bit of public scrutiny. But there is no cause for immediate optimism. Those like Gofman and Tamplin fighting within the scientific establishment, and those on the outside who believe the AEC can no longer be allowed to play judge, jury and nuclear hangman, face a long, long fight. The totalitarian polluter, despite all the adverse publicity, is still far more powerful than public opinion.

If you have any doubts about how these nabobs of nuclear power work, you should check out the current scene in Denver. While a few independent scientists wait on the fringes of the disaster to count extra lung cancers produced by the plutonium catastrophe at Rocky Flats, the AEC is on the scene with millions to spend on cleanup and publicity, piping in Muzak for the men scraping plutonium off the scorched floors and reminding all that the plant is a bulwark of national defense. Over 3000 employees are glad to have

their jobs and some of them write letters to local newspapers suggesting all the talk about plutonium contamination in Denver is actually a Bolshevik scare tactic. Press releases handed out by Dow Chemical's public relations man Mike Carroll (a former FBI agent) try to soothe the public. Meanwhile, the security system (the AEC spent over \$7 million for security investigations on its employees during 1969) is used to intimidate malcontents. After a newspaper article quoted a Rocky Flats worker complaining that he had leukemia and could not get workmen's compensation from the AEC, for instance, meetings were called throughout the plant. Management spokesmen castigated the man for talking to the press, and the plant manager wrote a letter to the editor noting that the workman's brother also had cancer, a fact that made it all a problem of heredity.

Its \$45 million cleanup operation continues, and the AEC is also spending another \$75 million to double Rocky Flats production facilities. There is one thing that is clear: there will surely be a fire next time. And another after that, and still others. There are only two ways for it to end: Either the AEC's power is shut off, or the Rocky Flats area becomes a plutonium mine.

Roger Rapoport is a free-lance journalist and co-author with L. J. Kirshbaum of Is the Library Burning? (Random House, 1969, \$4.95).

M. C. Esche

V.8-52

POISONED POWER

are worse per rad absorbed in tissue than any of the radiations discussed above, possibly several times worse.

Much confusion has been generated by some so-called authorities (in AEC) concerning alpha particle radiation. These "authorities" have stated repeatedly that, since alpha particles transfer so much of their energy in such a short distance and are then stopped, it follows that alpha particles are not serious. This assumption is false. It is true that a radionuclide (emitting alpha particles) lodged on the skin cannot irradiate internal tissues, simply because no alpha particles get any deeper than the skin. But they *can* provoke skin cancer.)

Much much worse is the *inhalation* of nuclides which emit alpha particles. Once inhaled, the radionuclide can be distributed along the lining of the respiratory tract and there irradiate those cells especially prone to develop cancer. Indeed, this is the source of lung cancer induced by radioactive exposure of uranium miners, one of the truly unnecessary tragedies that has already occurred in the nuclear electricity industry.

"Hot" particles are very small dust-like particles that are made up of alpha-emitting substances. One of the prominent ones, plutonium-239, is widely heralded as the "nuclear fuel of the future." Fine particles of pure plutonium-239 oxide (formed when plutonium burns) are very intense sources of alpha particles.

HOW RADIATION FROM ATOMIC ENERGY PROGRAMS GETS TO YOU

Geesaman and Tamplin have shown that such fine particles, referred to as "hot" particles because of their extremely high alpha particle emission in a localized region may be 10 to 1000 times more effective in producing cancer than would be expected if the same number of rads were delivered in a more diffuse manner to an organ, such as the lung.

It is this "hot" particle problem associated with plutonium-239 that makes the contemplated, future, widespread use of this radionuclide as a fuel in the nuclear-electricity-generation plants such an unmitigated nightmare for mankind. Not only may the hot particles of plutonium oxide be super-cancer producers, but with a half-life for plutonium-239 of 24,000 years, such plutonium oxide can be spread about the earth, re-suspended in air, and produce lung cancers in generations of humans for 100,000 to 200,000 years.

Manufacture of plutonium-239 and its widespread use in nuclear electric power may represent man's most immoral act.

Aside from the alpha-emitting radionuclides and the "hot" particle problem, the vast majority of other radionuclides can be considered to have equivalent effects, provided one considers simply the *rads* delivered to a particular tissue.

These points are stressed because so much confusion has been generated in the public's mind concerning possible special importance of one or another particular radionuclide. The question is commonly asked, "Which radionuclide, associated with

loaded with a 1000-kilowatt reactor. Forty-seven three-hundred-mile flights, between Fort Worth, Texas, and Roswell, New Mexico, were carried out. The reactor was not used to power the plane, but just to find out some things about radiation behavior under airborne conditions.

A lot might have been learned about radiation behavior under crash conditions, too, but luckily no such thing occurred. Later on, the crashes of nuclear weapons-bearing military aircraft in Spain and Greenland provided ample data to fill our information gap on the behavior of radioactive material—and of humans—when nuclear pay loads fall from the sky.

An ill-considered and ill-fated experiment occurred on April 21, 1964, when the AEC "lost" 2.2 pounds of plutonium 238, described as a "fiendishly toxic" isotope, when a transit navigational satellite failed to go into orbit. The plutonium's function was to run the satellite's electrical systems, but because someone forgot to throw a switch, the rocket went awry. For some time nobody knew quite where it had gone. Some experts said the rocket had re-entered the atmosphere and burned up along with its nuclear pay load. But nobody actually saw the rocket re-enter, and, the Commission acknowledged, "anomalies" can sometimes occur in which metal parts reach the earth without burning up. The maximum permissible dose of plutonium 238 in the bodies of atomic workers is two billionths of a gram. For all anyone knew, enough of the stuff to reverse the Afro-Asian population explosion was mucking about the Eastern Hemisphere. Eventually, unusually strong traces of the element were detected in the upper atmosphere, indicating that the pay load had indeed vaporized. Some scientists hailed the discovery as a Good Thing because it afforded them an extraordinary opportunity to track meteorological conditions. At the same time, humanity's radiation budget, already progressing toward exhaustion, was reduced to the tune of 2.2 pounds of plutonium.

While equipping of planes and cars with nuclear reactors is still thankfully low on man's agenda for systematic self-destruction, the outfitting of ocean vessels with them is something else again. Here, near-total disregard for the resources of the sea and the welfare of the people on its shores presents a whole new dimension to the issues before us.

Although military applications of nuclear material aren't strictly germane to this book, a brief look at naval experience with atomic reactors can shed much light on the dangers of a seaborne nuclear technology.

The special functions of warships demand special reactor considerations, and these in turn present special problems, problems of containment and cooling, problems of radioactive waste control, and of course problems of shielding against military action. A power reactor operating in a ship does not possess the margin of an exclusion distance, the safe zone between it and the personnel operating it. Therefore adequate shielding of the containment vessel is a must. Yet excessive shielding adds weight, a distinct disadvantage either in a merchant or a military vessel. Leakage rates of radioactivity must be severely restricted, yet because the structure is subject to movement, there will be difficulty maintaining tightness of joints, pipes, and cables. Ventilation control, especially in a nuclear submarine, is a most important matter. The facts that naval reactors commonly use a more concentrated form of uranium fuel and that the cooling system functions by means of pressurized water present unique challenges to technologists. These facts take on new significance when we consider the potential tally of victims should a serious reactor eruption occur in a large port city. Recognizing this threat, some foreign Governments have closed their harbors to nuclear ships, or strongly protested their entry despite the most vigorous reassurances on the part of the Navy and AEC.

These reassurances have been undercut, however, by alleged instances of radiation leaks by our nuclear ships

HANFORD'S RADIOACTIVE LEAK —A "DISGRACEFUL" ACCIDENT

Under intensive investigation at Atomic Energy Commission facilities near Hanford, Wash., is leakage of 115,000 gallons of highly radioactive waste from a huge storage tank.

Dixy Lee Ray, chairman of the Atomic Energy Commission, has described the incident as "not only regrettable, but disgraceful."

The Environmental Protection Agency has sent investigators to Hanford to determine the extent of the danger—if any—to people, livestock and wildlife in the area.

The Atomic Energy Commission has issued a preliminary 129-page report on the radioactive leak. The report and other aspects of the accident are discussed in the Aug. 24, 1973, issue of "Science," the official publication of the American Association for the Advancement of Science.

Excerpts from the article in "Science," by Robert Gillette, follow:

No one knew how long tank 106-T had been leaking, or how much of its caustic, boiling contents had seeped into the sandy soil near the center of the reservation. As a matter of fact, no one was certain how much liquid

For 51 days thereafter, roughly 2,500 gallons of liquid waste had dribbled out of the steel and concrete tank each day. . . .

The AEC has methodically and deliberately disposed of far larger amounts of radioactivity in Hanford's soil over the past 25 years, and quite safely, it insists. Other high-level waste tanks have also leaked. . . . But the leak in 106-T was something different. It was the largest single accidental release of radioactive waste in the Commission's history. . . .

Whether anyone is actually imperiled is a matter of dispute. AEC Commissioner Clarence E. Larson says that he's "distressed at implications that large masses of people are endangered." As evidence to the contrary, he notes that radioactivity in the Columbia River downstream from Hanford is less than half that in the Potomac River.

Nemzek [Thomas A. Nemzek, general manager of the AEC facility] contends that no high-level waste has ever reached groundwater at Hanford, and he adds that, even if all the waste stored at Hanford did somehow escape and reach groundwater, radioactivity in the Columbia River would still remain within drinking-water standards. . . .

More to the point is what the incident reveals about the keenness of the AEC's vigilance over the nation's vast and expanding store of nuclear-processing wastes, 75 per cent of which are stored at Hanford. Is the AEC really prepared to manage thousands of pounds of nuclear wastes that civilian nuclear power plants will be generating in the years ahead?

And how, exactly, could it lose the equivalent of a railroad tank car full of radioactive liquid hot enough

to boil itself for years on end and knock a Geiger counter off scale at a hundred paces?

Atlantic Richfield Company has made this statement:

Atlantic Richfield Hanford Company has taken appropriate steps to prevent recurrence of such an incident. . . . Procedures and policies have been given critical review and revised. . . . Disciplinary action has been taken where warranted.

Tanks under construction at Hanford, Wash.

had been in the tank in the first place. . . .

It was only around noon on Saturday, 9 June, that federal authorities and ARHCO technicians began to grasp the magnitude of the problem. [ARHCO is the Atlantic Richfield Hanford Company, AEC contractor for storage facilities at Hanford.]

Picking through what recent records they could find of the leaking tank's contents . . . technicians calculated that the seepage had begun "on or about" 20 April.

[continued from preceding page]

cause the storage tanks are 20 to 30 years old. Corrosion was cited as the probable cause of the most recent spills.

Other spills of radioactive waste have taken place at the Atomic Energy Commission's installation near Savannah River, S. C.

Low-level radiation wastes have leaked from drums at the National Reactor Testing Station near Idaho Falls, Ida., and radioactivity has been detected in groundwater in that area.

In addition to storage at the three Government installations, radioactive materials are being held at six privately owned sites. These are situated at Richland, Wash.; Beatty, Nev.; West Valley, N. Y.; Sheffield, Ill.; Morehead, Ky., and Barnwell, S. C.

Rules of the Atomic Energy Commission provide that radioactive waste must be reduced to a solid within five years after last use and be delivered to the Commission for permanent storage in 10 years.

Reprocessing 1 metric ton of spent fuel from an atomic power plant produces about 400 gallons of high-level waste. This will reduce to 2 cubic feet of solid matter, weighing about 200 pounds.

Government experts predict that all high-radiation waste accumulated in the U. S. by the year 2010—when reduced to solid form—could be stored safely on a 10-acre surface plot. It is proving difficult, however, to find an underground storage area where the waste material can be safely held for the centuries it remains radioactive.

Salt mines near Lyons, Kans., were considered, but the discovery of vent holes and the possibility of flooding from adjacent mines caused the project to be abandoned.

Now authorities are studying salt beds near Carlsbad, N. M., for possible long-term storage. Also under study is the AEC's Nevada test site. The earliest date any new holding facility can be ready is 1981, according to the Atomic Energy Commission.

Atomic time bomb. Meanwhile, the growing mass of radioactive waste in the U. S. is being likened to a sort of time bomb—not one that would explode like the first A-bomb dropped on Hiroshima in 1945, but one that holds immense potential for serious trouble as it is shipped and stored across the nation.

Nobody argues with the theoretical hazard presented by the used nuclear material.

The disagreement between the Atomic Energy Commission and its critics centers on just how much real danger exists right now—and what to do about it.

GOODBYE, COLORADO 2.

any danger of the triggers blowing up; it's that in making them the plant keeps experiencing plutonium fires. According to Dr. Peter Metzger, a Boulder citizen-activist who recounts their history in his book *The Atomic Establishment*, there have been over 200 spontaneously ignited fires at the Rocky Flats plant in recent years. The biggest one, in May 1969, was the most expensive accident in American industrial history, destroying more than \$50 million worth of delicate equipment. Over a year later, Gen. E. B. Giller, director of the AEC's Division of Military Applications, admitted the fire had been "a near catastrophe." Had it burned through the plant roof, Giller testified (it very nearly did), "hundreds of square miles could be involved in radiation exposure and involve clean-ups at an astronomical cost."

Harpers Apr. 74

1.
The result is the nation's highest level of carbon-monoxide pollution.

Denver has other potential dangers, too, such as the Pentagon's Rocky Mountain Arsenal, which covers twenty-five square miles on the city's northeast side immediately adjacent to Stapleton International Airport. As NBC News pointed out last spring, more than 2,000 GB nerve-gas bombs are stored there *aboveground*, near the airport's north-south flight pattern. Since the NBC report, it has been disclosed that bulk tanks of GB are also stored aboveground at the arsenal, and rumors persist that an even more powerful nerve gas, called CX, is stored there, too.

Denver is also graced with the presence of the Atomic Energy Commission in what is possibly its most grotesque incarnation anywhere in America—the Rocky Flats Nuclear Assembly Plant, operated for the AEC by the Dow Chemical Company. The Rocky Flats plant makes atomic-bomb triggering devices for thermonuclear warheads, just nine miles upwind of Denver and only four miles upwind of Arvada, Westminster, Broomfield, and other proliferating Denver suburbs. It's not that there's

Law Group Calls for Far Stricter Safe

By ANTHONY RIPLEY
Special to The New York Times

WASHINGTON, Feb. 16—In a move with major implications for the nation's nuclear energy program, the National Resources Defense Council has called for a drastic tightening of regulations dealing with the radioactive element plutonium.

Present Atomic Energy Commission standards to protect the public health from plutonium radiation hazards should be 115,000 times more stringent, the public interest law group has recommended in petitions to the commission and the Environmental Protection Agency. A commission spokesman said that the reporter would be given "full and very careful consideration." There was no immediate comment from the environmental agency.

Plutonium, which spontaneously catches fire if not properly preserved, has been described as "fiendishly toxic" by some scientists. One of its co-discoverers, Dr. Glenn T. Seaborg, former chairman of the commission, has said he does not disagree with that description.

Viewed as Energy Key

However, Dr. Seaborg and his successors at the commission believe it holds the key to the nation's future energy supplies and can be safely contained and used in nuclear power plants.

The commission spokesman said, "At this time, outside the national defense program, there is very little plutonium in use but in the coming decade it is expected that its use will increase. It is appropriate and reasonable that we continually re-examine the standards."

The present standards, called "maximum permissible lung dose" and "maximum permissible concentrations in air," were set in 1949 by the International Council on Radiological Protection and were adopted by the United States.

Unlike many other radiation standards, plutonium standards have not changed. Others have been made much more stringent.

The current standard, or guideline for marking off when there may be a danger arising from radiation, is credibly small already. It is 16-billionths of a curie for those working in the nuclear industry. A curie is a basic unit for measuring radioactivity.

New Generation

The present generation of

nuclear reactors in the United States is fueled with uranium and cooled by water. Still in a \$6.1-billion development program, of the commission is the next generation, liquid-sodium-cooled uranium reactors that are designed to "breed" plutonium as well as generate electricity.

This plutonium, according to the commission, is to be used eventually as a basic reactor fuel. Its present use is in atomic bombs and as atomic bomb triggers for larger hydrogen bombs. The hydrogen bomb effect, called nuclear fusion,

has been created only outside laboratories in uncontrolled reactions in the presence of the heat and pressure generated by an atomic-bomb triggering explosion.

Very tiny particles inhaled into the lungs emit heavy radiation to the sensitive tissues. Plutonium 239, a stable isotope of plutonium, remains heavily radioactive for ten of thousands of years without substantially decaying.

The study of which the resources council's petition was based described plutonium as

THE NEW YORK TIMES, SUNDAY, FEBRUARY 17, 1974

Guards on Radiation From Plutonium

"one of the most potent cancer producing agents known to man." It was prepared by former A.E.C. biophysicist, Dr. Arthur R. Tamplin, and a nuclear physicist, Dr. Thomas B. Cochran.

Led Successful Fight

Dr. Tamplin, who helped lead a successful two-year fight to tighten other commission radiation standards, said that the plutonium problems had been recognized by the commission and had been the subject of experiments and studies over the years.

"It's time they stopped cutting bait and started fishing on this problem," he said. "We hope they will seriously address this problem and see if they can handle it."

The study on which the regulations for radiation levels standards "practical" and said they could be "installed now" before the nation began the use of a breeder reactor.

The result of tightening standards would be to increase greatly the care with which plutonium is handled, and thus

increase costs of building and operating the breeders.

Dr. Tamplin said that the aim was not to "price reactors out of business but protect public health."

He added, "We would hope we would not get into polemic dialogue which has no place."

Dr. Tamplin's earlier struggle to revise radiation standards, carried out with Dr. John W. Gofman, another former commission scientist, touched off a furious and often bitter struggle with the commission and the nuclear industry.

PLUTONIUM AND THE ENERGY DECISION

DONALD P. GEESAMAN

"In the final analysis the present generation of light water reactors is a technological cul de sac, with little relevance to a solution of the ultimate energy problem. This technology is probably no more than a final offering at the altar of exponential growth of electric power. The future and the substance of the fission program is the breeder reactor, and the representative fuel of the breeder is plutonium." Donald P. Geesaman is a physicist who has been associated with John W. Golman and Arthur R. Tamplin for the last four years.

In our social climate of aggressive change, technology has evolved to a special station. As a catalyst of change, technology has become a basic implement of economic and political power. As a consequence, technological decisions are made on the limited social and physical scales dictated by specific economic and political responsibilities. This decoupling of decision from the complete world is the indulgence of a society that is socially diffuse and physically unconfined. It is an indulgence that can no longer be sustained.

The premium value placed by our society on growth and innovation manifests itself in a promotional attitude towards technology. Within this bias, benefits are regarded with indelicate optimism, and detriments as the hobgoblins of small minds. In the absence of any effective institution of contrary bias, the promoter's influence has become the dominant and hence the characteristic influence in our society's attitude toward technology. This situation deprives society of an overall appreciation of alternatives and implications, and hence, in the largest sense, is not beneficial.

Technology has conferred upon our society a way of life. Society is now vaguely coming to realize

that something must be done to assure that this way of life is acceptable and sustainable. If these expectations are to be realized, then decisional decoupling and promotional bias must be recognized as defects in the present relationship between society and technology. The energy crisis, the reactor controversy and, more specifically, the proposed plutonium economy of the future are representative of this problem. It is in this context that they will be considered.

The present energy crisis in this country is largely confined to the electrical sector of the energy market. During this century the electric utility industry has enjoyed an uninhibited growth through orders of magnitude. The dilemma in which this industry presently finds itself is a consequence of the intrusion of new growth limiting factors on its former economic isolation. Because of this intrusion the industry has begun to recognize the distinction between markets and needs. It is certainly true that the markets for electric power are not saturated, and to the extent that they are decoupled from the social and physical world, the markets could be expected to grow exponentially for some time to come. But it is naive to believe that saturation

tion of the markets will painlessly place the ultimate limit on the growth of the electric power industry. In fact, what the present crisis demonstrates is that physical limitations such as fuel availability, biological limitations such as air quality, and social limitations such as siting criteria are factors that intercede long before market saturation.

Recognition of this fact would be wider spread if a heavily subsidized nuclear technology had not materialized in the 1960s, and offered the possibility of bypassing these growth limiting factors. The Atomic Energy Commission and the reactor vendors promised clean, safe, cheap, abundant electrical power; and the utility industry accepted the nuclear solution to their restricted responsibilities, and in the years 1964-67, 60 reactors were purchased for some \$10 billion in an unprecedented economic commitment to a new technology. As a result of promotional bias and isolation of decision, the determination to implement this major technology was easy for society. Too easy in fact, for now when the reactor arguments are belatedly raised in a larger forum, society is faced with its own fait accompli, and technological judgement is further distorted by deep economic involvement.

Fission Cul De Sac

It has been eight years since the sale of the Oyster Creek reactor precipitated the rush to nuclear power. Some 110 commercial reactors are now completed or on order, and only now are the simplest implications of the commitment being widely appreciated. Radiation standards are being contested because of the potential increase in low level radiation exposure. The threat of major reactor accident has become aggravated as reactors have accumulated more rapidly than operating experience. The disposal of high level radioactive waste is an unsolved problem; no disposal site has been finally approved; and the practicality of large scale solidification of wastes is still undemonstrated. But reassessment of the reactor decision is awkward with so much committed, with some tens of thousands employed by the industry, with billions of dollars of reactor-funding utility bonds held by pension funds, insurance companies and foundations, and with the Federal Power Act's tradition of "greatest possible economy" as an added constraint on the production of electrical power.

In the final analysis the present generation of light water reactors is a technological *cul de sac*, with little relevance to a solution of the ultimate energy problem. This technology is probably no more than a final offering at the altar of exponential growth of electric power. The future and the substance of the fission program is the breeder reactor, and the representative fuel of the breeder is plutonium.

Plutonium is an element virtually nonexistent in the earth's natural crust; for all practical purposes it is of man's doing. It has several long-lived iso-

"There are many things about radiation exposure we do not understand, and there will continue to be uncertainties until health physics can provide a coherent theory of radiation damage. This is why some of the basic research studies of the AEC are so important. D. P. Geesaman and Tamplin have pointed out recently the problems of plutonium-239 particles and the uncertainty of the risk to a man who carries such a particle of high specific activity in his lungs." (K. Z. Morgan, Testimony presented at Hearings before Joint Committee on Atomic Energy, 91st Cong., 1970.)

topes, the most significant being plutonium-239, which because of its fissionable properties and ease of production is potentially the best of the three fission fuels. Plutonium-239 is an alpha emitter with a half-life of 24,000 years, hence its activity is undiminished within human time scales. It is 30 years since plutonium was first produced and isolated by Glenn T. Seaborg, now chairman of the AEC, and his colleagues. Until recently it was significant only as a nuclear explosive. Now, the Atomic Energy Commission is promoting it as the energy source of the not too distant future. How is this new technology to be assessed and appreciated by society? From Chairman Seaborg's "child-in-the-manger" descriptions of plutonium's origin; from romanticizations of the future, reminiscent of Jules Verne; from speculative projections of energy needs and markets to the year 2020? The more favorable side of the picture will assuredly be there; but is that enough for society or even utilities to judge by responsibly when considering the conjectured primary energy source of the future.

If the liquid metal fast breeder reactor is developed and implemented according to AEC projections, then by the year 1980 commercial plutonium production will be 30 tons annually, and in excess of 100 tons by the year 2000.

Plutonium is a fuel that is toxic beyond human experience. It is demonstrably carcinogenic to animals in microgram quantities. (Pure plutonium-239 in this amount would be roughly the size of a pollen grain.) One millionth of a gram injected intradermally in mice has caused local cancer. A similar amount injected into the blood system of dogs has induced a substantial incidence of bone cancer because of the element's affinity for bone tissue. It is fortunate that the body maintains a relatively effective barrier against the entry of plutonium into the blood system.

Under a number of probable conditions plutonium forms aerosols of micron-sized particulates. When lost into uncontrolled air these particulates can remain suspended for a significant time, and if inhaled they are preferentially deposited in the deep lung tissue, where their long residence time and high alpha activity can result in a locally in-

tense tissue exposure. The lung cancer risk associated with these radiologically unique aerosols is unknown to orders of magnitude. Present plutonium standards are certainly irrelevant and probably not conservative. Even so, the fact that under present standards, the permissible air concentrations are about one part per million billion is a commentary on plutonium's potential as a pollutant. Its insolubility and long half-life make the continuing resuspension of particulate contamination another unresolved concern of serious proportions.

Nor is plutonium contamination an academic question. In May 1969 the most costly industrial fire in history occurred in Colorado at Rocky Flats, the weapons-making plant operated for the Atomic Energy Commission by Dow Chemical. This major plutonium handling facility lies 10 miles west of Denver. A subsequent environmental study by an independent party, E. A. Martell, revealed that off site plutonium contamination was two to three orders of magnitude greater than would have been expected from measured plutonium losses in the heavily filtered air effluent of the plant. After-the-fact explanations seemed to fix the source of this anomalous contamination as wind blown plutonium that had leaked from openly stored barrels of contaminated oil. The plutonium involved in the fire was largely contained and apparently was not implicated in the off-site contamination. Nevertheless, it is hardly reassuring that consequent to this fire Congress voted a special appropriation of \$25.5 million (of a projected \$118 million) for the upgrading of "fire protection, safety and operating conditions" at Rocky Flats and similar facilities. And there is little comfort to be found in the irresponsible waste disposal practices which were revealed by the investigation after the fire. The leakage of plutonium from the contaminated oil led to an uncontrolled source of plutonium which was some orders of magnitude larger than the integrated effluent loss during the 17 years of plant operation. As a result of this source, tens to hundreds of grams of plutonium went off site, 10 miles upwind from a metropolitan area. The loss was internally unnoticed, the ultimate deposition is now speculative, as is its human significance.

Is present society so psychically stable, so civilly docile that it can have its energy addiction based on a material whose radiological toxicity is such that a few ounces might cause a million undetected and irremediable fatal injuries? A complex and sophisticated society must bear the burdens of vulnerability and constraint that are inherent in its technologies.

Implicit in the present nuclear industry is the production of fissionable material. Our transition to plutonium as a major energy source will inextricably involve our society with the large scale commercial production of a substance that is a suitable nuclear explosive. A mystique of scientific accomplishment surrounded the development of nu-

clear weapons during World War II. That mystique has become illusory. The main practical impasse to nuclear weapon manufacture was perfecting and implementing the expensive technologies for manufacture of fissionable material. Gaseous diffusion enrichment of uranium and reactor breeding of plutonium were major industrial projects in their own rights, but they are now implicit in the nuclear power industry. A reactor of even the present generation will produce some 250 kilograms of plutonium per year, and since the amount necessary for an explosive device is described by Theodore Taylor as "a few kilograms," the substantial weapon capability of one commercial reactor can be inferred.

By the year 2000 plutonium is conjectured to be a major energy source with an annual production in excess of 100 tons. Can these quantities be handled without internal subversion? Underworld involvement in the transportation industry is legendary, and theft in the industry is epidemic. University unrest is ubiquitous, radical activism is a reality. So far as accountability experience is concerned, Nuclear Materials and Equipment Corporation (NUMEC), over several years of operation, was unable to account for six per cent (100 kilograms) of the highly enriched uranium that passed through its plant; and at a recent safeguards symposium the director of the AEC's Office of Safeguards and Materials Management observed that "we have a long way to go to get into that happy land where one can measure scrap effluents, products, inputs and discards to a one per cent accuracy."

[A number of "misroutings" of special nuclear materials has occurred and these have pointed clearly to the need for enhanced safeguards to prevent loss by theft or hijacking.]

On March 5, 1969, a container of highly enriched UF-6 (uranium hexafluoride) was shipped from Portsmouth, Ohio, to Hematite, Missouri. It did not reach its destination in Missouri. The AEC, the Federal Bureau of Investigation and many individuals searched intensively. Finally, on March 19, the shipment was found in Boston.

In the same month of 1969, a shipment of highly enriched uranium destined for delivery at Frankfurt, Germany, wound up in London. In April 1970, a drum of waste containing some 70 per cent enriched uranium which was being shipped locally from one firm to another in the same California city ended up in Tijuana, Mexico. U.S. Representative Craig Hosmer of California, a member of the Congressional Joint Committee on Atomic Energy who described these incidents in a talk last year, recalled that the report on the Tijuana diversion was entitled: "Inadvertent export of special nuclear materials." Ed. Note]

When plutonium commonly exists, the possibility of theft will exist, and accountability will be diffi-

cult, and the technology needed to make an explosive device will be available in textbooks, as it is already. Finally the social price for dealing with the problem effectively may be paid for dearly by the loss of some poorly seen freedom.

Quite aside from this, if the plutonium economy is implemented in the United States, then by symmetry it will inevitably be implemented by other major powers, and the technology would be marketed in all the small and underdeveloped countries that are struggling for stability. With reactor fuel plutonium, fission weapon capabilities are only days away. This capability makes nuclear disarmament seem remote, and is part of the responsibility of accepting the nuclear economy.

Since the Eisenhower administration the exchange of peaceful nuclear technology has been a component of our foreign policy. The peaceful atom has been internationally promoted with enough effect that access to the technology is a significant factor in obtaining signatories to the Nonproliferation Treaty. Without criticizing the Treaty or its intentions, it must be recognized that the line drawn between peaceful and nonpeaceful nuclear technology may effectively define no more than an irony.

Unless fusion reactor feasibility is demonstrated in the near future, the commitment will be made to liquid metal fast breeder reactors fueled by plutonium. Since fusion reactors are presently speculative, the decision for liquid metal fast breeder reactors should be anticipated. Considering the enormous economic inertia involved in the commitment, it is imperative that the significance of the decision be symmetrically examined prior to active promotion of the industry.

In our present society, it is doubtful that this will be done. Promotional bias and isolation of decisions will preclude it. The Atomic Energy Commission, in its posture of promoter, will be functionally unable to serve also as a critical advocate for society in general. This responsibility will be outside the restricted economic sphere of utility and vendor. In this unbalanced situation uncertainties will be unnoticed and shortcomings degraded. Public, industry and government will be effectively uninformed. Unless some new institution of assessment intercedes the consideration affecting the decision will be defective. Technology is too dominant and society too restricted for such defects to be tolerable. A flawed judgement involving plutonium, and all other decisions could be irrelevant.

FISSION AND FUSION REACTORS: The Allven Memorandum

In the long run fossil fuels cannot satisfy the rising energy demand in the world. There are only three sources of energy known which are sufficiently powerful: (a) solar energy, (b) fusion energy, and (c) fission energy. The first one is completely pollution-free, the second one almost pollution-free. The third one is necessarily combined with production of large quantities of radioactive poisonous elements.

In my opinion, the dangers associated with fission energy have not received necessary attention. Whether the pollution caused by fission reactors in normal operation is below a safe level or not is a controversial matter. If a reactor goes out of control, the consequences may be terrible. Even if extreme safety precautions are taken, the large quantities of radioactive material in them constitute a permanent danger. For example, in periods of political or social unrest, sabotage against reactors may cause catastrophes. Furthermore, in a full scale fission program, the radioactive waste will soon become so enormous that a total poisoning of our planet is possible. Under such conditions safety margins, which are acceptable in other fields, are inadequate. It is not evident whether the waste problem can be solved in a satisfactory way.

If solar energy or fusion energy were available now at comparable cost no one would use fission energy (for peaceful purposes). Unfortunately this is not the case. Solar energy is available but at prohibitive cost. However, there are new interesting solar energy projects which should be examined carefully.

Concerning fusion energy, there is a general agreement that no fundamental obstacle is likely to prevent the construction of a fusion reactor, but there are a number of difficult scientific and technical problems which must be solved. There is much speculation about how much time is needed to solve these problems, but it is just as much a question of how much effort has to be spent.

In my opinion a solution of the fusion problem is less distant today than the Moon was when the Apollo project started. This means that if a national effort of the same kind as the Apollo program were made, fusion energy would be available in a comparable time. If this is achieved, the fission reactor, especially the breeder, will be of interest only as a danger which must be eliminated as soon as possible.

The views expressed here are shared by many competent physicists. They are basically different from those on which present policy is based. An important decision about the future energy policy of the United States — and of the whole world — should not be made until a thorough discussion has taken place involving advocates for all the three different alternatives for solving the energy problem. (Hannes Allven, 1970 Nobel laureate in physics, in a memorandum to Senator Mike Gravel, April 2, 1971.)

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back their own uranium and plutonium but will be taking their share of what comes from a continuous operation that runs twenty-four hours a day. Within such a framework, it would be vastly more difficult to keep accurate books on the flowing plutonium. "It's a serious matter," Judson said. "The utilities are not interested in atom identification. They're interested in money. We are interested, though. Once you've grabbed something like this, you can't let go. You're committed to a big responsibility for a long time."

John Van Hoomissen was at the Morris plant when we were there. He is based in California and is in charge of nuclear-materials management for all of General Electric. Three people under him work at Morris, counting atoms. Judson is not their boss. So if Judson, or someone under him, were to start siphoning off some plutonium, Van Hoomissen's men would not feel—they would be less likely to feel—inhibited about reporting it. A heavyset man with an appraiser's eye, Van Hoomissen seemed to take everyone present—Judson, Fine, me, Taylor—with a grain of doubt. "All sampling here is centralized in one gallery," he said. "This safeguards against someone bleeding the sampling line. That could never happen here at Morris, but I'll show you other places where it could happen, because funny little sampling lines are run in here and there, and on a given night someone could run a funny little sampling line off to a clandestine place. The thief wouldn't have to worry much about radiation. The most vulnerable place is the nitrate point, where the plutonium comes out of the pigot. We know this. We are aware of it. A reprocessing plant used to be thought of only as the place where you got your uranium back and your plutonium credits. Now it's seen as more than that. It is not an unattended problem."

The solution, as Van Hoomissen sees it, is for the plutonium to be moved rapidly out of the reprocessing plant and back into a power reactor, where it could be burned as fuel. Plutonium is more fissionable than uranium, after all. With a single exception, no plutonium is used in present commercial reactors, although the companies that own it have a great deal of it in reserve. The reason for this is that plutonium is one of the most toxic substances ever known in the world. Cobra venom is nowhere near as toxic as plutonium suspended in an aerosol. You could hold an ingot of plutonium next to your heart or brain, fearing no con-

sequences. But you can't breathe it. A thousandth of a gram of plutonium taken into the lungs as invisible specks of dust will kill anyone—a death from massive fibrosis of the lungs in a matter of hours, or at most a few days. Even a millionth of a gram is likely, eventually, to cause lung or bone cancer. Plutonium that enters the bloodstream follows the path of calcium. Settling in bones, it gives off short-range alpha particles, a form of radioactivity, and these effectively destroy the ability of bone marrow to produce white blood cells. Plutonium is rendered generally in one of three forms: metal, nitrate, oxide. The oxide is a fluffy yellow-green powder. It can be fine enough to be inhaled. The oxide is the form in which plutonium would be used as reactor fuel. Therefore, it is both difficult and dangerous to make plutonium-uranium-oxide fuel pellets and slip them into zirconium-alloy fuel rods—the process necessary for use of plutonium in power reactors. Special fuel-fabricating plants would have to be built, equipped with .03-micron absolute filters, continuous air monitors, glove boxes (workers put their hands into gloves that are in effect segments of the walls of glass boxes, and handle plutonium within), and other costly equipment, nearly all of which is unnecessary in a plant that fabricates uranium fuel. So the plutonium piles up—good fuel, but uneconomical. Plutonium is worth about ten dollars a gram, and is many times as valuable as gold. As time goes by, the utilities are building up millions of dollars' worth of plutonium in their stockpiles. Meanwhile, with ever-higher extraction costs and increasing demand, the price of uranium rises. In a present-day power reactor, only three per cent of the uranium fuel is used, because the uranium-235 fissions with unprofitable efficiency after that point. After uranium itself is reprocessed, it is supposedly enriched again and then refabricated as fuel and returned to the reactors, completing a closed circuit known as the nuclear-power fuel cycle. Actually, the isotopes U-232 and U-236 present in used reactor fuel are unwelcome in the enrichment cascades. As William Higinbotham, of Brookhaven, has put it, the U-232 and U-236 would "crap up" the uranium there. So the nuclear-power fuel cycle, much advertised for its conservational appeal, is not closed, and has never been closed. The reprocessed uranium is set aside. The uranium that goes into power reactors is new uranium. The result of all this is that two economic lines are mov-

get into the original chain reaction ready to repeat the process and produce even more plutonium. Because the fissioning plutonium puts out many extra neutrons and because there is high proportion of fertile U-238 in the reactor core, the breeder makes more plutonium than it uses up. Theoretically, the breeder can make four times better use of uranium than present-day reactors. Moreover, it can use as fertile material the two hundred thousand tons or so of leftover U-235 that has been separated from U-238 since the military weapons program began. Breeders are variously cooled with salt, sodium, helium; and they have fine set of names: the Molten-Salt Breeder Reactor, the Liquid-Metal Fast Breeder Reactor, the Gas-Cooled Fast Breeder Reactor. The Germans have one called SNEAK. The French have one called Rapsodie. They are research reactors. In July, the Soviet Union announced that it had begun commercial power production with a breeder at Shevchenko, on the Caspian Sea. Breeders as a working generation are still some time away, but when their time comes the figures for world flow of plutonium will be not so much increased as multiplied. So will the probabilities of the clandestine manufacture of atomic bombs.

Where is plutonium now—that is, plutonium owned by private companies? In greatly varying amounts, it is in Hanford, Washington; West Valley, New York; Pawling, New York; Morris, Illinois; Erwin, Tennessee; Pleasanton, California; Crescent, Oklahoma; Cheswick, Pennsylvania; Leechburg, Pennsylvania; and in transit among these places. It has ridden around the country sometimes with ordinary truck freight—linoleum, Congoleum, plutonium. New regulations forbid this. A ten-litre bottle of plutonium-nitrate solution in a birdcage—two and a half kilograms of plutonium—was shipped from Hanford to Crescent not long ago at the rear of a flatbed truck. Other cargo filled up the bed space, and the plutonium, the last thing on, was held by a single chain. It was clearly labelled "DANGER—PLUTONIUM." Generally the material goes by itself, in shipments of about fifty kilograms. Plutonium-uranium fuel pellets are made at Crescent by Kerr-McGee, and are put inside metal rods and sent back to Hanford, to the A.E.C.'s Fast Flux Test Facility—an experimental breeder reactor. Kerr-McGee handles about a thousand kilograms a year for NUMEC (Nuclear Materials and Equipment Corporation), in Le

binding Energy

30 miles from plant 366,000 people
 50 miles from plant 863,000 people

THE PLUTONIUM CHALLENGE

We challenge any scientist, independent or government employed, any appointed or elected official, federal, state or local, any employee of a utility, or any layman to produce a satisfactory explanation as to how this nation can accept a fast-breeder, plutonium based economy when the following facts about plutonium have been officially attested to.

1. The alpha radiation given off by plutonium is especially damaging to the blood-forming organs of the bones and can produce bone diseases many years later.¹
2. Plutonium may enter the body through cuts or abrasions of the skin, by being swallowed or most importantly, by inhalation.¹
3. Once in the body, plutonium is eliminated so slowly that as much as 80% of any amount taken in will still be there 50 years later.¹
4. The maximum permissible body burden, or the total amount of plutonium that can be accumulated in an adult without producing undue risk to health, has been set at 0.6 ~~microgram~~ ^{1 to 20 billionth of a gram} ~~microgram~~.¹ (A microgram is one-millionth of a gram)
5. According to the Atomic Energy Commission there will be an unavoidable loss rate of 1 to 2% in handling plutonium.²
6. The tons of plutonium to be produced by fast-breeder reactors will be transported across the nation to supply light water reactors with new fuel. These shipments will be subject to highway accidents and hijackings² and diversion for home-made bombs.³
7. Plutonium has a half-life of 24,360 years and will take 500,000 years to decay to an innocuous level.¹
8. The current plutonium inventory of 600 kilograms is projected to increase to 720,000 kilograms by the year 2000.²

1. "Plutonium," an A.E.C. publication.
2. "Science," (AAAS), April 9, 1971, pp 143-146
3. "The New Yorker," Profile, Dec. 3, 10, & 17, 1973

THE TASK FORCE
Against Nuclear Pollution
305 High Street
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ENERGY 4 fourth in a series by Jack Shepherd

THE
RADIANT
NUCLEUS

In 1970, Dr. John W. Gofman took on the Atomic Energy Commission over nuclear power. He and Dr. Arthur R. Tamplin, a colleague at the Lawrence Radiation Laboratory in Livermore, California, charged the AEC with risking "genocide" by approving dangerous levels of radioactivity from peaceful nuclear uses. Gofman and Tamplin argued that if Americans received the permissible "safe" dose of radiation set by the Federal Radiation Council and endorsed by the AEC, there might be 32,000 additional cancer deaths a year.

Dr. Gofman had worked on the entire Manhattan Project from its inception until 1944. He holds Ph.D. and M.D. degrees and has done special work in coronary heart disease. In 1965, he won a major award from the American Heart Association for research in combating heart disease, and in 1972, he shared a \$50,000 award from the Stauffer Foundation with three others for work in the field. "As I see the radiation-hazard question today," Dr. Gofman says, "cardiovascular disease, not cancer, is the biggest danger."

How did Dr. Gofman get entangled with the AEC? In 1961, after the Russians broke the moratorium on nuclear testing, the United States began a crash program of Pacific and Nevada atom bomb tests. And following tests above ground

in Nevada in 1962, the milk sampling network showed that Utah milk was being "clobbered," as Dr. Gofman puts it, with radioiodine from fallout. It was a public health scandal. Utah officials wanted to impound the milk. The Federal Radiation Council and the AEC fretted.

"This sort of thing was very bad for their image," says Dr. Gofman. "The Federal Radiation Council, in its own inimical way, got out of it by just raising the tolerance levels for radioiodine, which suddenly became safer by a factor of three. Their justification was that if they raised the tolerance, then they could say this milk that was contaminated was acceptable."

The AEC asked Dr. Gofman to help set up a long-range research project at the Lawrence lab on the impact of radionuclide release upon the biosphere.

In 1969, the AEC asked his associate at the lab, Arthur Tamplin, to analyze Dr. Ernest Sternglass' published calculations that atmospheric nuclear tests in Nevada had caused 400,000 infant deaths from fallout. While Dr. Tamplin agreed that Dr. Sternglass had raised an important question, his own calculations indicated that probably 4,000 infants died. AEC wanted Dr. Tamplin to publish his criticism of Dr. Sternglass but to tuck that 4,000 estimate in some other publication. Dr. Tamplin refused, and fighting broke out between Livermore and Washington.

Dr. Gofman's personal fight with the AEC began when he was scheduled to give a talk before the Institute for Electrical and Electronic Engineers. As he tells it, "My personal research in the lab was on low-dose radiation, chromosome injury and cancer. I began bringing up to date my own thinking on the magnitude of this cancer problem. And I realized that it had to be 20 times as big as anybody had thought. So I gave a very low-key, extremely conciliatory paper, suggesting that we of the AEC should reconsider the radiation standards with a view to tightening them at least tenfold because of the possibility of increased cancers and leukemias."

"As a result of that paper, the AEC immediately launched a vitriolic attack both on me personally and on my credibility."

Dr. Gofman began expanding his research and speaking out on radiation hazards. He and Dr. Tamplin wrote two books together. Now, Dr. Gofman has shifted from the Lawrence lab back to research and teaching in Berkeley. He continues to speak out at public hearings, and here, on nuclear power...

Gofman: Yes. And we also considered the amounts the AEC is legally allowed to give us and found that the damage would be bad. Now they say they never plan to give us the amount they're legally allowed to give. But if they really believed what they're saying, they would lower the legal amount by a great factor.

Q: Aren't we getting some natural background radiation all the time?

Gofman: The rough figure around the country for background radiation from natural sources is as high as 200 millirads in Colorado from the rocks and the higher elevation, down to 100 millirads. Natural radiation in the United States is probably responsible each year for about

18-20,000 cancers. The only thing we don't know is how to eliminate it. So we are forced to live with it.

Q: What about the cumulative effects of radiation from man-made sources?

Gofman: All of our studies are on the cumulative effects of radiation. And that cumulative issue represents the biggest uncertainty in the size of our estimate.

It works this way. We know that if you irradiate now, you don't have any effects in terms of leukemia or cancer for about five or ten years. Then the effects build up, and you get so many cases per 100,000 people per year from the irradiation. We do not know whether that radiation will last the rest of the life of that population, whether it will last for 30 years or 20 years or whatever. And that's the essence of the cumulative effect. If the radiation you get now lasts the rest of your life, then it, plus everything after it, accumulates.

Q: If that's so, then the danger from low-dose radiation...

Gofman:...Gets even worse. If it should turn out that the effect lasts the whole lifetime rather than the 30 years we estimated originally, then our numbers would go up. The 32,000 we published could reach 104,000 deaths from cancer per year for the allowable amount of radiation because of some of the unknowns in duration of effect.

When we started reporting this stuff, in October 1969, there weren't as many animal studies available. Now all those available point to a straight-line relationship between size of dose and cancer incidence. The animal data that have become available in the last two years have pushed way down into the low-dose region, and the linearity is holding up very well in every animal study.

Q: What does "pushed down" mean?

Gofman: Well, the first set of experiments available years ago compared rats that had no radiation with rats that had 50 rads. So you could say how many cancers you'd get when you had an increment of 50 rads. Since then, in addition to having the zero rads and 50, they've done a series at 40 rads and 30 rads and 20 rads, and now there are good enough numbers to show cancer at even 10 rads. And the line on the chart is straight.

The Atom Bomb Casualty Commission has published, within the last two years, evidence on the Hiroshima-Nagasaki people that proved linearity down to as low as 20 rads, which is five times lower than their other studies. In other words, it was proportional.

Did your calculations on radioactivity levels indicate that there could be radiation damage down to almost zero dosage?

Q: Then the relationship between size of radiation dose and incidence of cancer is proportional?

Gofman: Yes. There's no place along that line between rads and extra cancers per 100,000 people each year that you don't pay some price for exposure. You'll pay a price directly proportional to the dose. What the nuclear promoters hope for is that the curve looks like this: there's no effect until you get out to, say, 30 rads and then it goes up. That's what they hope for, but the evidence coming in supports the linear approach.

Q: Are these new studies saying that any increase above background radiation causes some cancers?

Gofman: Absolutely and precisely correct. That's the essence of the story.

Q: As we increase the number of nuclear power plants, will we also increase radiation doses to ourselves?

Gofman: That depends on how the engineering goes. It's true, for example, that if you have a nuclear power plant here and it emits some amount of radiation, someone 50 miles away gets a certain dose. That depends on how much the plant emits from the stack, into the water and so forth. If you now put a plant here, and here, and here, and each contributes a little, it can build up.

With longer operation, you have direct structural effects from all that gamma and neutron radiation. What if it turns out that after 3 to 4 years some weakness in the 1,000-megawatt plants shows up as the result of radiation effects on materials?

If leakages develop as a result of aging of the reactor and so forth, that man in that location may get a helluva blast when there are ten times as many plants.

The AEC has made projections that with the rapid increase in nuclear power plants up to the year 2000, when we'll have 900 or so big ones, the dose to the average person in the U.S. will be no more than it is today. But that's an average dose, not specifically for people living within range of the nuclear plants.

More important, that argument is based on the hope that the nuclear power industry can indeed contain all radioactivity at every step along the way. In other words, nuclear power is perfectly safe if radioactivity is contained perfectly.

I don't debate that question. What I put forward is this: Given equipment malfunctions, metal stress, sabotage, psychotics, construction errors, random accidents, human misjudgments, or natural events including earthquakes, are we convinced

that something that has to be contained perfectly for dozens of centuries will be?

Q: What are the dangers?

Gofman: We face two basic and dangerous problems. One is centuries long, the other hundreds of centuries.

In the centuries category, we must be concerned with strontium 90 and cesium 137. They are the prominent long-lived fission products that come from any nuclear power plant. If you operate a modern 1,000-megawatt nuclear power plant for one year, you generate the cesium 137 and strontium 90 equivalent of 1,000 Hiroshima atom bombs. That's 22 megatons of atomic fission bomb equivalent.

As a rough rule of thumb, if radioactivity has a half-life of 30 years, it takes ten half-lives to get the radioactivity down by

be carcinogenic.

This means that plutonium guardianship is not for 300 years, but for at least 240,000 years. That's longer than the recorded history of man. And the way I look at it, every bit of plutonium that escapes into the biosphere is a problem of forever on human time scales. Can you visualize an industry handling tons of plutonium, shipping it in casks on highways, and not having a few pounds get out?

Q: Does the AEC's record indicate that it can be 99.99 percent perfect?

Gofman: No. The testimony of the Consolidated National Intervenor proved that [*"Energy 3,"* ID, February 1973]. On a major level, there were accidents at the Fermi plant, Dresden II, R. E. Ginna, Rocky Flats.

Photo in San Francisco photographed by Jeff Cohen/College by George Keren

a factor of 1,000. Now strontium 90 has a half-life of 28 years, and cesium 137 has one of 30. If you think a thousandth of it isn't harmful, you've got to wait 10 times the half-life, or 300 years. So the guardianship, if you quit now, is at least 300 years—that's three centuries of vigilance.

But if you were to ask me what concerns me most about nuclear power, I would have to say plutonium.

Plutonium has a half-life of 24,400 years. And it's going to be produced in ton lots in a fully developed nuclear power industry. Roughly one-millionth of a gram, or a 30-millionth of an ounce, of plutonium is enough to produce a lung cancer. So in a pound of plutonium distributed into the biosphere, you've got enough plutonium for billions of lung-cancer cases. And that stuff can settle to the ground and get resuspended by wind over the next 10,000 years and still

There's an AEC report out now called WASH-1520, and it's a fantastic story. AEC has asked Congress for \$1.9 million to dig up plutonium at its Hanford, Washington, facility. Since World War II they buried their waste liquors from their plutonium recovery in a trench. They assumed that the soil would hold up the plutonium by ion-exchange methods. Well, now they realize that this trench, called Z-9, may have something like 200 to 400 pounds of plutonium in it. And they're worried that under certain conditions, like flooding with water, the whole trench could explode and spew plutonium into the atmosphere.

Q: Isn't such radioactive-waste storage a basic problem for the AEC?

Gofman: Yes, and they haven't solved it although they continue building up large amounts of high-level waste, in addition to large quantities of plutonium. They

were gung ho for the salt beds in Lyons, Kansas, as a dumping ground. But the American Salt Company was mining at one end of it and during one operation to flush salt up from the mine, they lost 175,000 gallons of water. AEC gave up on Lyons, but not on salt storage.

They have few alternatives. Above-ground storage tanks have leaked. The idea of burying wastes in the bedrock at the Savannah River Laboratory in South Carolina—which the National Academy of Sciences report said not to even think about—continues. It's attractive because it's cheaper than anything else.

In many respects I consider the nuclear-fuel-reprocessing plants a major problem, too. One plant gets the waste-fuel rods from about 50 power plants. Its storage tanks have even more astronomical inventories than do the nuclear power plants. I recently testified before the South Carolina legislature about the reprocessing plant in Barnwell. Barnwell will process five metric tons of spent nuclear fuel per day. The long-lived radioactive waste, after processing, will remain at Barnwell between five and ten years, assuming optimistically that some federal repository can be developed, which is very much in doubt. This radioactivity in Barnwell is about 15 times as much as all the fission-product radioactivity produced in all atmospheric weapons tests in all time by the combined testing of the U.S. and USSR. What might happen if only 1 percent of this radioactivity inventory got released to the atmosphere?

If we assume a wind of about 20 miles an hour, in 24 hours the radioactivity would reach Washington, D.C. People in the way of this radioactivity would get their yearly "allowance" in one day. In a year, they would get roughly 300 times as much, or about 50 rads. It is obvious that such exposure is unthinkable. So is evacuation of the affected areas—Washington, D.C., most of Maryland, Delaware, Virginia and West Virginia.

If the wind were blowing a little faster before the radioactivity encountered a rainstorm, it could center on Trenton, New Jersey. Then Philadelphia, New York City, most of New Jersey, eastern Pennsylvania and a fair part of southern New York State would have to be evacuated.

In any event, whichever way the wind was blowing, some 33,000 square miles of the U.S. would become uninhabitable.

Children drinking milk would receive 58.4 rads, more than 100 times the yearly "allowable" dose. Such a dose would cause

a sharp increase in cancers and leukemias. Milk from these 33,000 square miles would be *unthinkable* for drinking purposes. The loss to agriculture from this and crop contamination would be phenomenal.

After I testified, the vice president of Allied-Gulf Nuclear Services, which will operate the Barnwell plant, got up and said, "We would not disagree with Dr. Gofman at all that such a release would be catastrophic and would have terrible effects on Washington."

Q: Why go ahead with such a dangerous thing?

Gofman: Several reasons. The AEC and the nuclear industry like to consider what they call engineering problems: you go with this nozzle or valve, and what's the failure rate? They don't consider human fallibility, psychotics, sabotage—they put these in the realm of incredible because they throw engineering calculations into a cocked hat. They argue that with more money they'll design a technological fix for these problems. After all, Rome wasn't burnt in a day.

Q: But aren't they asking the American people to accept a scientific program today based on future technology?

Gofman: Precisely. And, with issues like the emergency-core-cooling system, plutonium, radioactive waste storage, asking us to bet on future engineering is, I consider, an immorality. The consequences of accidents in any of these areas are huge—a million people dead or homeless. To ask someone to bet on future engineering when these could be the consequences now is immoral.

Q: Shifting from nuclear power to something else would be difficult. We don't have alternatives now, and the nuclear program has momentum.

Gofman: Right. There's a tremendous momentum because all the energy research and development went into fission. They consider that they are ready to go. I don't. But they have tremendous push. There is \$40 billion in private money sunk in the nuclear-fission approach right now. You don't get a \$40-billion industry cranked up and then say, let's turn it off. A lot of men have put their reputations on the line in developing nuclear fission as the ideal power source.

Q: What alternatives do you see?

Gofman: I think we ought to explore several options: solar power, geothermal, magnetohydrodynamics. Synthetic gas could extend our coal supply. In the last two years, the number of concrete, hard-nosed proposals with engineering and

scientific backup for solar power have matured so rapidly that we may get \$13 million—a pittance compared to nuclear—for various solar projects.

The basic problem is replacing a working, but intolerable, source of power with an experimental, but environmentally sound, source of power. It's going to take publicity, a shift of priorities and money.

A number of engineers now agree that we could have demonstration solar plants in five years and shift most of our economy over to solar in 10 to 20 years.

Q: David Freeman, in "Energy 1" (ID, December 1972), said that AEC scientists inside really want to work on other energy forms.

Gofman: That's true. I know Livermore would love to unleash some of its scientists on solar power. But the unleashing would have to be done in a way that really makes them feel they aren't under a bureaucracy that's going to trample them if they work freely.

Q: Until then we've got nuclear power. Is anyone now studying nuclear-power-plant workers and radiation?

Gofman: It's still early. But scientists at the University of Pittsburgh are pulling together the vital statistics on workers and dose. If they do it right, I think it's going to be an abysmal story. I think it's going to be like the uranium miners.

In terms of the uranium miners it's been about a 15-year lag between radiation dose and disease. Nobody warned the uranium miners in the 1940s or '50s about lung cancer. Only by July 1967 was any safety standard enforced for them.

People find it hard to relate to a danger that doesn't show up for 10 to 15 years. They say, look it doesn't hurt me. I don't have a rash or anything. I feel fine. That's why it's hard to get many people exercised about radiation.

In the late 1960s, we appreciated the fact that we'd created an epidemic of lung cancer in the uranium miner. More than 125 are now dead, and another 500 to 600 will die no matter what is done for them. That's a fantastic epidemic.

And the same thing may be true of the workers in nuclear power plants. But it will be removed in time.

Q: That story will be written in the 1980s.

Gofman: Unfortunately, that's right. These deaths will just be absorbed as part of the cost/benefits. We'll need the power so much that irradiation and deaths of plant workers will be an acceptable cost. [E]

Plutonium: Biomedical Research

More is known about the toxicology of plutonium than about most other hazardous elements.

W. J. Bair and R. C. Thompson

Plutonium will figure prominently in the production of power during the next several decades because of its key role in fueling breeder reactors and because of its usefulness as a heat source in various thermoelectric power systems. This is a frightening prospect to some, who would characterize plutonium as "the most toxic substance known to man." Plutonium, in certain forms, is indeed a very toxic substance; but its hazardousness is not easily compared to that of other substances, primarily because of lack of information concerning these other substances with which plutonium might be compared. The toxicity of plutonium has been of concern since milligram quantities were first produced in the Oak Ridge reactor, starting late in 1943. In February 1944, 11 milligrams were allocated for studies in rats. Since that time, biological studies with plutonium have occupied the attention of increasing numbers of scientists in the United States and abroad. Much has been learned about the toxicology of plutonium—more than is known about most other hazardous elements (1).

Chemical and Physical Properties of Biomedical Interest

The most common isotope of plutonium, ^{239}Pu , has a 24,390-year half-life and emits energetic alpha particles (5.11 to 5.16 megaelectron volts). It is used as a fissionable material in explosive nuclear devices and as a fuel in nuclear power reactors. Another isotope, ^{238}Pu , is used as a heat source in thermoelectric power devices, such

as have been employed on lunar missions, on communications satellites, in heart pace-makers, and proposed for powering artificial hearts. Plutonium-238 is also an alpha-emitter and has a half-life of 86.4 years. The heavier isotopes of plutonium will become more abundant as they are produced in breeder reactors. Of these, ^{240}Pu and ^{242}Pu are long-lived alpha-emitters and should not differ in any essential biological respect from ^{239}Pu . Plutonium-241 is a relatively short-lived (13.2-year half-life) beta-emitter and is of primary interest as the parent of americium-241, an alpha-emitter that accumulates in tissues and constitutes a hazard comparable to plutonium.

Plutonium is a chemically "difficult" element. It will form compounds in solution exhibiting valences of +3, +4, +5, or +6. The +4 state is most commonly encountered under physiological conditions, where it is always complexed in some fashion. Weakly complexed Pu(IV) will hydrolyze in near-neutral solutions, forming a polymeric hydrated oxide of variable composition.

Plutonium dioxide (PuO_2) is probably the most important compound of plutonium, because of its desirable properties for use as a nuclear fuel. Plutonium metal oxidizes readily and PuO_2 is the compound most likely to be encountered following accidental release. The behavior of PuO_2 in the biological milieu may vary greatly depending upon such factors as exact chemical composition and particle size and shape—factors determined by the conditions under which the oxide particles are formed. The "biological variability" which toxicologists like to blame for the lack of precision in their animal toxicity data is often complicated by "chemical variability" in studies with plutonium.

History of Biomedical Research on Plutonium

The first biomedical studies with plutonium were conducted in Joseph G. Hamilton's laboratory at the University of California, Berkeley, in February 1944. Shortly thereafter, studies were begun at the University of Chicago and, somewhat later, at Los Alamos Scientific Laboratory and the University of Rochester. These studies involved the administration to laboratory animals of several chemical forms of plutonium by various routes. It was found that plutonium injected into the blood was deposited principally in bone and liver, that plutonium was not appreciably absorbed from the gastrointestinal tract when given orally, that it was not quickly cleared from the lung when introduced into the trachea, and that it was not quickly lost from the body. The acute toxicity of plutonium was described in a number of animal species and osteosarcoma was identified as a possible long-term consequence of plutonium deposition. By 1949 a coherent picture had emerged of the biological behavior of plutonium in the rat (2).

These early studies were motivated by concern for the safety of plutonium workers. Some of these workers were excreting small amounts of plutonium in their urine. To know what this meant required information on human excretion of plutonium following injection of known quantities. In 1945 and 1946 the Los Alamos Laboratory and the Manhattan District Project Laboratory at the University of Rochester injected several seriously ill patients with very small amounts of plutonium. A few other patients were studied by the Chicago and Berkeley groups. These are the only experiments performed with plutonium on human subjects; the plutonium excretion data obtained provide the principal basis upon which plutonium burdens in human beings are estimated from urinalysis data (3, 4).

During the late 1950's and 1960's the support of biomedical research on plutonium by the Atomic Energy Commission (AEC) probably never fell below the level of \$1 million per year. The AEC now spends more than \$12 million annually for research on internally deposited radionuclides, approximately 50 percent of this research being concerned with plutonium and other transuranium elements. This increased funding has resulted not only

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Fig. 1. The distribution of plutonium in beagles that have inhaled PuO_2 . [Data from Park *et al.* (6)]

from concern for the future utilization of plutonium, but also from the realization that more numerous data are required from larger animals studied over longer periods of time. Current interest centers on these larger experimental efforts.

Studies with injected plutonium in beagle dogs, initiated at the University of Utah in 1952, were expanded in the 1960's to include more animals at lower exposure levels, and to include animals exposed to other transuranium elements (5). Studies at Battelle's Pacific Northwest Laboratories, Richland, Washington, on the long-term effects of inhaled plutonium dioxide, involving an initial 65 dogs exposed in the late 1950's, were expanded in 1970 and 1971 to include an additional 120 dogs exposed to lower doses of polydisperse aerosols of $^{239}\text{PuO}_2$, and 120 more dogs are currently being exposed to $^{238}\text{PuO}_2$ (6). Coordinated with this effort is a study of inhaled monodisperse plutonium aerosols in beagles at the Lovelace Foundation for Medical Education and Research in Albuquerque, New Mexico (7). A third part of this effort is under way at the Los Alamos Scientific Laboratory where different numbers of microspherical particles containing different amounts of ^{238}Pu and ^{239}Pu are deposited in the lung capillaries of hamsters (8). The practical occupational problem of plutonium-contaminated wounds is being studied in beagles at Colorado State University (9).

Of special interest is the continued surveillance of human beings who have been exposed occupationally to plutonium during the past nearly 30 years. This activity, under the title of the U.S. Transuranium Registry, is coordinated by the Hanford Environmental Health Foundation with the cooperation of Battelle's Pacific Northwest Laboratories and Los Alamos Scientific Laboratory and with data being supplied by other participating laboratories (10).

In this brief historical survey we have neglected many smaller projects as well as substantial contributions from other countries. Studies in the United Kingdom have been closely coordinated with efforts in the United States and have made significant contributions, particularly in regard to plutonium binding at the molecular level in blood and bone. French and Russian research efforts have been substantial and are becoming more widely known, as is also a growing effort by the Germans and Japanese (1).

Routes to Man

Plutonium has found its way to man, in readily measurable quantities, only through occupational exposure, where the route is usually direct—by ingestion, inhalation, or by way of a plutonium-contaminated wound. These direct routes of entry will be considered first; the possibilities for plutonium reaching man through a more general contamination of his environment will then be examined.

Alpha radiation from plutonium on the skin surface does not penetrate to the sensitive basal layer of the epithelium. Absorption of plutonium through the skin occurs only to a very slight degree, and probably only when the skin is damaged (11). Ingested plutonium is poorly absorbed from the gastrointestinal tract; only 0.002 percent of a 0.01N nitric acid solution of plutonium(IV) nitrate was absorbed when fed to rats and pigs (12). Infrequently encountered chemical forms may be absorbed to a greater extent. A few tenths of a percent of ingested plutonium citrate is absorbed; up to 2 percent of hexavalent plutonium compounds or chelate complexes may be absorbed (13). Very young rats show an enhanced gastrointestinal absorption of plutonium; 0.25 percent for

plutonium nitrate in 1-day-old rats (14). The human infant might be expected to show less enhancement of absorption, since his intestine is more fully developed at birth than is that of the rat.

Inhalation is a more probable route of significant plutonium deposition in man, as borne out by experience in the nuclear industry (15). The fraction of inhaled plutonium that will be deposited and retained in the lung will depend in a complex manner upon the physical and chemical properties of the specific material inhaled, and upon the respiratory characteristics of the person who inhales the plutonium. Plutonium aerodynamically capable of reaching the alveolar regions of the lung will be largely retained in the lung or systemically redistributed within the body.

Entry of plutonium through wounds has occurred in industry. Depending upon the nature and quantity of plutonium deposited and the location of the wound, the plutonium may be sloughed off with damaged tissue, accumulate in regional lymph nodes, be largely translocated to other tissues, or remain *in situ*.

Plutonium does not easily penetrate physiologic membranes. Its limited biological transportability makes plutonium a poor candidate for accumulation along environmental food chain pathways. The absorption of plutonium from soil through the root system of plants is very limited. Discrimination factors (concentration-in-plant/concentration-in-soil) are of the order of 10^{-4} to 10^{-6} (16). If the plant is eaten by man, less than 10^{-4} of the plutonium is absorbed from the intestine (12); or if first eaten by an animal, which is in turn consumed by man, two gastrointestinal absorption factors of 10^{-4} must be applied.

If plutonium is to reach man via environmental routes, physical transport seems more likely than biological transport. Thus, plutonium in the soil might be resuspended and either deposited on food or directly inhaled by man. Grazing animals, inhaling near soil level, might be particularly prone to such uptake of resuspended plutonium. The many complex variables involved in such physical redistribution of environmental plutonium would seem to defy parametric evaluation. Some information has been obtained, however, from the observation of actual exposure situations following field tests or accidents involving plutonium. Jackrabbits in-

habiting the Nevada Test Site have accumulated plutonium in their bones equivalent to 0.05 to 5.0 times the amount of plutonium present in a gram of the soil on which they live (17). On the other hand, of 100 residents studied from the Palomares, Spain, area where plutonium was accidentally dispersed following the crash of a U.S. bomber carrying nuclear weapons, none showed detectable lung burdens or statistically significant amounts of plutonium in urine, even though the ground was highly contaminated (18).

The total earth may also be considered a "test site" in which an estimated 0.3 to 0.5 million curies of plutonium has been uniformly distributed as a result of weapons being tested in the atmosphere (19). In the world's oceans, there is evidence for the accumulation of plutonium in sediment-feeding organisms (20). The concentrations attained are similar to those measured in man. Average quantities of about 0.4 picocurie (10^{-12} curie) in lung, 1.3 picocuries in liver, and 0.4 picocurie in skeleton, or a total of about 2 picocuries in the total man, were measured in tissue samples from autopsies in the Boston area in 1965 to 1966 (21). Similar amounts have been measured in human beings in other regions of the world. These data suggest that each person might accumulate about 10^{-17} of the total amount of plutonium in the environment.

One must acknowledge, however, that the information available on environmental distribution and redistribution of plutonium is inadequate for predicting the probable accumulation of plutonium in man, particularly because of the possibilities of very long term changes occurring in the biological availability of the element.

Distribution, Retention, and Dosimetry

It is convenient to distinguish between what has been termed "systemic" plutonium and the plutonium deposited directly in a tissue by virtue of a particular route of entry. Thus, plutonium in bone, liver, or other organs, deposited from the blood, is termed systemic, and might be expected to show a similar pattern of distribution and retention whether initially absorbed from the lung, the intestine, or from a wound. On the other hand, plutonium deposited in the lung by inhalation or in a wound by injection will be directly influenced

Fig. 2. Autoradiograph showing nonuniform distribution of inhaled plutonium nitrate in the periphery of the lung of a beagle. [Courtesy of J. F. Park]

in its subsequent behavior by the physical and chemical nature of the material deposited. Because plutonium is most likely to gain entry by inhalation or through a wound, we will first consider such deposition and follow with a consideration of systemically distributed plutonium.

Lung and pulmonary lymph nodes. The initial deposition and early clearance of inhaled plutonium from the lung is determined by aerodynamic and physiologic factors common to the inhalation of any particulate material. These factors have been described by the Task Group on Lung Dynamics of the International Commission on Radiological Protection (ICRP) (22). An initial rapid clearance phase is largely completed within the first few days after exposure and involves, primarily, the larger particles deposited on ciliated epithelium in the upper regions of the respiratory tract. These particles are propelled along the respiratory passages by ciliary action, swallowed, and, in the case of plutonium, almost totally excreted in the feces. Particles deposited on the nonciliated epithelium below the terminal bronchioles and in the alveoli are rapidly phagocytized by alveolar macrophages which may transport the particles to the ciliated epithelium of the bronchioles (23). Plutonium is less efficiently removed by this mechanism than are most other particles. Plutonium immobilized in the alveoli

may be engulfed by alveolar epithelial cells, transported to pulmonary lymph nodes, or incorporated in fibrotic regions of pulmonary tissue; whatever the mechanism, plutonium is retained in lung for a long time (23).

The loss of deposited plutonium from the alveolar regions of the lung is usually described as an exponential process and characterized by a retention half-time, although this is a somewhat arbitrary procedure and half-times tend to become longer as retention is measured over longer time periods. In rats these half-times vary from about 100 to 400 days. In the beagle, half-times vary from 200 days for the more soluble compounds to 500 to 1000 days for $^{239}\text{PuO}_2$ (23, 24).

The most extensive data on the fate of inhaled plutonium are those for PuO_2 in the beagle (6). Nearly 100 dogs were exposed to $^{239}\text{PuO}_2$ aerosols with depositions varying from less than 1 microcurie to about 50 microcuries. About 80 percent of the plutonium initially deposited in the alveolar regions of the lung was retained in the dogs 10 years after exposure; 10 percent remained in the lungs, 40 percent was accumulated in thoracic lymph nodes, 15 percent was translocated to liver, and about 5 percent each to abdominal lymph nodes and skeleton (Fig. 1).

The mean concentration of plutonium per gram of tissue (and therefore the mean radiation dose) was highest for the thoracic lymph nodes and next highest for the abdominal lymph nodes; concentrations in lung and liver were about a thousandfold lower; and in skeleton and spleen, about one-tenth those in lung and liver. The mean dose to a tissue may be less important, however, than the dose to localized regions within the tissue. Autoradiographs show plutonium particles concentrated within certain regions of the lung as illustrated in Fig. 2. In lymph nodes, plutonium is also concentrated within the medullary sinus and around, but generally not in, germinal centers. In the same animal, some thoracic and abdominal lymph nodes may contain little if any plutonium, while other nodes may contain relatively high concentrations. A recent autopsy report provides striking evidence of the nonuniformity of plutonium distribution in man (25) (Table 1).

In summary, as deduced principally from studies in the beagle, inhaled "soluble" plutonium may be largely cleared from the lung within a year or

two and will be translocated principally to bone and liver. Inhaled "insoluble" plutonium will be retained much longer in the lung and will be translocated principally to lymph nodes draining the pulmonary region. Plutonium is heterogeneously distributed in the lung and in lymph nodes, with a correspondingly nonuniform distribution of radiation dose.

Wound-sites and regional lymph nodes. "Soluble" plutonium compounds, injected intramuscularly in rats, may move quite slowly but are eventually translocated to bone and liver (24, 26). However, plutonium metal implanted subcutaneously in rats and rabbits was absorbed only to a maximum of 1.2 percent during the subsequent life-span of the animals (27). Seven days after intradermal injection of miniature swine with plutonium nitrate in 0.2N nitric acid, 12 percent of the dose was present in regional lymph nodes, 7 percent in liver, and 5 percent in bone (28). In beagles with air-oxidized plutonium implanted subcutaneously in a paw, 17 percent of the activity had moved within a year to the proximal lymph node; during this same period, only about 0.1 percent had translocated to skeleton and about the same amount to liver (9). Because of the uncertain but potentially hazardous consequences of plutonium-contaminated wounds, such wounds, when they occur in human beings, are very thoroughly cleansed and the tissue surrounding the wound may be excised.

Systemic distribution of plutonium via the blood. Plutonium will reach the blood by absorption from the lung, the gastrointestinal tract, or a puncture wound. Much of the data on the behavior of plutonium in animals has come from studies in which plutonium was injected directly into the bloodstream. This difference must be kept in mind. As previously noted, plutonium is prone to hydrolyze at physiological pH. Such "polymeric plutonium," when injected, is rapidly lost from the blood and deposited primarily in liver; monomeric plutonium (complexed by citrate or some physiologic agent) is more slowly lost from blood and is more readily deposited in bone (29).

The retention of plutonium citrate in the circulating blood of several species, including man, is shown in Fig. 3. Plutonium in blood is associated with the iron-binding protein, transferrin (30); the stability of this complex ex-

Table 1. Concentration of plutonium in tissues taken at autopsy from a human being exposed occupationally to the element. [Data from Nelson *et al.* (25)]

Tissue	Plutonium (picocurie/gram)
<i>Lymph nodes</i>	
Carina	61
Intrapulmonary	20
Hilar	12
Hepatic	0.18
<i>Lung</i>	
Pleura and subpleura	0.52
Parenchyma	0.009
<i>Other</i>	
Lumbar vertebrae	0.34
Rib	0.10
Liver	0.04

plains the long time that plutonium remains in blood.

Liver. About one-third of intravenously injected plutonium citrate is deposited in the liver of beagles (31). This plutonium is initially deposited quite uniformly in the hepatic cells (32). Within these cells it is associated with the iron-binding protein, ferritin, and is accumulated in lysosomes. Over a period of years there is a tendency for aggregation of plutonium within reticuloendothelial cells and for compression of the older, plutonium-laden cells by regenerating areas of the liver (32). During the first 1000 days after injection, any loss of plutonium from the liver seems to be balanced by an input of plutonium translocated from bone. Beyond 1000 days, the amount of plutonium in the liver decreases with a

half-time of about 8 years (31). Based on extrapolation of data from several animal species, a half-time of 40 years has been estimated for the retention of plutonium in the liver of man (24).

Bone. Plutonium circulating in blood as a transferrin complex is preferentially deposited on the endosteal surfaces of bone where it is in a good position to irradiate the cells which are the presumed sites of cancer induction (33). Depending upon the rate of growth and remodeling of the particular bone, plutonium may remain on the bone surface, it may be buried by apposition of new bone, or it may be concentrated in osteoclasts involved in bone resorption. Plutonium freed from the bone surface is collected in macrophages which migrate through the bone marrow (34). Because of its migration to less sensitive sites, the critical period for exposure to bone-deposited plutonium may be a limited one and may be much shorter in the young, growing animal than in the adult. An autoradiogram illustrating the deposition of plutonium in bone is shown in Fig. 4.

Measured half-times for gross retention of plutonium in bone have ranged from about a year in mice, to several years in rats and rabbits, and to more than 10 years in dogs (24, 26). A half-time of 100 years has been estimated for retention of plutonium in the skeleton of man (24).

Other tissues. Tissues other than liver and bone account for about 10 percent of the total plutonium in man 1 year after intravenous injection of plutonium citrate, according to the rather meager data obtained from human beings (4). Studies in several animal species have given no indication, however, that tissues other than liver, bone, and lung accumulate sufficient plutonium to be of critical concern (26).

Excretion. Probably the most extensive biological data on plutonium are those related to its excretion in urine and feces. This is because analysis of excreta is the most sensitive indicator, and in many cases the only indicator, of the presence of plutonium in the body. In the evaluation of human systemic deposition of plutonium, the following equation has usually been employed:

$$\text{Initial intake} = \frac{\text{daily urinary excretion}}{0.002 t^{-0.75}}$$

where t is the time in days since intake (3). Total excretion is estimated to be about 5 percent during the first 20 days

Fig. 3. Retention of plutonium in the blood after intravenous injection of plutonium-239 citrate. [Modified from Durbin (4)]

after injection, about 10 percent by 2 years after injection, about 19 percent by 20 years after injection, and 22 percent after 40 years (4). Plutonium body burdens estimated from urinary excretion data cannot be considered to be very precise.

Biological Effects

No specific physical injury to man has been shown to be caused by plutonium exposure. Many workers exposed to plutonium have been greatly inconvenienced—even pained—by the countermeasures taken to avoid possible effects, and a certain amount of psychological trauma has undoubtedly occurred. It must also be acknowledged that the earliest exposures of human beings to plutonium occurred less than 30 years ago and the latent period for manifestation of possible carcinogenic effects is expected to be long. The U.S. Transuranium Registry was established in 1968 to maximize the biological and medical information obtainable from exposed workers (10). Some 3000 present or former employees of the major AEC laboratories have given permission for release of their medical and health physics records and nearly one-fourth of these have authorized autopsy. The accumulation of data in this program will be slow and costly, but these data are our only source of information on the possible effects of plutonium in human beings.

We must currently rely on animal studies for all information on the biological effects of plutonium. The acute toxicity of injected plutonium is due primarily to destructive effects on the hematopoietic system resulting from irradiation of the bone marrow by plutonium deposited on bone surfaces, or released from bone into the marrow. At lower doses of plutonium, effects on blood cells are noted but these are not responsible for the death of the animal. Thus, beagles injected with 0.1 microcurie of plutonium per kilogram show only a marginal leukopenia, and no hematopoietic effects are observed with injections of 0.016 microcurie per kilogram. With this latter dose, one-third of the animals that died had plutonium-induced osteosarcoma (35). Leukemia or other hematopoietic neoplasia do not seem to be induced by plutonium.

The most sensitive index of plutonium toxicity in bone is the induction

Fig. 4. Autoradiograph showing deposition of plutonium on the surface of a bone spicule of a beagle, 1 day after injection of plutonium(IV) citrate. [Courtesy of W. S. S. Jee]

of osteosarcoma. In Table 2 are shown the data on bone tumor incidence in the beagles studied at the University of Utah (36). The incidence of bone sarcoma is high in all groups of dogs for whom complete data are available. With decreasing dose the time to tumor appearance increases. Great interest centers on the dogs in the lower dose groups, injected in the later part of the experiment, and only now approaching the point when they might be expected to develop tumors.

Studies in rodents have also indicated osteosarcoma as the most sensitive effect of plutonium injection (37, 38). In studies of many hundreds of rats, Russian workers have reported osteosarcoma induction after inhalation, intratracheal, subcutaneous, intracutane-

ous, intraperitoneal, or oral administration (39). By all of these routes, bone sarcomas were induced when the average radiation doses in bone were as low as 30 to 70 rads (40). From these data, and assuming a time independent linear dose-response relationship, Mays and Lloyd (38) have calculated an increased osteosarcoma incidence of 0.38 percent per rad for beagles, 0.10 percent per rad for mice, and 0.06 percent per rad for rats. These numbers, it should be emphasized, relate to the average rad dose to the total bone; tumor-sensitive bone surfaces may receive a dose 20 times higher than this average dose (5).

Of more interest than absolute incidence figures is the finding in the Utah studies that plutonium-239 is five to ten times more toxic than radium-226 on the basis of the same total energy delivered to bone (5). This difference is attributable to the more hazardous localization of plutonium on bone surfaces. The surface-to-volume ratio in trabecular bone of man is about half that in the beagle. Since plutonium is deposited initially on bone surfaces, its concentration at these surfaces in man, relative to the average concentration in total bone, should be twice that in the dog. The rate at which surface deposits became buried by apposition of new bone in the 1.5-year-old dogs of the Utah study was probably ten times that to be expected in adult man. Both of these factors would suggest a greater toxicity of plutonium—relative to radium—in man than in the dog (41).

The comparison with radium is important because of the abundance of data on the toxicity of radium in human beings. These data serve as the basis for all evaluations of the hazards of internally deposited bone-seeking radioactive elements in human beings. The greater hazard of plutonium is

Table 2. Induction of bone sarcomas in beagles injected with ^{239}Pu . [Data from Jee (36)]

Amount injected (microcurie/kilogram)	Dogs (No.)	Sarcomas/deaths	Dogs with sarcomas	
			Mean time from exposure to death (years)	Rads to skeleton*
2.9	9	7/9	4.1	4900
0.91	12	12/12	3.6	1300
0.30	12	12/12	4.5	600
0.095	12	10/12	7.2	310
0.048	13	9/13	8.5	190
0.016†	13	4/12	9.9	78
Control‡	12	0/12	11.5	0

* Calculated cumulative radiation dose to skeleton at 1 year before death. † Additional studies at dose levels of 0.016, 0.006, 0.002, and 0.0006 microcurie per kilogram are still in progress. ‡ The mean time from exposure to death applies to all control dogs, none of whom developed bone sarcomas. Natural incidence of bone sarcoma in the beagle has been estimated at 1/10,000.

recognized in ICRP calculations by a "nonuniform distribution factor" of 5, a number which is apparently not over-conservative.

The acute and chronic toxic syndromes for inhaled plutonium have been well defined in rodents and dogs (1, 6, 23, 26). Lymphopenia is the earliest response seen in animals after inhalation of PuO_2 and occurs in dogs with total lung depositions as low as 0.2 to 1 microcurie (6). Figure 5 shows data from the study of inhaled $^{239}\text{PuO}_2$ in beagles, conducted at Pacific Northwest Laboratories (6). Forty of the dogs died between 55 and 200 days after exposure because of plutonium-induced pulmonary insufficiency. Twenty-two dogs that survived more than 1600 days had malignant lung tumors. The estimated initial alveolar deposition in the dogs with lung tumors was 0.2 to 3.3 microcuries or 0.003 to 0.05 microcurie per gram of bloodless lung. Metastasis occurred to thoracic lymph nodes and to many systemic organs, but no primary tumors were seen in lymphatic tissue.

The data in Fig. 5 are difficult to interpret because the incidence of lung tumors was essentially 100 percent at the lowest dose of inhaled PuO_2 tested. There is, however, a gradation of hazard with dose in terms of survival time. If we extrapolate the curve in Fig. 5 to the life expectancy of the beagle, we might conclude that a dose of more than 1 nanocurie per gram could cause premature death due to a lung tumor. The extrapolation is very uncertain, however.

Data from a number of studies in rats also point to lung cancer as the most sensitive manifestation of inhaled PuO_2 (6). In rats exposed by inhalation to more soluble forms of plutonium, osteosarcomas were seen, as well as lung tumors (39).

The tissue affected by the neoplastic process will depend on the route of entry and the form of plutonium involved. Inhaled insoluble plutonium will most probably result in lung tumors; inhaled soluble plutonium may produce both lung and bone tumors; systemically deposited plutonium will most probably produce bone tumors

Countermeasures for Internally Deposited Plutonium

Because human beings can be contaminated with plutonium, and because of its toxicity in experimental animals,

there has been a continuing effort to develop countermeasures for treatment of contaminated individuals. By far the most effective of these procedures has been the surgical removal of tissues adjacent to contaminated wounds. For the removal of systemically distributed plutonium, the only clinically approved procedure is that involving administration of the chelating agent, diethylenetriaminepentaacetic acid (DTPA). The DTPA forms a very stable chelate complex with plutonium which is then excreted in urine (42).

Several hundred people have been treated with DTPA following incidents of plutonium contamination; the DTPA is usually administered by a series of intravenous injections or by inhalation. Removal of about 50 percent of the plutonium that would otherwise be retained is probably an exceptionally good result (43). Much better results are obtained in animal experiments, where larger DTPA doses can be employed and the timing of treatment optimized (44).

Inhaled, insoluble plutonium is not effectively mobilized by DTPA treatment, nor by a wide variety of physiologically active materials that have been tested (42). Pulmonary lavage—irrigation of the lung with physiological saline solution—has removed as much as 50 percent of the plutonium deposited in lungs of rats, dogs, and baboons (42); when used in one human being with lung-deposited plutonium, there was evidence of some plutonium removal (7).

Evaluation of Hazards and Exposure Limits

The first attempt to evaluate the hazardous effects of plutonium in man and to establish exposure limits was made in 1944. On the basis of the accepted permissible body burden of 100 nanocuries for radium, and with the assumption of equivalent toxicity for equal energy deposition by radium and plutonium, a value of 300 nanocuries was derived as a permissible body burden of plutonium. As experimental evidence on plutonium toxicity was accumulated, this early limit was revised downward until, in 1949, a conference between British, Canadian, and American representatives at Chalk River, Ontario, initiated discussions that led to an internationally accepted permissible body burden of 40 nanocuries. This value for occupational exposure was

subsequently adopted by both the ICRP and the National Council on Radiation Protection (NCRP) and has persisted to the present day (8).

The 40-nanocurie limit for plutonium, as originally derived, was based upon three major assumptions: (i) that comparison with the limit of 100 nanocuries for radium is acceptable as a standard; (ii) that bone, which is the critical organ for radium, may also be considered the critical organ for plutonium; and (iii) that comparative effects of radium and plutonium on the bone of animals can be meaningfully extrapolated to man. An evaluation of the 100-nanocurie limit for ^{226}Ra would be beyond the scope of this article. Suffice it to say that no radiation exposure limit is better supported by human data on dose-effect relationships than the limit of 100 nanocuries for radium (45).

With regard to the second assumption, it is clear from animal studies that bone cannot be always considered the critical organ for plutonium. The exposure of liver, lung, and lymph nodes must also be considered.

In the case of bone, where comparison with radium is legitimate, can the comparative effects measured in animals be extrapolated to man? The ICRP and NCRP assume that plutonium is five times more hazardous than radium, because of its more hazardous localization in bone. Results from dog studies at the University of Utah indicate that this factor falls in the range of 5 to 10. There is reason to believe that the factor would be higher in man, because of man's lower bone surface area relative to total bone volume, and because of man's slower turnover of plutonium from bone surfaces. From this line of reasoning one would conclude that the 40-nanocurie limit for plutonium is severalfold "less safe" for bone than the 100-nanocurie limit for radium.

Comparison with radium is not appropriate when the critical organ is other than bone. In the case of lung, if one follows the customary approach of limiting occupationally incurred radiation doses to 15 rems (40) per year, the maximum permissible lung deposit becomes 16 nanocuries, or 0.016 nanocurie per gram of lung. This concentration may be compared with a level of 1 nanocurie per gram of lung, which seems not to shorten the survival time of a beagle dog (Fig. 5). The margin of safety is less than totally reassuring because of the absence of data for

exposure to smaller amounts of plutonium.

If one were to limit the lymph node dose to 15 rem per year, a much more restrictive limit would be derived than that based on dose to lung. Such a limit has not been applied, on the grounds that animal experiments do not indicate that lymph nodes are the critical tissue.

If one were to limit the dose to 1700 grams of liver to 15 rem per year, the permissible liver burden would be 27 nanocuries, which, depending upon the route by which plutonium reached the liver, might correspond to a total body burden of 50 to 200 nanocuries, a limit less restrictive than the present limit based on bone.

These speculations only hint at the complexity of the problem. We have not considered the necessity to limit daily, weekly, or annual intake so that the accumulation of plutonium over a lifetime is kept within acceptable limits; nor the distinction to be made between occupational exposure and exposure of the general population. A major problem is the basic contradiction of a system that evaluates hazard in terms of average radiation dose to an organ, when we know that this dose is very nonuniformly distributed within the organ. Unfortunately, we do not yet know enough about the precise distribution of dose, or the effect of very high doses to very small volumes of tissue, to handle the problem in any other way.

It should be noted that committees of the ICRP and NCRP are continually reviewing permissible exposure limits for plutonium and other radionuclides. We are members of both these committees; it is our personal view that plutonium exposure limits will be changed within the next few years, in the direction of tightened control—that is, lowered permissible exposures; but that the change probably will not be large.

The Future of Biomedical Research on Plutonium

Having noted in the introduction to this article that probably more is now known about the toxicology of plutonium than about most other elements, it might be logical for us to conclude that future efforts should be devoted to less well understood elements. Such a conclusion would, indeed, be justified if plutonium were a problem for a few

Fig. 5. Survival time of beagles as a function of PuO_2 deposition in the lung. [Data from Park *et al.* (6)]

thousand workers employed in a carefully controlled nuclear industry—the situation which has prevailed for the past 25 years. This is not, however, the prospect for the future, which has been touted as the “Plutonium Age”—an age when most of our energy will be derived from plutonium, an age when tens of thousands of people may be walking our streets with cardiac assist devices powered by ^{238}Pu , an age when millions of curies of plutonium wastes will have to be kept from contact with man for future hundreds of thousands of years (8). If these are the prospects, it behooves us to spare no efforts in our pursuit of information on the behavior of plutonium in man and his environment.

Priority must be given to the intensive follow-up of persons known to have been exposed to significant amounts of plutonium. Only from these persons can we obtain direct information on possible effects of plutonium in man. We should also take advantage of accidentally exposed environments to learn all we can, in a real-life situation, about the movement of plutonium in the biosphere.

More data on toxicity are required from studies of animals exposed to the lower amounts of plutonium that approach those now considered safe for man; such data are needed for a wider variety of plutonium isotopes and compounds. We are too dependent upon data from rodents and beagles which may—and in all likelihood do—possess peculiarities in their handling of plutonium that are not shared by man; comparative studies in other species should be undertaken. It must be recognized, however, that we can never collect enough data on observed effects in man or animals to be confident that significant effects will not occur in an

exposed population numbered in billions. Such confidence can come only from an understanding of the mechanisms involved in tumor induction, which could allow us to predict the relationship between cancer incidence and dose, and whether there is, indeed, a threshold dose below which no effects will occur.

The entirely proper concern now expressed in many quarters for the toxicity of plutonium, and of other potential radioactive contaminants of our future environment, is no doubt magnified by the unusual properties of these materials that are present in such small quantities, so invisible and mysterious in their action, while at the same time so readily detectable. This same combination of widespread concern, scientific accessibility, and small bulk, should prove uniquely advantageous for their future control. The key to this control is greater knowledge—knowledge that must be acquired before its application becomes critical.

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Plutonium and the "Hot Particle Problem"

In what could evolve as another round in the great debate over radiation standards, one of the nation's leading environmental law groups is asking the government to reduce drastically the legal limits on releases of plutonium from nuclear fuel, weapons, and power facilities. The Natural Resources Defense Council (NRDC) contends in a lengthy petition filed with the government on 14 February that present standards relating to plutonium are based on erroneous biological assumptions and should be reduced by a factor of at least 115,000.

Neither of the two federal agencies that share responsibility for radiation standards—the Atomic Energy Commission (AEC) and the Environmental Protection Agency (EPA)—had any immediate comment on the NRDC's proposal, although officials of both agencies said it would receive serious consideration. Strict new plutonium emission regulations would probably increase the cost of fabricating and processing nuclear fuel and weapons. But the NRDC contends such strictures are technically feasible and "would not price the nuclear industry out of business."

The NRDC consists of about a dozen attorneys and four staff scientists in New York, Washington, D.C., and California, all supported by a Ford Foundation grant and membership subscription. (One of the scientists, and the main author of the NRDC's case for stricter plutonium standards, is Arthur R. Tamplin, a biophysicist on leave from the AEC's Lawrence Laboratory at Livermore, California. Tamplin and his colleague John Gofman were central figures in the radiation standards debate of the late 1960's that led the AEC to tighten emission standards for water-cooled reactors by a factor of 100.)

Despite its small size, the NRDC has scored some

noteworthy courtroom victories in the past couple of years, and along the way has established itself as a thorn in the side of the AEC's liquid metal fast breeder program. Last year, the NRDC won an appellate court decision directing the AEC to assess, as best it could, the environmental impact of a nuclear breeder industry, rather than confining its analysis to the limited effects of a single breeder demonstration plant the AEC plans to build in Tennessee. The decision, which the AEC accepted without protest, established an important precedent for other R&D programs and encouraged the AEC itself to begin thinking about breeder-related problems that may not actually arise for decades. The NRDC now hopes to force one of these potential difficulties to an early resolution.

At issue is what health physicists have dubbed the "hot particle problem." Briefly stated, the problem is how to predict the biological effects of radiation when the radiation is absorbed by man or animal not uniformly (as in a chest x-ray) but rather as tiny radioactive particles that lodge in the lungs for months or years. Small insoluble particles can deliver very intense doses of radiation to microscopic areas of the lung. Are the resulting effects—and is the risk of cancer—the same as if the total amount of radiation absorbed were applied uniformly over the lungs?

The question has been debated in radiological circles off and on since the late 1940's, with no general agreement and little evidence one way or the other. Present radiation standards treat the distribution of a given dosage to lungs as irrelevant; the NRDC disagrees.

* "Radiation Standards for Hot Particles," Arthur R. Tamplin and Thomas B. Cochran (available from NRDC, 1710 N Street, NW, Washington, D.C. 20036). 32 pages, \$3.

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SCIENCE, VOL. 191

Environmental Group Proposes a Draconian Answer

According to a position paper* prepared by Tamplin and NRDC physicist Thomas B. Cochran, present standards set the maximum permissible radiation dose to a nuclear worker at 5 rem per year to the whole body or 15 rem per year to the lungs. (The rem is a unit of radiation dosage; the limit for a member of the general public is one-tenth the occupational standard.) To receive the maximum permissible lung burden (MPLB), a worker need inhale only 0.016 microcurie of plutonium oxide dust, or about 53,000 aerosol particles.

Using figures presented in a 1972 report from the National Academy of Sciences on the biological effects of radiation (*Science*, 1 December 1972), Tamplin and Cochran estimate that the risk of cancer from 5 rem to the whole body is 1 in 1000 and that the risk of cancer from 15 rem to the lungs is 1 in 300,000 per year.

The Academy's report, however, did not deal with the hot-particle problem. Cochran and Tamplin contend that, in fact, the risk of cancer from such particles is vastly out of proportion to the overall dose they deliver to the entire lung. This hypothesis is based in turn on some research and a review of the rather scanty literature on the subject by Donald P. Geesaman, the last of several scientists once assigned to Tamplin at the Lawrence laboratory. Geesaman was layed off in a "reduction in force" by the laboratory last year and is now on the faculty of the University of Minnesota.

Geesaman calculated that if one were to inhale the allowed 53,000 plutonium particles (for an overall lung dose of 15 rem) the tissue immediately around these virus-sized particles—about 3 percent of the lungs—would actually receive about 4000 rem per year. Each spot dose of this magnitude, Geesaman estimated, carries a risk of between 1 in 1000 and 1 in 10,000 of causing

cancer; thus the cumulative risk from the maximum allowed dose of hot particles would add up to almost certain cancer. This contention is the heart of the NRDC's case for a strict hot-particle standard, and is likely to prove controversial.

Tamplin and Cochran arbitrarily pick a middle-range estimate of 1 in 2000 as the risk of cancer from a single hot plutonium particle. They suggest that two such particles—with a total radioactivity of 0.14 trillionths of a curie—be set as the maximum limit for accidental or routine releases of plutonium, for a reduction by a factor of 115,000 from the present MPLB.

The biological evidence to support this proposal is meager, a point Cochran and Tamplin acknowledge. Only one human cancer case is clearly linked to plutonium exposure, although several hundred workers have been accidentally exposed since the 1940's; the best of the few animal studies produced cancer in 20 of 21 beagles exposed to plutonium dust, but all the dogs, Tamplin notes, received doses at least 100 times the current standard, on the assumption that nothing would happen at lower levels. The AEC is supporting new beagle studies with much lower levels of exposure, but they still have a long time to run.

In the absence of countable corpses, canine or otherwise, the NRDC is likely to encounter the same resistance from the radiation standards establishment that led to the acrimonious standards disputes of the late 1960's. Tamplin said he hoped it wasn't so.

"We want to give them something to shoot at, but think we can defend numbers," he told a news conference. "It is the same old issue, but you'd hope we wouldn't get into the same polemic dialogue. There's no place for that."—R.G.

Ending January 5, 1974

THE NATION

HOT WATER PROBLEM

... A town frets over AEC's radioactive oversights.

By William J. Lanouette
FROM BROOMFIELD, COLO.

"If I'd known about that plant in 1969 what I know about it now, I'd never have moved here," Hank Stovall said one night not long ago. "I thought this was a quiet little town, with good services. And it is. But I never realized my family and I'd be drinking radioactive garbage."

Stovall, a production engineer and father of six, was one of about two dozen Broomfield residents who crowded into the basement of the Mamie Doud Eisenhower Public Library one fall evening to attend a City Council meeting.

"That plant" is the Rocky Flats Plant, an Atomic Energy Commission (AEC) facility that has been run on contract by the Dow Chemical Co. since it was built in 1951. It is also the source of the town's contaminated water, a fact that Broomfield residents discovered in mid-September.

More disconcerting to some residents was the discovery that the AEC didn't even realize there was radioactive leakage until the state found it.

Uneasy From the Start

The Rocky Flats plant is the country's only AEC facility for processing plutonium, a highly toxic, radioactive substance with a half-life of 24,000 years. (The half-life of a substance is the time required for half of its radioactive atoms to disintegrate to a nonradioactive form.) The plant's 3,000 employees manufacture nuclear warheads and bomb triggers for the Defense Department, and they reprocess and recover the valuable and dangerous plutonium from the scrap of other AEC facilities.

Broomfield residents have felt uneasy about Rocky Flats from the beginning because the four-square-mile site runs along the western side of the town of 13,000 persons. The plant has also given some concern to residents and public officials in Boulder, 11 miles north, and in Denver, 8 miles southeast. But as Broomfield's city manager, George DiCiero, puts it: "We have the dubious distinction of being hit first by anything escaping."

Tritium in the Water

Broomfield's distinction has been earned on more than a dozen occasions in the past 22 years, although three incidents are referred to most often by residents. One is a plutonium fire in May 1969 which led to the contamination of several acres of land around the site and caused damage estimated at between \$45 million and \$75 million. Another is the accidental release of plutonium waste into Broomfield's Great Western Reservoir, just east of the plant, in October 1972.

The accident now on everyone's mind, and a principal topic of concern at recent City Council meetings is the release of tritium, a radioactive hydrogen isotope, into the local drinking water last spring.

Broomfield's problems were first de-

tected by the state health department in April. The department's monthly water sampling at Walnut Creek, which flows from the plant to the reservoir, revealed abnormally high levels of tritium.

According to calculations released by the Dow Chemical Co. after the tritium spill was announced, a Broomfield resident drinking the city's water for one year would receive about as much radiation as a person flying from Denver to New York, or about one-fifth the radiation he would receive from wearing a radium-dial wrist watch. But some scientists are not reassured by such calculations, noting that the new source of tritium is in addition to other radiation a person receives.

No Deductions

Normal "background" levels of tritium are about 1,000 picocuries per liter of water in this part of the country. When state inspectors found levels of 30,000 picocuries on April 24, and 3 million picocuries on May 24, they alerted the AEC and Dow of their findings. Rocky Flats personnel replied that they didn't make or process any tritium at the plant and couldn't possibly be the source.

But they were, according to later verification by both the state and the AEC. State and Federal officials add, however, that the permissible safety level for tri-

Coping

tium in drinking water was one million picocuries, and the highest level found in the town's reservoir was 23,000.

These reassurances did little to calm the residents of Broomfield. Sales of bottled water at the local Safeway supermarket more than quadrupled, and supplies were sold out for several days after the Sept. 18 announcement. Demand has fallen somewhat since then, and it is now about double what it was in mid-September. "Can I deduct the price of bottled water from my municipal water bill?" one resident quipped. "No," replied a city official, smiling.

"Our first reaction," DiCiero says, "was that the AEC shouldn't be emitting any radioactivity above natural background levels. And if their safety procedures had worked, this situation really shouldn't have occurred. But the AEC didn't even know it was releasing tritium, and wasn't equipped to test for it. It was the state that first picked it up. The spill occurred in April and May, but it took them until mid-September to confirm that there was even something wrong. Just imagine if it had been a serious discharge. That after-the-fact testing program just isn't good enough."

Robert Siek, the state's director of occupational and radiological health, says: "We were confident there was no health hazard to the people of Broomfield. Our real worry was for the potential of a health hazard that this incident showed

us. The tritium problem was an unusual and unpredictable incident, but it concerns us very much because if you can have one incident you can have another."

Siek says he believes that the everyday operations at Rocky Flats are very safe, but he remains concerned about unscheduled and undetected releases of radioactive waste. Another unscheduled release—last October—produced plutonium levels of 235 picocuries per liter of water in Walnut Creek, just above the reservoir. The health standard for plutonium in drinking water is 1,600 picocuries. "We've also found traces of strontium 90 and one classified isotope, but in small amounts," he says.

The appearance of strontium 90 surprised the Rocky Flats personnel because their operations don't routinely include it. "Until the tritium episode we only analyzed our effluents for plutonium radioactivity because that's our bag, that's what we deal with here," says AEC spokesman Jim Nicks. "But now we're monitoring Walnut Creek and the settling ponds daily for all radionuclides."

Dow's Reaction

Yet another surprise to the AEC was the presence of radioactive contaminants—including tritium and strontium 90—in a landfill off the plant site that wasn't supposed to contain any nuclear waste. The AEC says it has no explanation for this situation, which was discovered by the state after the tritium incident.

To some, the tritium release itself is not as disturbing as the way the AEC and Dow dealt with it:

✓ On Sept. 14, four days before the tritium release was announced by the state health department, but nearly five months after the department first told Dow it suspected tritium contamination, Dow issued a press release lauding the company's successful "environmental monitoring program."

✓ When pressed for an explanation by Republican Rep. Donald Brodzman, who represents the Broomfield area, the AEC's Washington headquarters as late as September denied any responsibility for the tritium release.

✓ Some Rocky Flats officials suggested publicly that the tritium release was the result of sabotage, although no evidence has been cited.

✓ After a search of records, Rocky Flats officials concluded that the plutonium waste that contained tritium had come from the Lawrence Livermore Laboratory in California, and they blamed that AEC installation for not warning them of this fact. Livermore spokesmen said they assumed all the tritium had been removed and thus didn't bother to

Radioactive tritium escaped from plant (background) through pond into Broomfield water.

report that the plutonium had once contained it.

"The AEC system made a mistake," Bill Colston, the AEC area office manager, said recently. "But I think we've been able to learn from it. . . . The bad part was that this incident happened at all, but the good part is that now we don't assume anything. We now monitor all shipments when they arrive, all materials prior to processing, and all effluents. We even require a history of each shipment, to show what's in it and what's been done to it prior to its arrival here."

More Surprises?

An AEC spokesman in Washington said that this additional precaution at Rocky Flats would not be followed at other AEC facilities.

• The Rocky Flats Plant, which already represents an investment of more than \$200 million, is undergoing improvements and repairs costing an additional \$170 million. When these are completed, perhaps by the end of 1976, the facility will be self-contained, and it will recycle all wastes and haul them to AEC burial grounds in other states. The AEC also plans to buy 4,070 acres around Rocky Flats to create an additional, mile-wide "buffer zone" to protect encroaching housing developments from soil contaminated with plutonium, and to provide an additional margin of safety in case of another accident.

"One good thing with this tritium situation," says Paul Smith of the Environmental Protection Agency's regional office in Denver, "is what it shows us about the whole AEC system. It's sort of disturbing to think that so much radioactivity can slip through the system with the top brain power in nuclear physics watching it. It points to the fact that you can't regulate and promote yourself, as the AEC is now doing. That's why we have the Rocky Flats situation. That's why we have the Grand Junction situation. . . . homes in that area are Colorado

city were built on landfill contaminated with uranium-mine tailings). If you're doing both you get kind of smug, and then these things happen. But if you have someone looking over your shoulder you're going to be more careful."

Dr. H. Peter Metzger, a biochemist now living in Boulder, whose book, *The Atomic Establishment*, details many AEC activities and blunders, relates the Rocky Flats affair to the leak last spring of 115,000 gallons of high-level radioactive waste from a storage tank at the AEC's Hanford Reservation on the Columbia River in Washington state. These and dozens of other incidents, he says, are typical of the AEC's whole waste-management program.

'Corner Cutting'

"Anytime you have a dull and dangerous job being done in total secrecy, the people doing that job are going to cut corners," says Metzger.

The Broomfield council has voted unanimously to send a letter to the AEC demanding that the agency build the retention reservoir and divert the creek immediately. They also asked that no more radioactive waste be released from the Rocky Flats Plant.

The AEC replied that the effluents are within set standards and thus not hazardous to health. However, most radioactive effluents will be contained at the plant as an added precaution, the AEC said. The commission also announced to Broomfield's residents that it would hire an independent consulting company to study the other requests, and that the company's report was expected by next summer.

"We're not a bunch of kooks or rabble rousers here," Hank Slovall asserted. "We're mostly professional people who are deeply concerned about our home town and its environment. We're not interested in being bothered by the AEC or Dow, or having the wind pulled over our ears in the name of 'national defense.' But if we

don't do something to correct this situation then we and our kids will continue to drink and use this water, and spray it on our lawns. And if that goes on for very long then the town of Broomfield and its people will be nothing more than a filter plant for the AEC's radioactive garbage. I think we've finally put our foot down. Now it's up to the AEC and Dow to act."

On May 11, 1969, the most expensive single industrial accident in American history took place. Even though it was more costly than the great General Motors fire at Livonia, Michigan, fifteen years before,²³⁴ the remarkable fact that the damage caused by the fire could hardly be noticed outside the two buildings in which it occurred attests to its special nature. It was a plutonium fire, and the problem was not so much destruction as it was radioactive contamination.

Dow Chemical's Rocky Flats atomic plant, located just eight miles upwind of the densely populated areas of suburban Denver, Colorado, is the Atomic Energy Commission's only facility for the mass production of plutonium parts for atom bombs, now the trigger for the modern thermonuclear weapon. The importance of this plant, and the two buildings in which the fire took place, can be appreciated by the fact that a serious impact on weapons delivery schedules and stockpiles would have occurred had the fire taken place a year later. According to Major General Edward B. Giller, the director of the AEC's Division of Military Applications (and one of the most able scientific military officers in the country), "The fire occurred at a particular period in which our requirements for deliveries of new devices was at a minimum. . . . If we are unable to get back into production in April, in the spring [of 1970], then we will not be able to meet our commitments to the Department of Defense and our production will indeed slip."²³⁵

The day after the fire, Robert Hollingsworth, the general manager of the AEC, appointed a special board to investigate. Its report received little publicity, because, by a remarkable coincidence, it was released on November 18, only hours before the Apollo-12 astronauts landed on the moon. But what it said was worth noting.²³⁶

The fire began in a "glovebox" area where plutonium is machined. Plutonium, like phosphorous, can *ignite spontaneously* and produce the intense heat characteristic of burning metals. The report suggests that the source was some loose scrap plutonium which was improperly stored in uncovered cans under the glovebox. The glovebox liner itself was made out of six hundred tons of *combustible*

material. The first indication of the fire was an alarm finally sounded by the heat-sensing system installed throughout the buildings. However, by this time the fire was well out of control, because the astonishing facts are, as the report states, that "since the heat detectors were located outside and under [the glovebox] and *were insulated* by the floor of the storage cabinet, *they were incapable* of sensing the fire."^{*}

Similar industrial installations, subject as they are to state, local and insurance-company fire regulations, typically have fireblocks along production lines. Not so for this top-secret installation; the report went on to say: "The long interconnected conveyor system without physical barriers provided a path for the fire to spread. The closed metal door in the North Line demonstrated the effectiveness of even a simple firebreak in the line."

On May 20, an AEC delegation, in closed-door testimony before a Senate commission, requested and received the funds needed to restore Rocky Flats to full operation. In retrospect, it is tempting to speculate how many of these contributing causes would ever have been allowed had a private insurance company instead of the general public carried the fire risk.

At hearings for extra funds "to eliminate fire and safety hazards at various AEC installations," Representative Glenn R. David of Wisconsin observed, "Are we fairly subject to the charge of negligence in failing to have some of these basic things at these installations? Nobody would permit operations to go on without firewalls and automatic sprinklers and things of this kind unless they were under the jurisdiction of the federal government where they can do nothing about it, I suppose."⁷²

It was at these same hearings (over a year after the fire) that the AEC finally admitted to the real danger that the fire had presented to the public. Describing it as "a near catastrophe," General Giller testified that if the fire had burned through the roof (it didn't), "then hundreds of square miles could be involved in radiation exposure and involve cleanup at an astronomical cost as well as creating a

* Emphasis added.

Dr. H. Peter Metzger

*very intense reaction by the general public** exposed to this. . . . If the fire had been a little bigger, it is questionable whether it could have been contained."

Clearly, then, this fire was not simply an accident that could happen anywhere, as Dr. Lloyd M. Joshel, then Dow's general manager at Rocky Flats, implied at a meeting in Denver.²³⁷ It was caused by the everyday incompetence and negligence inevitably found in any system which polices itself. Joshel, fifty-seven, retired at the end of 1971.²³⁸

3 • THE TROUT FARMER

OF COURSE, newspapers all over the country carried the story. Robert A. Erkins, president of the Snake River Trout Company, the world's largest trout farm, received a *New York Times* clipping in the mail from one of his customers back East.²³⁸ The story said that for "several months, hundreds of railroad cars will be carrying from Rocky Flats to the Snake River plain of eastern Idaho an estimated 330,000 cubic feet of contaminated waste to be buried below ground by the Commission's National Reactor Test Station."²³⁹ The customer was worried that his trout might become contaminated with plutonium. So was Mr. Erkins.

He wrote a letter to Idaho's Governor Don W. Samuelson, expressing worry that the Snake River aquifer (an underground river and the largest in the country), which feeds the springs that support the state's trout farming industry, might become polluted with radioactivity.²⁴⁰ He had reason to worry: it turned out that the open trench which was used for plutonium disposal was separated from the underground aquifer by a layer of basalt rock only six hundred

* Emphasis added.

feet thick, and according to the chief of the Water Pollution Section of the Idaho State Health Department it was "crevassed and fissured all the way down to the aquifer."²⁴¹ Not only that, but deep disposal wells are used in Idaho to inject liquid radioactive wastes directly into the aquifer.²⁴²

As usual, AEC assurances were extravagant. "We have substantial technical experience. There's no real or potential basis for alarm—ever," said William F. Ginkel, manager of the AEC's Idaho Operations Office. He went on to say that his operation was "reviewed continually by the Department of Health, the AEC and people like the National Academy of Science."²⁴³ Ginkel thereby implied something not true, that the National Academy of Sciences (NAS) had examined his Idaho operation and found it safe. Ginkel never mentioned the fact that the NAS had reviewed AEC radioactive-waste-disposal practices for years and roundly condemned not only the Idaho operation but AEC atom dumps everywhere they existed!

4 • THE "SUPPRESSED" 1966 REPORT OF THE NATIONAL ACADEMY OF SCIENCES

THE EXISTENCE of the NAS reports became known, but nobody outside the AEC could obtain copies (at least one author couldn't even get a copy for himself).

Idaho's Senator Frank Church became involved and asked for an independent federal review of the AEC's waste-handling practices in his state. He also asked AEC Chairman Seaborg, "I would appreciate a report from the AEC explaining why this report has not been made public."²⁴³ The unpublicized report Senator Church was asking about was the National Academy of Sciences Report of 1966 (the same one referred to by the AEC's Mr. Ginkel, above).

The AEC's official reasons for hiding this information are contained in Seaborg's response²⁴⁴ and in two unsigned AEC "staff

The Atomic Energy Commission will have to prepare an environmental impact statement on the Liquid Metal Fast Breeder Reactor program. This was ordered by a three judge court of appeals in the District of Columbia, reversing a lower court ruling and providing a major victory for the Scientists' Institute for Public Information, appellant in the case. The court ruled that the expensive AEC breeder program has already passed beyond the research stage and now requires what may be irretrievable allocation of resources, whereas one purpose of the National Environmental Policy Act, under which impact statements must be filed, is to promote public discussion at the decision-making stage, before commitment to technology that has serious environmental implications; "To wait until a technology attains the stage of complete commercial feasibility before considering the possible adverse environmental effects... will undoubtedly frustrate meaningful consideration and balancing of environmental costs against economic and other benefits." Environment July/Aug. 1973

Plutonium concentration levels in air around the Rocky Flats, Colorado plutonium-recovery plant are higher than have previously been reported, Dr. Edward Martell noted in a paper delivered to the Colo. Committee for Environmental Information. March 16. Plutonium is one of the most toxic chemicals known to man. Martell claimed that offsite concentrations of plutonium that "approach and exceed one tenth of a picocurie per cubic meter." This level is higher than the Atomic Energy Commission standard of .06 picocurie per cubic meter set for health and safety protection. In order to alleviate plutonium contamination, the AEC plans to rebuild the Rocky Flats plant and to buy up land around the plant in an attempt to extend the present buffer zone. However, Martell told Environment that housing developments are rapidly extending towards the buffer zone and that residents, particularly those two to three miles east of the plant, may be vulnerable to plutonium carried by prevailing winds from the west.

ENVIRONMENT

April 1972

2 More Bodies Found in Enid;

Toll Now Four

Radio Oklahoma File Oct. 12, 1973

Hall Requests **ATTITUDE DESCRIBED**

Disaster Aid
For 5 Counties

15-Inch Deluge
Tops 1940 Mark
Set in Sapulpa

No 'Caretaker'
In Nixon Plans

ing Thursday. (Staff Photo by Al McLaughlin)

By Jon Ellis

Two more bodies were found in the swirling floodwaters engulfing north central Oklahoma Thursday, bringing to four the number of persons killed as a result of all-time state record rainfall deluging the five-county area.

Gov. Hall appealed to President Nixon for declaration of a national disaster area where 15.68 inches of rain left some \$3.8 million in property damage in Enid alone.

All four of the dead were located near their homes

Full Page of Pictures on Page 6. Other Pictures and Stories on Pages 4, 11, 16.

In the Brookside area of Enid, where torrential rains hit the state hardest.

Authorities identified the bodies as 2-year-old Twila Kay Swartwood and Edgar Vance Donnell, 45.

Searchers found Donnell some six blocks from his home, under a washed out bridge. Volunteers from Phillips University located the girl's body near her home, but reported no trace of her mother, still listed as missing Thursday evening. Her father, James, was reportedly safe in a neighbor's home.

All four killed in the flooding were in the Enid area when the ordeal began.

Found earlier in the day were the bodies of Jack Dunn, 61, located in a stream near his home, and Mrs. Lucille Strangland, 58, of Dixon, Ill. The woman died after being hit by a car while fleeing her sister's home.

The governor put a "minimum" damage estimate on Page 2, Col. 1

WASHINGTON (AP) — President Nixon believes he has a free hand in choosing a new vice president and need not confine himself to selecting a "caretaker" without 1976 presidential ambitions, White House sources reported Thursday.

They said Nixon hopes to nominate a successor to Spiro T. Agnew within the next few days and perhaps by the end of the week.

The selection process got under way in earnest Thursday — less than 24 hours after Agnew resigned as vice president and pleaded no contest to a tax evasion charge.

Under the 25th Amendment to the Constitution,

ratified in 1967, Nixon's nominee must win majority approval from the Democratic-controlled Senate and House. That provision has prompted some Congress members to suggest they should be the President's partners in naming a new vice president.

One Nixon associate emphasized the President feels he can act "without parameters" of any kind and is seeking a "strong man" he would regard as well-qualified to take over the presidency in the event of Nixon's death or disability.

Deputy White House Press Secretary Gerald L. Warren was asked if Nixon

Continued on Page 2, Col. 6

Dayan Says

him from Cairo attacks on northern del-

in sources said States was pre-rush munition to Is-

radio said Egypt peninsulas to

wipe out a fleeing column of Israeli armor.

—In the naval war, Syria and Israel reported conflicting versions of a battle off the Syrian coast. The Greek Merchant Marine Ministry said an Israeli gunboat sank one of its ships, killing two crewmen.

Early Friday morning, the Syrian command re-

Continued on Page 2, Col. 1

IONS

ing Jury Truant's

ersons who re-notice are ex-cused reasons as school teacher, a mother with 1dren in the is said.

excused is just f phoning in to clerk or writing taining the re- requested ex-rom service,"

Oklahoma County generally winds up with about 270 to 280 persons who come to serve as jurors for three weeks, Owens said.

During the first week of October jury trials, there were only 150 jurors, the judge said. In the next week there were 211.

At one time there were 11 judges requesting je-

Continued on Page 2, Col. 8

Teachers Invited To Party for Hall

By Ed Montgomery

The state's 40,000 school teachers are being asked to attend next week's \$25-a-couple happy birthday gala for Gov. Hall.

Dr. Lederle Scott, executive secretary of the Oklahoma Education Association, said the OEA is not involved in the mailing of a letter asking for support of the event. However, Mrs. Betty Ward, Gov. Hall's education liaison officer, said the letters were addressed by the OEA's machine.

She said Scott did not handle the project but his assistant was aware of it. She said the OEA would be paid for the use of the machine but she hasn't learned the cost yet.

The Oct. 20 campaign fund-raising effort in

Oklahoma City Myriad convention center will follow by a day the annual OEA convention.

Four teacher-coordinators of the education committee for the gala, who signed the letter to "Dear Fellow Teachers" said they had rented booth space for the convention.

The envelopes containing the letters carry the return address of Dr. J. Don Harris, the Oklahoma City dentist who is general chairman for the fund-raiser.

The postage meter number on the envelopes checks to the Delong Mailing Service of Oklahoma City. A spokesman for Delong said Dr. Harris was the customer for the mailing transaction.

Included in the mailing was a business reply envelope containing a form for

Two More Bodies Found in Enid

Continued From Page One
one of \$2-million on devastation wrought by the heavy flooding.

Ed Hardy, the governor's press secretary, conceded that the damage may run much higher, but Hall's estimate was made for the purpose of seeking disaster relief and not early must be within the low limit.

He was joined by Sen. George Bellmon and Dewey Dettmer and Rep. John N. Latta in the request for disaster area declaration.

The three legislators requested increases to the federal disaster agency and the Federal Emergency Management Administration, for authorization of low water levels.

He said that Ray, Norman, McClain, English and Grant counties be included in the disaster area. The request was sent to the governor. He said the governor would be as much as six feet out of its banks by Friday morning.

Dover officials reported Turkey Creek near the crest point Thursday afternoon as they began gearing up for the Cimarron

quest that you declare the five-county area a national disaster area."

Cities on major rivers below the regions of phenomenal rainfall prepared for the worst as waterways became bloated to the point of inundating instruments used for determining water levels.

Enid was left in a shambles after witnessing more rain falling in one location in Oklahoma than had been seen for more than 30 years.

The National Weather Service announced at 4 p.m. Thursday that the official 13.68 inches recorded there made the barrage an all-time record for an Oklahoma rain storm, breaking the record previously held by Sapulpa, where 13.39 inches fell in 1940.

The city of Dover, 20 miles south of Enid on the Cimarron River, was already reeling from flooding on Turkey Creek when the Weather Service issued a warning that the Cimarron would be as much as six feet out of its banks by Friday morning.

Dover officials reported Turkey Creek near the crest point Thursday afternoon as they began gearing up for the Cimarron

surge expected to hit early Friday.

Upstream, readings at Okeene indicated the rampaging river should crest near 17 feet in Dover and be nearly three feet out of its banks downstream at Guthrie and Perkins late Friday morning.

Farmers and persons close to the river from Dover downstream to near the Keystone Reservoir were warned to move animals and machinery to areas of safety above the expected flood levels.

Meanwhile, the Chickasaw and the Salt Fork of the Arkansas in the Blackwell and Tonkawa areas were routing residents from their homes with high water that broke all-time river level records.

The Weather Service reported the Salt Fork more than 11 feet above flood stage, standing at an estimated 28 feet at 3 p.m. Exact measurements were impossible because the river measurement gauge was under water.

The swelling water was expected to crest at an incredible 34 feet — more than 16 feet above flood stage — early Friday morning.

Tonkawa police reported nearly two dozen persons had been plucked from

roof tops by helicopter Thursday and rescue crews were out looking for scores of others reported still missing.

Motorists along I-35 were caught between flooded low spots on nearly every stretch above water. Similar conditions were reported on the highway for southern Kansas.

School gymnasiums and churches in Tonkawa were set up as emergency centers for stranded travelers.

In Blackwell, the raging Chickasaw River was standing at 33 feet and still rising Thursday, as several residents were still unaccounted for, according to police.

More than 100 homes and businesses were destroyed or heavily damaged by the water, and boats and National Guard helicopters were crisscrossing the area searching for the stranded and injured.

The highway patrol said nearly every Kay County road, except for U.S. 60 and U.S. 177, was inundated and impassable.

Numerous bridges, including a railroad bridge on U.S. 64, were reported washed out or damaged, and travel was discouraged.

South and east of the hit areas, Ponca City was bracing for a crest on the Arkansas River of more than five feet above flood stage by Sunday.

Downstream, Ralston was warned to expect four feet of flooding as the swell hits over the weekend.

The U.S. Army Corps of Engineers office in Tulsa prepared for a heavy rise in the water volume at Keystone Lake, where the Canadian and Arkansas meet, when the deluge hits on Sunday.

A corps spokesman said some 25,000 cubic feet of water per second was being released from the reservoir Thursday and a much larger release, perhaps as high as 70,000 cubic feet per second, was being considered for near midnight Thursday.

The spokesman said the large release was not definitely set late Thursday, and that corps officials would re-evaluate the situation Friday morning.

Fair to partly cloudy skies are predicted for the state Friday, with afternoon highs mostly in the 70s. Oklahoma City is forecast to be mild and partly cloudy, the high approaching 75.

Rainfall Table

Rainfall amounts recorded throughout the night and Thursday included the following:

No 'Carefaker' In Nixon Plans

Continued From Page One
would forego choosing a nominee who might prove a strong contender for the 1976 GOP presidential nomination, a limitation urged upon the President by many Democrats in Congress.

"I would not limit the President's options in seeking a successor," Warren replied, underscoring the description of Nixon's attitude as expressed by other associates.

The President's distaste for selecting a caretaker candidate came soon after the reporting of a strong undercurrent of bipartisan opposition to John B. Connally, who is regarded as a leading potential contender for the 1976 GOP nomination. One congressional source made a flat prediction that a Connally nomination would be rejected by the Senate.

As described by associates, Nixon's approach to the search for an Agnew successor would be wholly consistent with making Connally his final choice. The former Democratic governor of Texas who became a Republican in May is the only man Nixon has twice lauded publicly as eminently qualified to be president.

Nixon, in finding a replacement for Agnew, had called on Republican

Teachers Get Party Notice

Continued From Page One
given out. An exception might be an answer to a state Department of Education request for its use to serve a specified educational function, he said.

"I haven't given permission for any use of the list," he said. He also said he knew of no request for use of the list.

Dr. Harris said Thursday he was not sure where the names for the mailing were obtained, but he said response to the mailing has been exceptionally good, indicating widespread support for the governor among teachers in his anticipated campaign for re-election next year.

He said the general response also has been good but he was not in a position to estimate the turnout. The Myriad Arena can seat 12,000.

The event will mark Gov. Hall's 43rd birthday.

The convention Oct. 18 and 19 at the Myriad is expected to attract 20,000 state teachers.

Christmas Tree To Be the Last

WASHINGTON (AP) — A 40-foot Colorado blue spruce arrived on the Ellyse behind the White House Thursday as the new and this time perma-

The Hall gala scheduled for 8 p.m. Oct. 20 will feature as speaker Sen. Henry Jackson of Washington, a possible presidential candidate, along with entertainer Glen Campbell.

Judge Chases Jury Truants

Continued From Page One
ries.

"It usually takes between 18 and 40 prospective jurors for each trial until lawyers agree on 12 who will sit as jurors in the case," Owens said.

Often, many of the returns for jury service are returned by the post office with a notation that the person called no longer lives at that address.

But there were 60 whose summonses were never returned, indicating they got their letters but disregarded them, the judge said.

"This was highly disturbing to me and I discussed it with the other district judges and decided to bring these people in a

Hunt for Victims Continuing

Continued From Page One
patients were moved from their homes were lysed and isolated commu-

Tues. Oct. 9, 1973
 3900 Cashion Pl.
 Oklahoma City, Okla 73112

Atomic Energy Commission
 Washington D.C.

Gentlemen:

Since the writing of our letter of October 1, 1973 we have reviewed the AEC Public Records at the Public Library, Guthrie, Okla. We commend you for the excellent attitude of candor and openness that this concept represents. It is appropriate affirmative action in respect to the public right to have access to the relevant facts. We were also impressed with the directness and thoroughness of the AEC inspection reports of the Cimarron facility and the related AEC correspondence with the Kerr-McGee Corp.

As a consequence of this review, we offer the following additional commentary:

1. We are furious because Mr Finn and Mr Ridgeway verbally gave us a public-relations type picture of a well conducted operation at Cimarron; one that held no unusual safety hazards for the employees. This is in sharp contrast to the general conditions that they reported in their inspection of the Cimarron Plant on June 18-22, 1973. In that report we noted seven new violations, three significant new problems and comment that six previously reported violations were still unresolved. Further, on page 8, under Management Interview it reads: "... The inspector discussed the violations. He stated that most of the violations indicated a lack of concern for following procedures and posted limits and also an absence of management audit of performance of employees and enforcing compliance with the procedures."

The previous inspection reports also cite various failures in procedures and documentation, as well as several fires (March 5 1973 and October 18, 1972) and several excessive exposures of employees. (March 5, 1973 and Nov.11, 1972.)

This situation seems to typify the conflict that some of your personnel have between telling the public the unvarnished truth and promoting nuclear power. While their inspection reports were candid about the safety conditions, they verbally seemed to be protecting Kerr-McGee.

2. The content of the news story to Jim Reid of the Daily Oklahoman of Sept. 29, 1973 by your Chicago office is misleading. It reads "... Kerr McGee Corp. has received a clean bill of health from the Atomic Energy Comm. following an investigation of a minor leak of nuclear material at its Cimarron facility." While this is probably Mr. Reid's reasonable conclusion, based on what he was told, it leaves an overall impression that does not correlate well with the general conditions outlined in your June inspection report. The fact that some violations were involved was buried at the end of the story, therefore, the lead line will tend to be slanted. That is slanted news.

2.

Further, the story indicated that the plutonium nitrate waste had a low level of radioactivity. That seems to conflict with verbal AEC reports to us that is over 100,000 dpm. Further the story categorically conflicts with the inspection report of June 18-22, 1973, page 17, C. "Higher concentrations are solidified for dis-

posal through a licensed waste disposal agency." (Low level liquid wastes being disposed via holding tanks, evaporation ponds, lagoons and the Cimarron River.)

Elsewhere in the story, confusion is again created by giving the right answer to the wrong problem. We were well aware that the mass of plutonium in the 55 -gallon drum was so small that it could not go critical. We resent that type of smoke screen news, or to suggest that the overall topic of criticality at the plant is not germane. For example, your inspection reports document inadequate spacing of "milk drums" (criticality) and inadequate shielding/separation to minimize neutron action. Further, on the overall subject of accidental nuclear criticality vs design features to prevent it, the March 12, 1973 letter (ITS-014) from the Directorate of Licensing to Kerr McGee states: "You properly point out that the probability of a criticality incident is effectively minimized by design features and appropriate procedures. However a criticality incident is creditable. We therefore request that the consequences of criticality be more thoroughly and quantitatively analyzed."

Consequently, in view of your documented reports of Kerr-McGee's inability to write and enforce adequate operating procedures, or to assure the reasonably constant availability of a radiation physicist, our faith is a little strained in respect to not having a criticality accident. Further, there is no compelling evidence that the design competency will be better than the operational competency.

Further, the story infers the trivial nature of record keeping problems, however; the license and inspection reports seem to indicate that the maintenance of accurate data at the glove boxes and the accountability of fissionable material are significant. In view of the incredibly carcinogenic nature of plutonium, it would seem that precise accountability would be highly important.

Again, we do not find the statement "... But as long as the contamination is contained on the plant site there is no danger," to be acceptable. High winds and cloudbursts do not respect plant fences and may carry away some plutonium waste. Gone With the Wind may apply to the population as well as the plutonium. From a long range cumulative aspect, which is the only rational way to view so incredibly dangerous and long persistence material, any emission must be viewed with alarm. A 99.99 % containment of plutonium, for example, would be quite unacceptable.

3. We conclude, from the above, that the public's right to know the facts would be better served if news releases were prepared in Oklahoma based on the AEC public records.

3.

4. We note a serious conceptual oversight in license requirements for the technical staff, i.e. redundancy or readily available qualified back-up for key technical personnel when attrition occurs. Attrition is particularly inherent in the employment of highly educated and skilled personnel.
5. Another conceptual oversight in staffing policy was not anticipating the possibility of labor-relations problems and consequently not having sufficient depth in technical supervision to maintain both production and safety with management type of inexperienced workers as production personnel.
6. Another concept that you need to consider is one that has been found to be valid in many industries. That the foreman is the key to effective occupational safety. He must be strong enough to insist on either safe production or no production, no production-no pay. This means that the foreman must be equally competent in production, safety and human / labor-management relations. Since the foreman represents management, it is absolutely essential that management policy and practices be conducive to good labor-management relations. Further, when an enlightened policy prevails, another positive force may appear-- a good union will chastise its own members for violations of safety rules.

In view of the problem in safety, attrition and labor relations, as documented in the public records, we conclude that there is a cause-effect relationship between management's labor policies and the safety record. This therefore raises doubts as to Kerr McGee's ability to understand and cope with the complex mix of requirements and performance stipulated by the plutonium license.

7. We were appalled by the many violations and personnel exposures documented in your reports. In view of the over-exposures to plutonium, we conclude that some of the workers will die, possibly 5 to 15 years hence. It is a shame that people so often have to be protected from those charged to protect them.
8. It has now become so very obvious why we received the telephone calls from the anonymous workers at the plutonium plant. Incident after incident- report after report- words after words, and no improvement occurred. Apparently it was "no big deal" to management. In view of all of the foregoing, the workers called us out of concern, frustration, and a feeling of powerlessness.
9. It would appear, in spite of its inspection reports, the AEC has indulged Kerr McGee management, showing that it has not yet commanded the adequate attention of their top management.
10. The plutonium license was issued on April 2, 1970, however as indicated by public records, the AEC Directorate of Licensing, in their letter of May 12, 1973, is still trying to obtain responses

- 4 -

from Kerr-McGee relative to various aspect of the Environmental Impact Statement. Since the Public Record contains no further information, we assume that the Directorate could not yet have reached a decision because to have done so would deny the public the facts upon which such a decision would have to be based.

11. There is evidence, in the Public Records, of the patent lack of good faith on the part of Kerr McGee in respect to the public's right to know the facts. It appears that Kerr McGee did not want to be a "Good Neighbor" in the community in that it wished to conceal from the public that it was manufacturing a highly, carcinogenic and persistent material. For example, in their letter of April 17, 1973 to the AEC Directorate of Licensing; first paragraph.... "Moreover, we believe that some of the information requested should not be included in the environmental report, and request your consideration of our proposal to omit the items discussed below from our submittal. The items of information which Kerr McGee objects to having included in the environmental report are those items indicated by the following listed questions of your letter of March 12:

1. Purpose of Facility

1. What....
2. Do you have ...
3. What would be ther...

2. The Site (b) Local environmental acceptance

1. What has been done in public relations to gain the acceptance of a plutonium plant in the region?
2. Have there been any local groups actively supporting or rejecting the concept of a plutonium plant?
3. Have you held any public meetings or hearings for the purpose of discussing the plant activities?

7. Alternatives (a) and (b)

1. Discuss the consequences of shutting plant down.
2. Discuss the impact of.....
3. Discussion for....

We do not believe that the above questions are proper subjects for inquiry in an environmental study. The information solicited will not contribute significantly to a better understanding of the environmental impact of the operation of the Cimarron Plutonium Plant. We realize that.... However we would prefer to furnish such information to the Commission by separate, private communications rather than having it included in a public record. Please let us know if you concur with our proposal to omit the answers to the above questions from the supplemental information to be submitted. If so, we would be willing to make the information requested by these questions available to the Commission if not for the Commission's purposes.

-5-

George B. Parks
Executive Vice President
Kerr McGee Corp. "

Consequently, contrary to the intent of the Calvert-Cliff's decision (July 23, 1971 Federal Court of Appeals) to date the public right-to-know has been abridged. None of the environmental groups have been advised of the existence or the dangers of having a plutonium plant in their midst. Likewise the news media and most key citizens interested in the environment did not know. On the other hand, AEC did not take any strong affirmative action to tell the public about the plant, nor was there any strong and effective action to tell the public about the Public Records at Guthrie, Okla. The AEC has been part of the information problem, not withstanding the excellent concept of public records. Consequently, had it not been the coincidence of being called by the anonymous workers, we and the public would still be unaware. This is a completely unacceptable situation. We recognize, however that in the AEC letter of May 12, 73, AEC emphasized that Kerr-McGee must respond.

13. In view of Kerr McGee's lack of good faith towards the community and its public health, its lack of interest in plant safety, it would appear to be in the public interest to revoke their plutonium license. We would hope this could be accomplished through the established administrative channels of the AEC. 18
14. Please advise us of the pertinent details of when and where the formal Environmental Impact hearing will be held for the Plutonium Plant at the Cimarron Facility. 19

Thank you,

Llene H. Youngkin

By Mr. Donahue, Chicago

Enclosure: Newspaper Clipping

Kerr-McGee Agenda

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

JAN 11 1974

Mr. and Mrs. Gaylord Younghein
3900 Cashion Place
Oklahoma City, Oklahoma 73112

Dear Mr. and Mrs. Younghein:

This is in reply to your letters dated October 1 and 9, 1973, expressing your concerns relating to the operation of the Kerr-McGee Corporation's Cimarron facility located in Crescent, Oklahoma.

With respect to the allegations relating to the leakage of plutonium waste, which you brought to the attention of the Atomic Energy Commission on August 29, 1973, we conducted a comprehensive investigation at the Cimarron facility during the week of September 17, 1973. Our investigation findings concerning these allegations, which were discussed with you by our inspectors on the evening of September 19, 1973, are summarized in the attached Enclosure 1.

I am also enclosing for your information a copy of a report covering our most recent inspection at the Cimarron facility (Enclosure 2). This report discusses our inspection findings with respect to Kerr-McGee's handling of radioactive waste at the Cimarron facility and addresses many of the questions and comments raised by your letters. With respect to the other matters in your letters not covered by our inspection report, we have prepared answers which we believed to be responsive to your concerns. This information is provided as Enclosure 3.

In your letter of October 9, 1973, you expressed concern for the "public relations type picture" our inspectors gave you concerning operations at Cimarron. I regret the apparent misunderstanding in this regard. The intent of our inspectors in meeting with you on September 19 was to provide you with factual information. The statements given to you by our inspectors were directed toward the corrective efforts relating to the decontamination associated with the waste drum leak to assure you as a concerned citizen that no safety hazards were identified with this operation. They did not intend to infer that plant operations had been trouble free.

As you pointed out in your letter, there have been inspection findings by AEC inspectors in regard to the activities conducted at the Kerr-McGee Cimarron Fuel Fabrication Plant where noncompliance with Commission

Mr. and Mrs. Gaylord Younghein

- 2 -

rules and regulations have been identified. Again, as you have noted, these findings are documented in inspection reports which are a matter of public record and available at the Public Document Room in Guthrie, Oklahoma. Measures to correct the specific deficiencies have been taken; however, as a result of the deficiencies identified by our inspection program during the past year, we met with Mr. McGee and other corporate management representatives on November 2, 1973, to discuss our concerns in this regard and the need for improving the quality of operations of the Cimarron facility. We plan to continue to audit operations at the Cimarron facility to assure that appropriate corrective actions have been taken with respect to the identified weaknesses and deficiencies.

The Regulatory Operation's primary role is to protect the health and safety of the public and our continuous program of inspection is aimed at satisfying this commitment. When Commission rules are violated, we will take appropriate action to achieve full compliance.

I trust this letter and the enclosed information will be of assistance to you.

Sincerely,

James G. Keppler
Regional Director
Directorate of Regulatory Operations
Region III
799 Roosevelt Road
Glen Ellyn, Illinois 60137

Enclosures:

Enclosures 1 thru 3

ENCLOSURE 1

SUMMARY OF ALLEGATIONS AND INVESTIGATION
FINDINGS - KERR-McGEE CIMARRON FACILITY

On August 29, 1973, the Director, Directorate of Regulatory Operations, was advised by the AEC Chairman's Office that allegations had been received regarding "spills of plutonium" and some "leaking tanks" at the Kerr-McGee (K-M) Crescent, Oklahoma, plutonium (Pu) fuel fabrication facility.

The specific allegations and our investigative findings related to these allegations are summarized below:

Allegation No. 1: An incident of a leaking plutonium waste drum allegedly occurring on or about August 25, 1973, should have been reported to the AEC. The occurrence of three other similar incidents were alluded to. In general, unsafe working conditions with respect to the spill clean-ups were alleged.

Findings: From a review of testimonies of employees involved in decontamination efforts and management representatives as well as K-M records, it was established that the leakage from a drum containing plutonium nitrate waste was discovered at 0755 on Saturday, August 18, 1973, during a routine yard check by a Health Physics Technician. The leak occurred from a single drum which was stored in a stationary truck van located on the licensee's property. Storage of waste in this van is permitted by License No. SNM-1744. The van is used for temporary storage of dry solid waste and solidified liquid wastes pending its pickup and transfer offsite by Nuclear Engineering Company truck to burial sites at Morehead, Kentucky, or Sheffield, Illinois.

The leaking drum of "solidified" waste discovered on August 18, 1973, was one of four such drums in the van. The remaining drums in the van were dry waste. During the course of the investigation it was established that a problem with the liquid waste solidification process was experienced. This problem contributed directly to the leak. This same solidification problem was experienced with the waste drum leaks noted to have occurred on July 22, 1972, April 23 and 24, 1973, and May 7, 1973.

Contamination, resulting from the August 18, 1973, leak, was confined to the storage van, its undercarriage and a small area of ground immediately below the leaking drum. All decontamination was conducted under the supervision of qualified K-M Health Physics personnel. There was no personnel contamination, exposure or release of material offsite. Interviews with numerous employees and a review of records failed to substantiate the allegation of unsafe working conditions.

- 2 -

Allegation No. 2: Two employees were "recently given letters of reprimand for having left the site in a contaminated condition." No date of this occurrence was furnished as a part of the allegation. Concern was expressed that contamination may have been deposited at a cafe used by two employees.

Findings: The incident referred to above was documented in K-M records. The contamination incident occurred on April 17, 1972, at approximately 0700 in one of the glove boxes in Room B-02 of the wet ceramic area. The men became contaminated while performing maintenance on a pump.

The investigation did confirm that the men had received reprimands for having left the site in a contaminated condition on April 17, 1972, in violation of established K-M internal procedures. The offsite areas visited by the two employees were not surveyed by K-M. This failure by the licensee constitutes noncompliance with Section 20.201(b) of 10 CFR 20.

Allegation No. 3: That licensee reports dealing with the recent drum leakage incident, (see Allegation No. 1) should be "backdated" to reflect the date of occurrence as August 18, 1973.

Findings: No information was developed to substantiate this allegation.

Allegation No. 4: A K-M plant at Cushing, Oklahoma, where thorium was allegedly being processed had experienced some explosions and was "out of commission." It was alleged that workers were tearing out walls that were contaminated and welders were cutting structural steel. No time frame for this allegation was given.

Findings: Based on information provided by Region IV and K-M management, it was found that the K-M Cushing plant had been sold approximately two years ago to Dewey Enterprises, Inc. K-M performed no thorium processing at this plant since mid 1960's.

AEC License No. SNM-695, which authorized processing thorium at the Cushing plant was terminated on July 6, 1966. Prior to license termination, Region IV performed an inspection at the plant and found that less than de minimus contamination levels existed. With respect to the explosions, it was learned from RO:IV that hydrogen explosions had occurred at the Cushing plant during June 1965 and February 1966, however, no radioactivity was involved.

ENCLOSURE 2

U. S. ATOMIC ENERGY COMMISSION
DIRECTORATE OF REGULATORY OPERATIONS

REGION III

RO Inspection Report No. 070-925/73-05
RO Inspection Report No. 070-1193/73-06

Licensee: Kerr-McGee Corporation
Kerr-McGee Building
Oklahoma City, Oklahoma 73102

Cimarron Facility
Oklahoma City, Oklahoma

Licenses No. SNM-928
and No. SNM-1174

Priority: I
Category: A(1)

Type of Licensee: Special Nuclear Material

Type of Inspection: Routine, Unannounced

Dates of Inspection: September 17 - 21 and 26, 1973

Dates of Previous Inspection: June 18 - 22, 1973

Principal Inspector: *K.R. Ridgway*
K. R. Ridgway

11-5-73
(Date)

Accompanying Inspector: J. A. Finn

Other Accompanying Personnel: J. F. Donahue

Reviewed By: *G. Fiorelli*
G. Fiorelli, Chief
Reactor Operations Branch

11/5/73
(Date)

SUMMARY OF FINDINGSEnforcement Action (License SNM-1174)

The following violation is considered to be of Category I severity:

10 CFR 20.103 states that "No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual in a restricted area to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table I, of this part." The limits are based upon exposure to the specified concentrations for forty hours in any period of seven consecutive days.

Contrary to the above, during the week of July 8 - 14, 1973, an employee working at a slot box in the plutonium laboratory was exposed to airborne concentrations of plutonium, which, when averaged over forty hours, were 1.3 times the specified limits. (Paragraph 23)

The following violations are considered to be of Category II severity:

- A. Condition 27 of License SNM-1174 states, "Nuclear poisons used for secondary nuclear safety control shall be limited to borosilicate glass Raschig rings and the use of such rings shall be in accordance with the proposed ANS standard, "Use of Borosilicate-Glass Raschig Rings as a Fixed Neutron Absorber in Solutions of Fissile Material," published in the Nuclear Engineering Bulletin, 3 - 3, November 1965, by the American Nuclear Society. This condition supplements the specification regarding use of nuclear poisons on page 21, Appendix A of the application."

Contrary to this the required inspections in the proposed November 1965 standard and the subsequently approved ANSI standard N16.4-1971 have not been carried out. Only one inspection of the rings has been made since plant startup and this inspection did not fulfill the requirements of the standards. (Paragraph 18)

- B. Condition 28 of License SNM-1174 states, "This license does not authorize the delivery of licensed material to a carrier for transport except as may be authorized pursuant to 10 CFR 71."

Section 71.10 of 10 CFR 71 states that an exemption to the requirements of this part of the regulations is permitted when delivery of a type B quantity of radioactive material, as defined in paragraph 71.4(q), to a carrier for transport is accomplished in accordance with the provisions of a special permit, which has been issued by the Department of Transportation and is in effect on June 30, 1973.

On two occasions the special DOT permit requirements governing the shipments were not fully adhered to in that wastes shipped for burial were not in the dry solid form. In one case the shipment received on July 11, 1973, was made in a "Poly Panther," DOT SP 6272 package, which held one waste drum containing liquid, thus violating the conditions of the DOT permit. This shipment therefore did not comply with the provisions of Section 71.10 and 71.12 of 10 CFR 71 in that a general license was not secured to cover the shipment, which contained the waste drum of contaminated liquid.

In a second case the shipment received on June 5, 1973, was made in a "Super Tiger," DOT SP 6400 package. When the "Super Tiger" package arrived at the burial site it held three drums which contained liquids. This shipment which is governed by a special license (SNM-338) did not comply with the terms of the license nor 10 CFR 71 Section 71.12(b) in that the inner packages containing liquids did not meet the drop test requirements specified by paragraph 173.393(g) of the DOT regulations. (Paragraph 20)

- C. Item 8 of license SNM-1174 states that the licensee will operate the Plutonium Plant in accordance with the statements, representations and conditions contained in Appendix A of the application dated March 3, 1969, and supplements dated August 28, 1969, January 2 and 12, 1970.

Appendix A specifies the Nuclear Group organizational structure with management and technical position responsibilities and the training and experience requirements for these positions.

Contrary to the requirements of Appendix A of license SNM-1174 the licensee, late in 1972, significantly changed the organization structure of the Nuclear Manufacturing Group and the Physical Science and Measurement Department, combining responsibilities of health and safety technical positions, eliminating other positions and filled the License and Safety Officer position with an employee whose experience does not meet the requirements of Appendix A of the license. This organization structure change has not been formally reported to the Commission. (Paragraph 2)

- D. 10 CFR 20.201(b) states that "Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part."

Contrary to the above, no offsite surveys were performed on April 17, 1972, to evaluate the consequences of two contaminated employees leaving the Cimarron Plutonium Plant on that date. (Paragraph 25)

The following violations are considered to be of Category III severity:

- A. Condition 18 of License SNM-1174 states, "The licensee shall prepare and retain for Commission review a management appraisal of the effectiveness of the actions taken following each one-hour tornado warning taking into account the types of operations being conducted, the forms and quantities of plutonium involved, the forms and quantities of plutonium removed to the vault and remaining outside the vault following the one-hour warning actions, number of persons involved, time required to complete the actions and improvements indicated."

Contrary to this, on May 24, 1973, and June 4, 1973, one-hour tornado alerts were received by the licensee and the required management appraisals were not documented. (Paragraph 13)

- B. 10 CFR 20.401(b), requires, in part, that each licensee maintain records of the results of surveys required by 10 CFR 20.201(b).

Contrary to the above, records were not maintained of the results of surveys for contamination on the solid waste storage trailer prior to coating with paint in August 1973. (Paragraph 26)

Licensee Action on Previously Identified Enforcement Action

A. License SNM-928

1. The licensee failed to provide required valve protectors for UF₆ cylinders in storage.
 - The licensee has obtained additional valve protectors and has instructed personnel on this license requirement.
2. In two cases, the licensee stored fissile material within 12 feet of a concrete donut storage array contrary to posted safe operating limits.

The licensee has revised the posted limit so that storage within 12 feet of the array is permitted if the outer row of containers in the donut array do not contain fissile material. Employees have been reinstructed.

3. The licensee stored a container of fissile material in an unauthorized location.

The situation was immediately corrected and employees reinstructed in the correct storage of fissile materials.

4. The licensee stored several overloaded pellet boats in violation of procedures.

Employees were reinstructed in the correct storage of these boats.

5. Containers of stored high enriched material were unlabeled as to the fissile content.

The containers were counted and properly labeled. Employees were reinstructed in properly labeling fissile containers.

The above matters are considered resolved.

B. License SNM-1174

1. The licensee failed in two cases to follow posted safe operating limits in Glovebox 40 when the number of permitted containers was exceeded and the minimum spacing limit between containers violated. The condition was corrected.
2. The licensee failed to post Glovebox 1A to show the quantity of fissile material present.

The glovebox status sheet was posted.

The above items are considered resolved.

Unusual Occurrences

- A. On July 18, 1973, the licensee informed Region III by telephone of the exposure of an employee to about 1.3 times the 40-hour MPC for airborne concentrations of soluble plutonium during the period July 8 - 14, 1973. The exposure occurred at a slot box in the general laboratory at the Plutonium Plant. Bioassay samples showed no detectable uptake of plutonium. The telecon was confirmed by a written report dated July 31, 1973, submitted to the Commission pursuant to 10 CFR 20.405(a)(1). (Paragraph 23)
- B. On July 18, 1973, the licensee informed Region III by telephone of contaminated air samples from several locations in the plutonium laboratory for the period July 3 - 4, 1973. Involved employees were restricted from certain work until bioassay results were received. Urine and fecal samples showed no detectable uptake of plutonium. The licensee concluded from his investigation that the air samples were not valid and that significant exposures did not occur. Analyses, bioassay records, and licensee evaluations were reviewed during the inspection. (Paragraph 24)

- C. On April 17, 1972, an operator and two maintenance men became contaminated while replacing a pump in a glove box in the wet ceramic area. The maintenance men left the plant without adequately checking themselves for contamination. When leaving the process area, the operator found he was contaminated. Surveys of the two maintenance men when they returned to the plant revealed contamination on hands, face, hair, and personal effects. Several spots of contamination were found in a personal car used by the two men. All three employees were decontaminated successfully. Urine and fecal samples showed no detectable uptake of plutonium. (Paragraph 25)
- D. On August 18, 1973, liquid was discovered leaking from a stationary trailer van used for waste storage at the plutonium loading dock. The source of the leak was one of four 55-gallon drums containing low-level plutonium waste which supposedly had been solidified for shipment to a licensed disposal agency. Decontamination of the trailer and replacement of contaminated gravel beneath the trailer took 11 days. There was no personal contamination and no release offsite. (Paragraph 26)

Other Significant Findings

A. Current Findings

1. The licensee had been given QA clearance on the FFTF pin contract and was preparing to proceed with fuel fabrication.
2. Activity at the Uranium Plant was limited to waste recovery and maintenance work. The ceramic and pellet lines were expected to start up in November 1973.
3. License SNM-928 has been amended to lower the uranium possession limit. (Paragraph 6)
4. No licensing action has been taken on facility organization and personnel changes. (Paragraph 2)
5. Waste handling at the Plutonium Plant was reviewed. No problem areas other than waste solidification were detected. (Paragraphs 19, 20, and

B. Status of Previously Reported Unresolved Items

1. The Nuclear Safety Officer and the Licensing and Regulations Officer required in Appendix A and Appendix B have not yet been replaced with qualified personnel. The audit and criticality safety function continues to be performed by BNW consultants. (Paragraphs 3 and 8)

2. The new position of Health and Safety Coordinator and other organizational changes from that shown in the licenses and the amendment applications submitted in 1968 and 1971, and having to do with the Nuclear Operations Group's safety program have still not been resubmitted for Directorate of Licensing's consideration.^{1/}

3. A glovebox criticality safety drain system recommended by the Criticality Safety Officer was found to be installed but due to the size of the drain lines and their vulnerability to plugging, it is questionable that there will be an effective safety system in the present state.

The licensee has placed screens in the gloveboxes to protect the drains; however, the screens were not fastened down and in one glovebox the screen was found across the box from the drain. The licensee stated that the screens would be fastened over the drains.

4. A Change Review Request (CRR) form has been used informally in connection with facility changes. The CRR system requires a criticality, radiological and/or industrial safety review and a review for agreement with license requirements, before the change is initiated. No formal procedure existed for handling these CRR forms.

A formal procedure for administering the CRR system has been drafted and is circulating for approvals. (Paragraph 7)

5. Technical support in the area of radiation protection was previously questioned. The licensee has not as yet considered improvement in this area.

The above items will be reviewed during the next inspection.

Management Interview

Two interviews were conducted at the conclusion of the inspection; one at the corporate offices, and one at the Cimarron Plant. The following individuals were present during the interviews:

P. S. Dunn, Vice President, Nuclear Manufacturing
W. J. Shelley, Director, Regulation and Control
M. Moore, Manager, Cimarron Facility
G. J. Sinke, Health and Safety Coordinator
K. Hendrick, Attorney

1/ RO Inspection Reports No. 070-925/72-03 and No. 070-1193/72-03.

G. M. France, III, License and Safety Officer
R. J. Adkisson, Contract Relations Representative
R. L. Kiehn, Superintendent, Maintenance
J. V. Marler, Superintendent, Plutonium Plant
D. Rhodes, Superintendent, Uranium Plant
B. J. Buntz, Manager, Engineering and Technical Service
R. Janka, Manager, Administration and Accounting
A. W. Norwood, Manager, Health Physics and Industrial Safety

The inspectors reviewed the corrective actions taken on previous enforcement actions and stated that the corrective actions appeared to have been implemented. He also remarked that evidence had not been given to confirm that instruction had been given to employees concerned with the previous operational violations. The licensee stated that most of these instructions had been recorded as material covered in shift safety meetings.

The inspectors stated that several apparent violations as listed in the Enforcement Action section had been detected and these were reviewed.

The recent leakage of dilute plutonium waste solution from the drum stored on the storage van was discussed. The inspectors stated that the actions following the detection of the leak appeared to be proper and the cleanup was accomplished in a safe manner. It was stated, however, that the recurring problems of unsolidified waste had not been thoroughly investigated in the past as leakages had reoccurred. The inspector stated that in addition to the study being carried out on the compatibility of the waste material with urea formaldehyde, a study should be made to determine the required mixing of the two components before and after adding the catalyst.

The inspectors stated that further solidified waste shipments should cease until the associated problems were resolved. The licensee agreed to this and stated he would advise RO:III of the resolution of the problem prior to further shipping.

The inspectors requested that the licensee document the history and associated problems that he has experienced in their liquid waste solidification program. The licensee plans to do this. However, he stated that in the past they had not received feedback from HQ representatives from the documentation of specific problems that had been submitted, i.e., their evaluation of the bag-out fire early in March 1973.

The licensee was advised that management should review their health physics staffing, since staffing inadequacies appear to be a cause of survey record deficiencies and frequent cancelling of routine health physics surveys.

11. Previously Reported Unresolved Items

a. Pellet Shipping Container Inspections

A procedure had been drafted to schedule periodic inspections of the pellet shipping containers as required by a license condition. The procedure specifies the:

- (1) Frequency of inspections.
- (2) Containers to be inspected.
- (3) Void level permitted.
- (4) Void level where additional vermiculite must be added.

b. Solution Vacuum Cleaner Muffler

The inspector observed that a CRR had been submitted for the safety analysis of the solution vacuum cleaner. It was being reviewed by BNWL.

There are no further questions on the above matters.

Plutonium Plant

12. Status

On September 14, 1973, the licensee received the QA certification and notice to proceed on the FFTF fuel contract. Activity during the inspection was limited to cleanup and maintenance of the facility in preparation for the production run.

13. Tornado Warnings

During 1973, the licensee received two one-hour tornado alerts on May 24 and June 4. These notifications were recorded in the guards's Daily Log Sheet and in the Operations Log. No record of the management's evaluation of the facility's tornado alert procedures and actions following an alert was available as required by the license. A licensee representative stated that one evaluation had been documented but it had been lost. The brief notations of the alerts in the log book were not considered to be a proper evaluation of the procedures and actions taken. Failure to document evaluations is considered a violation of Condition 18 of License SNM-1174.

This condition supplements the specification regarding use of nuclear poisons on page 21, Appendix A of the application. The proposed ANS standard referenced in the license conditions has since been revised and issued as an American National Standards Institute standard, ANSI N16.4-1971 which has been adopted as an acceptable procedure in Regulatory Guide 3.1. The required sampling and testing of the rings in the proposed standard were more rigorous than those required in the present standard which now requires inspections for:

- a. Ring setting
- b. Solids Accumulation
 - (1) in the tank
 - (2) on the rings
- c. Physical Properties of the Rings
 - (1) mechanical condition (broken, cracked or chipped ring)
 - (2) Boron content

The frequency of inspections in the proposed standard was stated as "at frequent intervals" while the inspection frequency is specified as a minimum of once every 13 months in the approved standard. An examination of the records indicated that only one Raschig ring inspection had been made (February 28, 1972) since the approval of License SNM-1174 on April 6, 1970. This is not considered to be at "frequent intervals" as required nor was there any record of analysis for boron content.

19. Waste Handling Process

a. Liquid Waste

Liquid wastes from the Plutonium Plant are separated into four streams:

- (1) Sanitary Wastes - Toilets only enter this stream which discharges into two sanitary lagoons that in turn discharge into the Cimarron River.
- (2) Change Room and Decontamination Room Wastes - Lavatories, showers and floor drains in the change rooms and decontamination rooms, and a sink in the laboratory discharge alternately into two 10,000 gallon underground tanks which are sampled and released to the sanitary lagoons when content concentrations are below the discard limit of one tenth MPC or 4.0×10^{-7} $\mu\text{Ci/ml}$.

- (3) Hot Laundry Waste Water - Waste from one washing machine is collected and sampled in a tank and discharged alternately to two 6,000 gallon underground tanks when the concentration is below MPC (4.0×10^{-6} uCi/ml). The underground tanks in turn are sampled again to assure the wastes are below MPC before discharge into the Plutonium Holding Pond.
- (4) Liquid Process Waste - Wastes from the scrap plant and wet ceramic filtrates are collected in geometrically favorable tanks and analyzed before transfer to non-geometrically favorable hold tanks. The plutonium concentration limit for the hold tanks is 0.03 g/l to assure that the safe mass limit (200 g Pm) is not exceeded. After the large tanks are full they are mixed and sampled, the pH adjusted using ammonia gas and mixed three parts to one with urea formaldehyde (UF) in 55 gallon drums for shipment offsite as solid wastes.

b. Solid Wastes

Solid wastes contaminated with fissile materials are collected in packages and are counted in the vault by the custodian. Recoverable material is recycled to the scrap plant. Unrecoverable wastes are packaged in 55 gallon drums for offsite shipment. Solid wastes, including the solidified liquids, are temporarily stored in a covered van outside the plant, but within the exclusion area until sufficient material is accumulated to warrant a pick up by Nuclear Engineering Company, Inc. (NECO). NECO uses either "Super Tiger," DOT Special Permit (SP) 6400, or "Poly Panther," DOT SP 6272 authorized packages to transport the solid wastes to either the Sheffield Nuclear Center, Sheffield, Illinois, or Morehead, Kentucky, burial sites.

A review of shipping records for solid wastes shipped from the Pu Plant since May 1972 showed that a total of 327 drums of solidified waste containing a total of 438 grams of plutonium had been shipped. One hundred seventy five drums were shipped to Morehead and 152 drums were shipped to Sheffield.

20. Low Level Plutonium Waste Leaks

a. Solidification Process

Prior to May 1972, the licensee used a flocculation-filtration process to remove plutonium-amerícium from process wastes. Wastes were discharged into a plastic lined holding pond when the concentration was below MPC (4×10^{-6} uCi/ml). Subsequent to this date, liquid process wastes were solidified in urea formaldehyde in preparation for transport

to licensed burial grounds. The solidification process is conducted in Room BO-2 of the Plutonium Building where the large liquid waste tanks are located. The dilute (less than 0.03 g/l plutonium) waste is solidified in drums fabricated to DOT Specification 17H which contain plastic liner bags. The solidification process requires that a measured 12.5 gallon volume of urea formaldehyde (UF) be placed in the drum into which 37 gallons of liquid waste, neutralized with ammonia, is added. The drum top is installed and the contents mixed for 15 minutes with a disposable agitator. The agitator is about 18 inches long with blades small enough to enter the drum bung hole. The mixture is then catalyzed by adding concentrated nitric acid (about 800 ml) until a pH of 1 is attained. The mixture is stirred another five minutes. After five minutes, when solidification starts, the agitator is released and lowered into the drum and the drum bung installed. The drum is checked for external contamination and if clean released by the Health Physicist. It is then transferred to the trailer van for storage. This process is continued until the large waste tank is empty.

b. Drummed Waste Leaks

Several leaks and contamination spreads have resulted from solidification process problems in the past.

(1) Leak of July 22, 1972

On July 22, 1972, liquid waste from a "solidified" drum leaked through the bottom of the trailer and contaminated a 2 1/2 foot diameter of ground below. Effective decontamination of the ground, inside of trailer and the dock was promptly accomplished by K-M.

The leak cause was attributed to incomplete solidification of the drum contents and was considered by K-M to be due to a bad batch of urea formaldehyde. The UF is purchased from NECO. NECO in turn obtains it from several vendors. The batch in question was more viscous than previous batches. Urea formaldehyde has a shelf life of about one year, and its viscosity increases with age.

The licensee's recommendations at that time to prevent further leaks were:

- (a) Test each batch of UF for hardening properties.
- (b) Use a heavier plastic liner (12 mil poly-vinyl chloride).

- (c) Use a different stirring rod for more effective mixing.
- (d) Require supervisory inspection before moving drums from Room B0-2 to the storage van.
- (e) Add absorbent material to the barrel to contain any remaining liquids.
- (f) Carefully lower stirring rod into the drum to prevent puncturing the PVC liners.
- (g) Use new barrels that had been leak tested.

Not all of these recommendations were incorporated in the written Liquid Waste Solidification Procedure, KM-NP-37-2, Revision 1, dated May 2, 1972, and presently in use. Discussions with employees disclosed that the recommendations were partially being followed.

(2) Leaks of April 24 and May 7, 1973

On two other occasions leaks attributed to leaking "solidified" waste drums had been recorded. On April 24, 1973, the loading dock was contaminated by leaking drums. On May 7, 1973, routine surveys detected contamination levels up to 10,000 d/m per 60 cm² on the ground under the trailer. Licensee records show that the trailer and dock were decontaminated and that contaminated gravel was removed for disposal as contaminated waste. Air sample records show concentrations below MPC. No exposures of offsite releases resulted.

Licensee representatives stated that early in 1973 almost every drum of solidified waste had residual liquid in it, liquid content varying from dampness to complete separation. Large volumes of residual liquid were removed back to the waste tank by vacuum transfer. Cement and Sorb-All were then added to the top of the drummed solid waste to absorb any remaining liquids. This was done before moving the drums to the trailer.

Each batch of waste was tested in the laboratory to assure that it would solidify. No problems were detected in the laboratory tests of small volumes.

On June 5, 1973, NECO representatives at Morehead, Kentucky, notified the licensee that three drums of solidified wastes in a "Super Tiger" package had been received from K-M. The liquid was subsequently solidified and the drums buried at the Morehead site.

During a visit on September 26, 1973, by the inspectors to the NECO Sheffield, Illinois, Nuclear Center, it was noted from records that on July 11, 1973, a shipment of solid wastes had been received from K-M with about five gallons of milky liquid in the bottom of the inner liner of a "Poly Panther" package. Absorbent was added to the liner to contain the liquid and the liner containing the drums was buried. According to NECO representatives no problems were encountered in either of these burials.

Condition 28 of License SNM-1174 states, "This license does not authorize the delivery of licensed material to a carrier for transport except as may be authorized pursuant to 10 CFR 71."

Section 71.10 of 10 CFR 71 states that an exemption to the requirement of this part of the regulations is permitted when delivery of Type B quantity of radioactive material, as defined in paragraph 71.4(q), to a carrier for transport, is accomplished in accordance with the provisions of a special permit, which has been issued by the Department of Transportation and is in effect on June 30, 1973.

On the two specified occasions the special DOT permit requirements governing the shipments were not fully adhered to in that wastes received for burial were not in the dry solid form. In one case the shipment was made in a "Poly Panther," DOT SP 6272 package, which consisted of one waste drum containing liquid, thus violating the conditions of the DOT permit. This shipment, therefore, did not comply with the provisions of Section 71.10 and also 71.12 of 10 CFR 71 in that a general license was not secured to cover the shipment, which contained at least one waste drum of contaminated liquid.

In the second case, the shipment was made in a "Super Tiger," DOT SP 6400 package, the "Super Tiger" arrived at the burial site it held three drums which contained liquids. This shipment which is governed by a special license (SNM-338) did not comply with the terms of the license nor 10 CFR 71, Section 71.12 in that the inner packages containing liquids did not meet the drop test requirements specified by paragraph 173.393(g) of the DOT regulations.

(3) Leak of August 18, 1973

See paragraph 26 for details.

21. Solidification Process Testing and Extent of Process Use

The licensee is currently conducting laboratory tests to ascertain the cause of "weepage," "breakdown" and "nonsolidification: of the urea

formaldehyde - waste mixtures. Cold tests were made with varying ammonium nitrate concentrations and mixtures of ammonium and sodium nitrate solutions. The tests indicated that solutions with ammonium concentrations above 7 molar failed to set up and in all cases weepage was observed. The tests using ammonium concentrations < 7 molar required from 10 to 30 minutes to harden and after 10 days the contents were still solid. Cold tests on sulphate salt solutions and hot tests performed on actual waste solutions from tanks 184 and 185 contained varying amounts of liquids after setting a few days.

Further laboratory testing had convinced the licensee that wastes neutralized with caustic instead of ammonia would set up and remain solid. Plant tests were to be conducted to confirm this process change.

Tests were conducted with cement as the solidifying agent with and without Sorb-All added.

Protective Packaging Industries (PPI), a subsidiary of NECO supplied another resin for testing. This resin was eliminated by K-M because its water holding capacity was much less than UF and it did not set up properly. A representative of PPI was contacted by Region III to obtain information on the use of UF as a solidifying agent and to determine if any other of their customers were encountering similar difficulties. The representative stated that although PPI had sold their Tiger-loc integrated radwaste system to about nine nuclear power stations, none of them as yet have produced any solidified waste with this system. The Palisades reactor will be the first to produce solid waste for shipment using this system, possibly by November 1973.

NECO has used UF to solidify liquid wastes at the Morehead site. An integrated system of proportioning meters combine the flows of waste and UF. They are mixed in an internal kinetic mixer after which a catalyst is added with additional mixing prior to discharge. Initially the wastes were discharged into lined open trenches and covered. Now the liquid wastes at Morehead are preconcentrated and solidified with UF into 55 gallon drums which are buried.

NECO and PPI do not have any other known users of UF but stated that Hittman Nuclear and Development Corporation (HNDC), a subsidiary of Hittman Corporation was also using UF as a solidifying agent.

The PPI representative stated to the inspector that the licensee's problems with UF - waste separation could in part be caused by insufficient mixing, either before or after adding the catalyst, and that the batch mixing process used by the licensee would be difficult to control.

Representatives of HNDC were contacted by the Region III inspector to determine the extent of their liquid waste solidification service. The representatives stated that they had solidified about 8,000 gallons of both BWR wastes (25 weight percent sodium sulphate) and PWR wastes (12 weight percent boric acid) into 1500 gallon, 1/4 inch thick steel tanks inside of a six-inch concrete shield vessel. The shield and all is buried. The burials have been at the NFS site in New York. He stated that they have had no problems with liquidification of the mixtures, but had done much experimentation to arrive at the best UF and catalyst as well as the proper mix ratio of waste and UF. The HNDC system is similar to that of PPI and it has been sold to several nuclear stations. At present the HNDC mixing system is stationed on a truck and taken to the source of the waste where the solidification operation is carried out. HNDC uses one part of UF to 2 parts of liquid wastes.

22. Final Corrective Actions Relating to Solidification Process Problem Resolution

Following the inspection the licensee was contacted for the purpose of learning the status of the licensee's corrective efforts. The inspector was informed the following actions were being taken:

- a. Waste solutions are to be neutralized with sodium hydroxide to remove ammonium gas.
- b. The neutralized waste will be digested for 8 hours to eliminate more of the ammonia.
- c. The ratio of waste of UF will be decreased from 3:1 to 2:1.
- d. The mixer blade will be modified to prevent cutting the liner.
- e. The contents of each drum will be inspected 5 days after solidification for any residual liquid.
- f. The drum liner will be changed to a 40 mil polyethylene free standing liner.
- g. The liner will be tested for leaks and the 17H DOT drums will undergo a quality inspection before use.

An AEC inspection will be made to verify that the above changes are effective in solving the solidification process problem.

REPORT DETAILS**Part II (Radiological Protection)**

Prepared by

J. A. Finn11/2/73
(Date)

Reviewed by

W. L. Fisher11/5/73
(Date)**23. Reported Overexposure to Airborne Radioactivity**

By telephone on July 18, 1973, the licensee informed Region III that an apparent overexposure of an individual to airborne plutonium had occurred at the east slot box in the general laboratory (Room 129). In accordance with 10 CFR 20.405(a)(1), a written report dated July 31, 1973, was submitted to the Commission stating that, based on air samples, an employee had been exposed to a concentration of 2.6×10^{-12} microcuries per milliliter during the period July 8 - 14, 1973, as averaged over 40 hours. This is 1.3 times the concentration for soluble plutonium specified in Appendix B, Table I, Column 1, (2×10^{-12} microcuries per milliliter). Urine samples taken after the exposure showed no uptake of plutonium. Preventive action described in the licensee's letter of July 31, 1973, has been taken and the employee has been notified in writing of the extent of his exposure. After investigation, the licensee concluded that the most probable cause of the incident was failure to follow procedures. Contamination control at slot boxes requires strict adherence to procedures which specify that no material may be removed through the slot and that paper lining the bottom of the box must be frequently replaced with clean paper. Laboratory personnel have been reinstructed in proper work methods and precautions for use of the slot boxes.

The reported overexposure constitutes noncompliance with 10 CFR 20.103(a), "Exposure of individuals to concentrations of radioactive material in restricted areas."

24. Unusual Occurrence

On July 18, 1973, the licensee informed Region III by telephone that 48-hour air samples for July 3 - 4, 1973, indicated potential exposures to airborne concentrations of plutonium up to 500 MPC-hours.

Ten employees were placed on restricted status pending investigation of the matter. Fecal and urine samples indicated no detectable uptake of

plutonium. The highest fecal sample was 10 disintegrations per minute per total sample. Urine samples analyzed by the licensee's Technical Center were, with two exceptions, less than 0.4 disintegrations per minute per liter of urine (minimum detection level). The two exceptions were 0.4 disintegrations per minute per liter and 0.7 disintegrations per minute per liter.

One of the air samples was subjected to pulse height analysis, which indicated that the activity was about 80% americium 241 and 20% plutonium 239. These proportions represent scrap recovery type material rather than the type of material used in the laboratory rooms where the high air samples were incurred. These rooms include the Metallography Laboratory, the Dark Room, the Spectrographic Laboratory, and the Dry Preparation Laboratory.

Autoradiographs of the air sample filters showed activity patterns of the size and shape of finger prints instead of the normal uniform distribution of activity over the entire surface.

There was no contamination in the rooms having high air samples. Air samples in the general laboratory were at or near background for the same period.

The licensee concluded, on the basis of this evidence, that the high air samples were not valid and hence the matter was not reportable under 10 CFR 20.

A review of licensee records of air samples, surveys, and bioassays, and inspection of autoradiographs substantiated licensee conclusions that the air samples were not valid.

25. Personnel Contamination Occurrence

On April 17, 1972, an operator and two maintenance men became contaminated while replacing a pump in a glovebox in the wet ceramic area. The maintenance men left the plant site. A few minutes later, the operator discovered that he was contaminated during a routine self-survey, and notified health physics personnel. Upon returning to the plant, the maintenance men were surveyed by health physics and found to be contaminated. Contamination levels on hands, head, and face were greater than 100,000 disintegrations per minute per 60 square centimeters. Nasal smears ranged up to 160 disintegrations per minute. In addition, varying levels of contamination were found on personal clothing belonging to the three employees. Contamination levels found outside the control areas but within the licensee plant included 1,000 disintegrations per minute on the door of the locker room, up to 20,000 disintegrations per minute on a pair of coveralls hanging in the locker, 100,000 disintegrations per minute on safety glasses, and

2,000 disintegrations per minute on the time clock. Several contamination spots up to 2,200 disintegrations per minute were found in the personal car used by the maintenance men.

The cause of the contamination was attributed to glove failure. The cause of the spread of contamination was attributed to failure of the two maintenance men to make adequate personal surveys before leaving the work area and the plant. The men reportedly surveyed their hands and shoe covers before leaving the wet ceramic area, but they did not survey their head, face, arms, or their coveralls, and did not survey themselves in the locker room after removal of their protective clothing. Existing written procedures required (as a minimum) survey of hands each time after removal of hands from glovebox gloves; survey of hands, forearms, and front portion of their protective clothing and shoe covers before leaving the assigned work area; survey of shoe covers after reaching the exit survey station in the corridor before exiting into the nonradiation area; and survey of shoes after removal of shoe covers. Portable survey instruments are provided at the work location, at the exit of the wet ceramic area, at the exit of the wet processing area, at the process area exit survey station in the corridor, and the exit of the locker room into the front office area. These stations are all passed enroute from the wet ceramic area to the plant exit.

Action taken included decontamination of the area and of the individuals. Urine and fecal samples taken from the individuals showed no uptake of plutonium. The highest fecal result was 1.3 disintegrations per minute per total sample. The highest urine sample was 0.9 disintegrations per minute per 24-hour sample and followup samples were less than 0.1 disintegrations per minute per 24-hour sample. The two maintenance men were given letters of reprimand for failure to follow written procedures and plant personnel were advised of the occurrence.

There were no significant exposures. The licensee indicated that offsite contamination surveys were not made because of the low levels of contamination found in the personal automobile used by the employees. The licensee was advised that failure to evaluate possible contamination levels in unrestricted areas constitutes noncompliance with 10 CFR 20.201(b).

26. Plutonium Waste Leak, August 18, 1973

Packaged solid waste is stored in a trailer van at the loading dock outside the plutonium building (inside the fenced yard) while awaiting shipment to a licensed burial facility. The trailer is used for storage only. This use is authorized by License Condition 31 (Amendment 1 to the license).

At 7:55 a.m. on August 18, 1973, a health physics technician discovered liquid dripping from the trailer. The liquid was found to be leaking

from one of four 55-gallon drums containing low level liquid plutonium waste which had supposedly been solidified with urea formaldehyde.

The area around the trailer was established as a contamination control area. Decontamination efforts were begun immediately and continued over a period of 11 days under the constant supervision of health physics personnel. The four drums were removed into the building for rework and the trailer was decontaminated. Tires and other removable parts of the trailer were packaged as contaminated waste. Contaminated gravel and dirt were removed from underneath the trailer until there was no detectable contamination. The removed material was packaged as contaminated waste.

Contamination levels at the beginning were greater than 1,000,000 disintegrations per minute per 60 square centimeters on the trailer floor and on the ground underneath the trailer. Trailer tires were greater than 100,000 disintegrations per minute. According to health physics technicians involved in the surveys, contamination levels on the outside of the trailer were less than 500 disintegrations per minute smearable and less than 30,000 disintegrations per minute direct reading prior to fixing with paint. However, no records were made of these readings. Following extensive decontamination, the contaminated areas were coated with red oxide paint and two layers of gray paint. There was no detectable contamination subsequent to painting the surfaces.

Individuals doing the decontamination wore protective coveralls, booties, rubber gloves, head covering, and full face respirators.

No personnel contamination or exposure to airborne radioactivity was incurred and there was no release to the environs. Air samples were taken inside and outside the trailer during decontamination. The maximum airborne concentration outside the trailer was 5.9×10^{-13} microcuries per milliliter. Inside the trailer, the concentrations ranged from 1.2×10^{-13} microcuries per milliliter to 8.6×10^{-12} microcuries per milliliter. MPC for soluble plutonium in restricted areas is 2×10^{-12} microcuries per milliliter.

One item of noncompliance was incurred, in that, contrary to 10 CFR 20.401(b), no records were made of the residual contamination levels prior to covering with paint.

ENCLOSURE 3

RESPONSE TO MATTERS ADDRESSED BY YOUR LETTERS
NOT COVERED BY OUR INSPECTION REPORT

October 1, 1973 Letter

1. Items a-e - Refer to inspection report. (Enclosure 2)
2. Item f - The site conditions which you identified were evaluated by the Directorate of Licensing as part of their review of the facility operating license application. It was concluded that there was reasonable assurance that the plant could be operated within Regulatory Requirements with no undue risk to the health and safety of the public. The plant was constructed with the recognition of Oklahoma weather conditions. Those portions of the plant where plutonium is stored were constructed to resist even the direct impact of a tornado. In addition, operations are required by the Operating License to be shut down during any period when meteorological data indicate there may be tornado activity in the area. During tornado alert periods the plutonium is stored in a concrete vault.
3. Item g - The Department of Transportation and Atomic Energy Commission regulations concerning transportation of radioactive material are based on the assumption that not all transportation accidents are entirely preventable. This assumption has resulted in detailed packaging and labeling requirements which are intended to minimize any hazard to carrier personnel during shipment, and to the public following a transportation accident.

October 9, 1973 Letter

1. Item 1 - Discussed in our letter.
2. Items 2 and 3 - With respect to the misleading information that appeared in the newspapers, we can only comment that the AEC does not have control over this activity. We would like to emphasize, however, that the AEC did furnish a press release to the Oklahoma City newspapers regarding the waste drum leak. We regret that the referenced news story stated that Kerr-McGee had received a clean bill of health as a result of our recent inspection.

The news story's statement concerning criticality resulted from the reporter's questioning whether the waste drums could explode. We view this as a logical question answered logically and reported fairly.

3. Items 4, 5 and 6 - This matter was addressed in our November 2 meeting with corporate licensee management.

- 2 -

4. Item 7 - We would like to call your attention to the publications of authoritative bodies, such as the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection, for factual information concerning the effects of radiation exposure and the meaning of exposure limits. For example, ICRP Publication 2, "Report of Committee II on Permissible Dose for Internal Radiation," states: ". . .occupational exposure for the working life of an individual at the maximum permissible values recommended in this report (essentially the same as the AEC limits published in 10 CFR 20) is not expected to entail appreciable risk of damage to the individual or to present a hazard more severe than those commonly accepted in other present day industries."
5. Item 8 - No comment necessary.
6. Items 9 and 13 - On November 2, 1973, we met with Mr. McGee and other corporate management representatives to discuss our concerns respecting the deficiencies identified in our inspection program and the need for improving the quality of operations at the Cimarron Plant. On the basis of these discussions with top management, we are confident that appropriate corrective measures will be taken at the Cimarron Plant to assure the safety of plant operations and compliance with the Operating License. However, we will continue to monitor these matters with an augmented inspection program and will take other actions as necessary and appropriate.
7. Items 10, 11, and 14 - The AEC has undertaken an environmental review of the Kerr-McGee Cimarron facility. As yet, no date has been scheduled for the issuance of the draft environmental statement by the AEC; however, the Directorate of Licensing is taking action to obtain the additional information needed from Kerr-McGee to enable the staff to expedite preparation of the statement. As soon as the draft environmental statement is issued, a copy will be placed in the public record maintained at the Guthrie, Oklahoma, library and the public will be advised of the statement by a notice in the Federal Register inviting comments. At the same time, the draft statement will be sent to Federal and Oklahoma State agencies for their review and comment. In view of your interest in this matter, we have arranged for our Directorate of Licensing to add your name to the distribution list for this draft environmental statement. Any comments that you may have will be considered with other comments received in the preparation of the final environmental statement. Substantive comments are taken into account by the AEC to assure that the plant's operation and its impact on the human environment is appropriately assessed.

Records from G.uthrie Library

March 12, 1973

LPS-011

76-1103

to Kerr McGree Attn. Mr. W. L. Skelley, Dir. Regulation and Control.

This is in reference to your revised environmental report discussing the environmental impact related to your Cimarron Plutonium Plant, Begun Co. Okla. We find we need supplemental information to permit a reviewer independently to reach conclusions on the various environmental considerations associated with the activities of the Cimarron Plant. How much plutonium has been processed in this period. What are your projections of processing through 73? What are your capabilities for processing beyond the completion of the PPIF program. Do you have firm or anticipated commitments for future plutonium containing fuels. What would be the consequences of not having the Cimarron facility available for preparation of these fuels. ? What is the present employment resulting from operation of this plant?

2. The Site -- Location and Layout. Please provide a map showing the coordinates of the site and its location with respect to State, County, and other political sub-divisions. In addition to the location of adjacent highways, please note the location and distance to nearest railroad, and navigable waters. A contour map of the site would be helpful. Have there been any plans developed for additions or modifications to the site.

Please provide a detailed sitelayout (to scale) for the plutonium plant the and nearby uranium plant showing such details as the location of perimeter fences, retention ponds, waste storage areas (if outside of process bldg) stacks, etc.

3. Demography -- A map (and or table showing population at 1,2,3,4,5,10,20,30,50 mile radii in the 10 cardinal compass directions with the plutonium plant at the center should be provided. Projected population densities throughout the plant life should be estimated. Population centers with population, distance and direction from the plant within this area should be indicated.

More detailed information is needed on land use in the area within a 5 mile radius of the plants. Please include such information as location of any other industrial facilities (including kind) schools, hospitals, residences, dairy farms, and number of cows, other farms, major crops and production, recreation facilities, etc.

c. Hydrology-- In addition to information on surface waters, which you have provided, please provide available information on depth and flow of groundwaters. Are planned withdrawals in the vicinity sufficient to affect these. What data can be provided on historical floods from the Cimarron R.? What are the projected, probably flood levels?

d. Meteorology-- Please provide not only average precipitation, temperatures, and evaporation rates but also extremes on a monthly basis.

e. Ecology-- Provide inventories of plant and animal life- important game animals; birds, and plants supporting these. What are not residences but may migrate through the area. Identify any endangered species. Are there nearby breeding grounds and game preserves. What is the population of species of aquatic life, including plankton and bacteria in the Cimarron River. What is the average and range of composition of the Cimarron River waters (Chemical concentrations, turbidity, dissolved oxygen, BOD, COD, PII, etc.) Include estimates of temperature average and extremes on a monthly basis. What, if any recreational activities occur on the river. What is the river flow in relation to the flow of sanitary wastes reaching the river. What is known of the life cycle (food chains) in the river, including spawning area?

f. Regional historical and natural landmarks. You indicate there are no historical landmarks on the site-- within 10 miles? Do transportation lanes, oil or gas pipelines, and power lines into and out of the site pass near any historic landmarks.

g. Radiological background-- What information is available on the natural radiological background of the site or region?

2.

Local environmental acceptance-- What has been done in public relations to gain the acceptance of a plutonium plant in the region. Have there been any local groups actively supporting or rejecting the plant? Have you held any public meetings or hearings for the purpose of discussing the plant activities.

4. Other enviro features; Please include a discussion of any other environmental features not included- which may be peculiar to the site and useful in evaluating the environment impact of operating a pluto plant.

5. The Plant

A. Enviro. Effects of Plant Operation

Special attention to the thermal discharges

Non-radioactive chemical and biocide discharges

and Radiological impact on biota and exposure pathways.

Interactions of effects from the uranium plant (additive effects e.g.) possible local impact from stack releases.

Unavoidable adverse effects, identifying those which are irreversible and those which are temporary.

Short-term uses and long term productivity, and irreversible and irretrievable commitment of resources. Include a discussion of decommissioning of the plant at the end of its life.

5. Surveillance and Monitoring Programs-- indicate any special surveillance such as monitoring wells in the vicinity of the evaporative pond and sanitary lagoons to assure notice of any unintentional leaks of radioactivity or toxic chemicals to the uncontrolled environment. Describe procedures used to assure that cooling water discharged to the lagoons is not inadvertently contaminated

6. Environmental Effects of Accidents--

a. A criticality-- You properly point out that the probability of a criticality incident is effectively minimized by design features and appropriate procedures. However, a criticality incident is credible. We therefore request that the consequences of a criticality incident be analyzed thoroughly and quantitatively analyzed. Location assumed for the incident should be that for which the greater release of reactivity to the environment should be probable (as compared with other plants in plant locations. Personal exposure at plant boundaries and nearby farms should be estimated using appropriate MLD values. Total exposure for skin, bone and thyroid should be estimated. Both adult and child exposure should be calculated for.

b. In your analysis of the environmental impact of a fire or explosion you assume that each HEPA filter remains operational at 99% efficiency. What is the probability that a fire or explosion would result in damage to one or both of the filters resulting in bypass. In this unlikely event what would be the lung dose at the site boundary and nearest residential. Special attention should be given to the possibility of an explosion or fire in a pluto or uranium nitrate concentration, in a plutonium ion exchange unit or the solvent extraction system.

c. Tornado-- confirm that tornado control remains as that described in the life and operation. Provide a summary discussion of your experience of four hour and one hour tornado warnings. Indicate the frequencies of the plant and operational performance of transfer and storage of plutonium compared to your predictions.

7. Alternatives.

a. Discuss the consequences of shutting the plant down.

b. Discuss the impact of building a new plant at a new site. Include discussion of other feasible sites.

c. Plant design alternatives.

Discuss alternate methods of treating waste effluents -- compare with current practices. Include discussion on 42 foot stacks.

Dr. Orville Hill will have site visit. Material should be sent us before May 15, 1973.

Richard Chitwood
Technical Support Branch
Directorate of Licensing

10 Inspection Report for Feb 12-16, 1973: (From public records file) /0

10. Liquid Effluent

19. Sanitary waste from the plutonium and uranium plants is discharged to sanitary lagoons. Lagoon overflow is discharged to the Cimarron River. This constitutes the only liquid effluent discharged from the Cimarron facility. The annual average gross alpha activity discharged to river in 1972 was 1.6×10 to minus 6 power uCi/ml. MPC for plutonium is 5×10 to minus 6 power uCi/ml. MPC for uranium 235 is $x \times 10$ to minus 5 power uCi/ml.

21. By telegram on Nov 30, 1972, the licensee informed Region III of a fire which occurred in the incinerator baghouse on October 18, 1972. All dust collector bags failed and all six incinerator HEPA filters were damaged. Incinerator stack air concentrations were twice MPC on October 19 but were below levels reportable under 10CFR20

Part 11. Plutonium Plant (From page 12)

27. A review of film badge reports for calendar year 1972 showed maximum annual exposures of 2.1 rem (gamma) and 4.3 rem (beta)

29. (not verbatim) On 11-11-72 two employees were exposed to 8 times the MPC (maximum permissible dose) for soluble plutonium during maintenance on a glove-box. Monitoring revealed, upon removal of hand from the glove-box, arm contamination of up to 300,000 dpm. The glove box had a puncture accidentally caused by a sharp tool. Wadal smears indicated on one employee 3 and 21 dpm. No smears were taken of the 2nd employee.

Page 14 (verbatim): From Oct 1972 through Jan 1973 four shipments made of wastes. Compacted 55 gal drums had a maximum of .1 grams of plutonium and solidified wastes contained two to four grams of plutonium per drum.

From AEC Inspection Report, June 18-22, 1973, Cimarron Facil (public rec.) /2

(Not verbatim) Seven new violations were reported in detail citing violation vs. the regulation. In addition 3 other significant faults were reported. Six previously reported problems were still unresolved.

The report shows that Kerr-McGee Management, P.S. Dunn, Vice President of Nuclear Manufacturing down through plant operating officials and supervisors were briefed in two separate briefings (one at the plant and other at corporate headquarters) by the AEC inspector. (verbatim) "Management Interview", page 8 "The inspector discussed the violations. He stated that most of the violations indicated a lack of concern for following procedures and posted limits and also an absence of management audit of performance of employees and enforcing compliance with procedures."

Plutonium Plant, page 16 "Forms AEC-4 have been completed to permit whole body exposures of up to 3 rems per calendar qtr. The highest cumulative gamma dose for the period of Jan 1 to May 31, 1973 was 1600 millirem the highest whole body dose for the 2nd qtr through May 31 was 910 millirem.

29. (not verbatim) (verbatim)

a. Wastes from the Plutonium plant and from the uranium plant are discharged through separate septic systems to sanitary lagoons (two lagoons in series), which overflow through a weir to the river. Industrial wastes from the plant utilities also flow to the sanitary lagoons. Additionally, liquids from the plutonium plant 10,000 gallon hold-up tanks are sampled and discharged to the sanitary lagoons if gross alpha concentrations are below 4×10 to minus 7 uCi/ml (1/10 MPC for Americium 241). The minimum detectable concentration is 1.4×10 to minus 7 uCi/ml. Daily grab samples of the lagoon overflow are composited for weekly analysis for gross alpha and gross beta. A review of records showed the following ranges: Gross Alpha 2 to 4.5×10 to minus 7 uCi/ml. Gross beta 3 to 5×10 to minus 7 uCi/ml. Limiting MPC's for discharge to the river are 4×10 to minus 6 uCi/ml, alpha (Americium 241) and 2×10 to minus 5 uCi/ml, beta (thorium 234)

(cont'd)

Inspection Report of Cimarron, June 18-22, 1973. Public Record, (Cont.)

(page now identified in transcript) "Limits of waste is .03 grams plutonium per liter, but efforts are made to reduce this to .005 grams per liter."

From page 17, (continued, verbatim):

- b. Process wastes from holding tanks are discharged to the plutonium evaporation-holding pond if gross alpha concentrations are above $1/10$ MPC for Americium 241 but less than 100×10^3 (4×10^3 to minus 3 uCi/ml)
- c. Higher concentrations are solidified for disposal through a licensed disposal agency. Limits are less than .03 grams plutonium per liter but efforts are made to reduce this to .005 grams per liter.
- d. During the period from February 21 to May 20, 1973, 70,000 to 80,000 gallons of liquid have been discharged via the 10,000 hold up tank to the sanitary lagoon. Discharge batch concentrations were less than 1.4×10^3 to minus 7 uCi/ml to 3.9×10^3 to minus 7 uCi/ml .
- e. During same period, 3,400 gallons were discharged to the evaporation pond at a concentration of 2.2×10^3 to minus 6 uCi/ml .
- f. Sampling of the evaporation pond showed concentrations in the unstirred liquid about 7% of MPC for Americium 241 (4×10^3 to minus 6 uCi/ml) and samples taken after stirring up sludge were

Items on Record at Guthrie Public Library

March 7, 1973 No. M-29

To Directorate of Regulatory Operations, AEC
Notification of an Incident.

Licensee, Kerr McGee, AEC License SWK-1174
Becket No 70-1193

Problem- Plutonium Contamination Incident resulting in exposures to employees.

R.O.III (Chicago) was informed by telephone on March 5, 1973 by the licensee of the following:

At 7:12 a.m. on March 5 upon removal of waste material contaminated with plutonium from a glove box, using standard bag-out procedures, the bagged waste ignited, resulting in the release of plutonium contamination to the wet ceramic area and adjacent scrap recovery area of the Cimarron Plutonium Plant. One employee was involved in the bag out procedure and 6 others were in the general area. None of the employees were wearing respiratory protection when the incident occurred. Wet towels were thrown on the fire and all personnel left the area. Reentry was made using supplied air respirators to blow water on the waste and place it in a drum.

Preliminary estimates indicate that personnel exposures could be as high as 1,000 times the weekly permissible limit for insoluble airborne plutonium. Nasal smears showed 1200 disintegrations per minute (dpm) for one employee; all others were less than 100dpm. Personnel contamination which ranged from 1,000 to 90,000 dpm was promptly removed. Special urine and fecal sampling was initiated. The licensee is utilizing its medical consultant to assist in medical aspects of the case.

Stack air samples showed no increase in the activity released from the building to the environment. Contamination tracked into the hallway leading to the decontamination room inside the building has been removed. It is estimated however that decontamination of the wet ceramic area and adjacent scrap recovery area will take at least two weeks. A station R.O.III ~~XXXXXXXXXX~~ with the assistance of an AEC medical consultant is conducting an investigation. There has been no publicity, however the licensee has been advised that the AEC will issue a press release if the licensee elects not to issue one. The State of Oklahoma has been notified. The technical assistants to the Commissioners, the Staff of the Joint Comm on A. Energy and the Office of Information Services have been informed by telephone.

G.H. Bedinger X747

G.W. Roy X7347

R.H. Engelken x 7356

From Public Records Guthrie

Kerr McGee Cord Apr 17, 1973

Re LHO Attn. Richard B. Chitwood, Chief, Tech. Support Branch
Directorate of Licensing

Enclosure:

By your letter of March 12, 1973, you requested certain information to supplement your environmental report previously submitted for our Cimarron Plutonium Fuel Plant in Logan Co. Okla. We are in the process of reviewing this. However, we believe that some of the information requested should not be included in the environmental report, and request your consideration of our proposal to omit the items discussed below from our submittal.

The items of information which Kerr McGee objects to having included in the environmental report are those items indicated by the following listed questions in your letter of March 12.

I. Purpose of Facility

1. What are your capabilities of processing beyond the completion of the PLEF program?
2. Do you have firm or anticipated commitments for future plutonium containing fuels.
3. What would be the consequences of not having the Cimarron Facility available for preparation of the fuels.

II. The Site a. Local environmental acceptance.

1. What has been done in public relations to gain the acceptance of a plutonium plant in the Region?
2. Have there been any local groups actively supporting or rejecting the concept of a plutonium plant?
3. Have you held any public meetings or hearings for the purpose of discussing the plant activities?

Alternatives (a) and (b)

1. Discuss the consequences of shutting plant down.
2. Discuss the impact of building a new plant at a new site.
3. Include discussion of other feasible sites.

We do not believe that the above questions are proper subjects of inquiry in an environmental study. The information solicited will not contribute significantly to a better understanding of the environmental impact of the operation of the Cimarron PLUTONIUM Plant. We recognize that the Commission may have a legitimate interest in gathering information of this nature. However, we would prefer to furnish such information to the Commission by separate, private communications rather than having it included in a public report.

Please let us know if you concur with our proposal to omit the questions from the supplemental information to be submitted. If so, we would be willing to make the information requested by these questions available to the Commission if necessary for the Commission's purposes.

George B. Parks
Exec. Vice President.

May 29, 1973

D-40-CPH
70-1193

McKerr McGee Attn. George Parks,

This refers to your letter of April 17, 1973 in which you requested that we consider the omission of certain items that are requested elsewhere in our March 12, 73 letter for inclusion to your environmental report of the Cimarron Plutonium Plant in Logan Co. It should be understood that your environmental report provides us with a basis for an independent evaluation of the environmental impact of the operation of the plant. As a result of the Calvert Cliffs decision, we are required to consider and analyze all environmental effects, including the need for the plant, cost benefits and public acceptance.

It is certainly true that we can make an independent analysis in the absence of the information requested from you in the 9 questions which you ask that we consider for deletion. However, we must address the environmental statement to these areas and your assistance in gathering the information is solicited to enable us to make the best and most acceptable statement possible. We therefore resubmit our request that you address these areas in your supplement.

1. Purpose of the Facility. The intent of the question asked in this section is to establish need for the facility- that a plutonium plant is a necessary and continuing part of the fuel cycle supporting nuclear reactors. The long term and continuing operation of the facility will however, have an environmental impact, not only in the vicinity of the plant, but also in the transport of materials to and from the plant. Thus quantities and rates are relevant to an analysis of environmental impact over the life of the plant.

2. The Site (h) Local environmental acceptance. The information requested here is to further our evaluation of efforts in gaining environmental approval and consultation. The third question might be considered the pertinent one here, with the 1st and 2nd questions being supplementary. Refer to Sect. 12 of Regulation Guide 4-2 and especially last paragraph.

7. Alternatives (a) and (b). The Calvert Cliffs decision requires the Environmental Statement to consider a thorough analysis of all alternatives including not operating the facility. It is apparent that a cost benefit analysis of an existing operating plant must be somewhat different in approach than a comparable analysis for a plant which has not yet been built. Yet such an analysis must be made. Although the AEC staff will independently make a cost-analysis, you are asked to perform these phases of the analysis to assist us in our evaluation.

R.B. Chitwood Chief
Technical support Branch
Directorate of Licensing

D-40-CPH 70-1193 May 29

To Skelly- Kerr McGee

Dr Kerr Dance and Dr Orville Hill. Purpose of visit on June 11-12 1973 to discuss environmental effects.

Plutonium license for Crescent-- Apr. 2, 1970
Bellasaw (Uranium Hexafluoride Plant Feb 20, 1970

Many documents can be obtained through Okla. City Clearing House
Office of Community Affairs and Planning, 507 Will Rodgers Bldg.

Apr 18 73
 To: Kerr- McGee attn: Mr Morgan Moore

License Condition No 3.4 -- contrary to above, records of calibration data and limits of error calculations were not maintained as required.

2. License Condition No. 6.5 -- Contrary to above you failed to perform monthly in process physical inventories as required.

3. License Condition no 7.1 Contrary to above your Materials Balance Area and Plant records were not reconciled at the end of each accounting period.

4. License No 8.1 requires Manager conduct an annual internal review. Contrary to above Manager failed to conduct an internal review as required

Nov 9, 1972 To: Kerr McGee Attention Skelly

Your failure to establish and maintain a measurement quality control program that has a capability for providing control data on all elements of the measurement system is of great concern because it appears to be contrary to License Condition 3.1 and 3.3 of your current safeguards amendment and prevents effective operation of LEMUF as a control index of MUF. A detailed review of all the elements of your measurement quality control program will be conducted during review.

Your failure in the parametric studies to characterize and demonstrate your inventory taking capabilities prevents us from producing accurately what your inherent capabilities is for closing a material balance. The approach described in the conclusion to the parametric study for determined inventory hold up values appears to be unsatisfactory.

R.G. Page
 Materials Plant Protection Branch

Write to
 U.S. Atomic Energy Commission, Washington D.C. 20545
 Document Room Coordinator
 Room 016 Regulatory (may be 616 rm.)
 telephone 301-973-7333 for documents.

From A EC, Frank Malone, Chief, Adm. Services Branch
Office of Administration

License No. SNM 1174 Amendment No. MPP-1

Measurements and Statistical Controls.

3.1 The licensee shall determine the U235, U233 and or Pu content of all receipts, shipments intentional discards and inventoried, along with the limits of error except as specified in Condition 6.2. Measurements are not required on items which have been determined by other means to contain less than 10 grams U235, U233

and or Pu each. Limits of error as used herein means the boundaries within which the true or best value of the parameter being measured lies with a probability of 95%.

3.7 If the cumulative LEMUF for plutonium for a six month period exceeds the larger of (a) 1.5 kilograms of Plutonium or (b) .5% of additions to plutonium in process for the period, or (c) the cumulative MUF exceeds its LEMUF for a six months period, the licensee shall promptly notify the Region 3 Office, and shall take immediate action to investigate the cause of the excessive values. This evaluation shall be performed at the end of each 30 day material balance period for the previous 6 months. Under this condition the first evaluation shall be performed for the July-Dec. 1973 time period.

3.8 At the completion of the FFTF project, the licensee shall submit to the Materials and Plant Protection Branch, Directorate of Licensing, USAEC Wash. 20545 with a copy to Region 3, Office of Directorate of Regulations, a report which summarizes all components of the material balance for the project; the limits of error for each component, the cumulative material unaccounted for, and the cumulative limits of error for the material unaccounted for. This report shall be submitted within sixty days after the last product shipment is made.

June 8, 1973

To Boyce Grier, Region 3, 799 Roosevelt Rd. Glen Ellyn, Ill. 60137

Dear Mr. Grier: We are in receipt of your letter for May 21 relating to the inspection conducted subsequent to the fire which occurred at our plutonium plant on March 5, 1973.

While we do not believe we have a basis for withholding any portion of the enclosed inspection reports from the public on the basis of proprietary information, we do wish to object to certain items within the report because of implication which can be drawn. We base these objections upon the fact that none of the objects would result in reduction of body burden nor improvement of treatment. They seem to be couched in philosophical language to the effect that the AEC would have ~~xxxxxxxxxx~~ done things differently. We believe that the attitude that a commercial operation must be equipped to completely research the cause and effect of any such incident as we have experienced is beyond the requirements of the regulations and sound business judgement.

Comments on Report dated May 21, 1973

From W.J. Skolly to AEC.

Page 8 - continued

AEC 1. "Delays were encountered in obtaining these samples. In addition, there was an inordinate delay between the time samples were submitted--- and the receipt of the results."

Additional or more prompt analytical results would have not altered the treatment nor the degree of exposure.

2. "Medical consultant was not notified until the day following the occurrence".

Our medical consultant was notified in accordance with procedures provided by that consultant and available for inspection. Earlier inspection would not have altered our current treatment procedures.

3. "Procedure would not require the use of respiratory protection during bag-out operations."

In retrospect, the use of respiratory protection during bag-out operations would have reduced intake of radioactive material.

4. "The continuous room air monitor chart was allowed to run out before----"

This error was in direct contraindication to procedures in effect. Incremental additions to normal ambient air concentrations would have been determined promptly if these procedures had been followed. However, we do not believe the lack of this information was a serious detriment in securing prompt treatment of personnel nor affected the eventual exposure nor affected the eventual body burden of exposed personnel.

Inspection report No 070-1193/73-04

Part 2 "No provision was made to count the samples locally."

There is no local capability for measuring plutonium.

Para. No 36 "As late as March 9 the seven employees had not yet been whole body counted to determine the extent of lung burdens. Particle size analysis of the air samples had not been performed. Plutonium to americium ratios and plutonium isotopic percentages had not been determined."

This additional information would have not altered the treatment or the total exposure of the individuals involved.

Para. 41 Dr. Neil Wald and Dr. Roger Caldwell of U of Pittsburgh were retained by Region 3 to follow the medical and dosimetry aspects of the incident. They were in frequent contact with Dr. Sternhagen and with Region 3. A written report has not been received from the consultant as yet.

Page 2.

May 21

32. On March 8, the licensee took soil and vegetation samples downwind from the stack. Results have not yet been obtained. Plutonium levels in samples taken by Region 3 at the sample locations were not distinguishable from levels attributable to fallout.

33. Several smear samples were taken on the roof of the X Ray building just S.E. of the plutonium plant. These showed no detectable plutonium activity.

34. The floors, gloveboxes, equipment and piping in Room 128 and B0-2 were contaminated to about 100,000 dpm per 100 cm² alpha. About 2 weeks of continuous decontamination was required to reduce this to normal working levels. Adjacent rooms were contaminated to a lesser degree and were more readily decontaminated. Some contamination had been tracked in the corridors as far as the first air interlock. This was confined to the production areas of the building and was readily decontaminated.

35. Initial exposure estimates were made on the basis of air samples collected over a 14 hour period which included 7 hours prior to the fire. A urine sampling program was initiated immediately for all 7 employees. A fecal sampling program was initially established for Employee D, and was expanded to include the others on the next day. No provision was made to count the samples locally. Sent to commercial lab for priority handling, but first results were not received until March 13.

GUTHRIE DAILY LEADER, Fri. March 9, 1973

Kerr McGee Reports Minor Fire.

Kerr McGee Corp announced Friday that there were no injuries to employees or significant damage to the plant as a result of a minor fire at the company's Cimarron Plutonium Facility on Mon.

The nuclear manufacturing plant is located south of Crescent.

The fire occurred in a bag of waste materials from processing operations and resulted in combustion of the waste and bag which contaminated two rooms of the plant. It is believed that the fire was the result of spontaneous combustion within the bag.

Personnel and all emergency equipment functioned as planned, and the fire was immediately contained. No radioactive material was released from the plant, the company said.

Applicants' Environmental Report

USAEC Docket No 70-1193, Plutonium Fuel Plant, Nov. 1971

Contact National Technical Information Service, Dept. of Commerce
Springfield, Va. 22151 for copies.

Discussion and Finding by the AEC (Docket No 70-1193) Division of
Licensing AEC Relating to Consideration of Suspension pending
NEPA Environmental Review for Kerr McGee, Cimarron Plutonium Plant.

Nov. 29, 1971

Sept 24, 1971.

to Parker S. Dunn, Vice President, Nuclear Operations
Kerr McGee, 73102

Under the provisions of Sect. E of Appendix D, you are required to furnish to the Commission before Oct. 19, 1971 or such other later date as may be approved by the Commission upon good cause shown, a written statement of any reasons, with supporting factual submission why, with reference to the criteria in Para. 2 of Section E, Your Licenses SUB 1010 covering operations at your Sequoyah Uranium Hexafluoride Product Plant and SM 1174 covering operations at your Cimarron Plutonium Fuel Fabrication Plant should not be suspended in whole or in part, pending completion of the NEPA environmental review specified in Sect. B, C, or D of Appendix D as appropriate.

Harold L. Price, Director of
Regulations

Federal Register Vol. 36 No. 175 Thur. Sept 9, 1971
Title 10, Atomic Energy. no 190 Sept 30, 1971
no. 218 Nov 11, 71

A CASE AGAINST THE FAST BREEDER REACTOR AND THE PLUTONIUM ECONOMY

Henry David Thoreau has said, "The cost of a thing is the amount of what I call life which is required to be exchanged for it, immediately or in the long run." We should consider this quotation very carefully, especially as it relates to the liquid metal fast breeder reactor (LMFBR) and the plutonium economy. I am submitting this paper to point out some of the adverse effects of the LMFBR and plutonium, which is the principle fuel of the fast breeder reactor.

According to the March 29, 1974 issue of Science, "The Atomic Energy Commission has released a draft environmental statement on the liquid metal fast breeder reactor program predicting that full scale use of the breeder reactors would have no significant adverse effect on the environment and would meet environmental quality and safety standards."

I challenge this conclusion and wish to point out the following reasons why the breeder would have severe adverse effects on the environment, the quality of life and even of life itself. I have tried to be factual, but, also, want to discuss with you feelings, impressions, and fears- all of which are a very real part of a good or bad environment. After all, human emotions are as real and as legitimate as the logarithmic scale.

It is difficult to believe that the A.E.C. can be objective on this issue. There has been pressure on the A.E.C. for a long time to divide their safety functions from their promotional and operational functions with the result of more believable, fair and independent judgements. With President Nixon pushing for self sufficiency in energy by 1980, it is unlikely that the A.E.C. officially would take a position contrary to the expressed wishes of the

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president. Presidents come and go, but we may be trying to live with the fast breeder for a long time. Dr. Richard Carpenter, with the Environmental Commission of the National Academy of Science, speaking on April 5 at an Oklahoma University energy lecture, said that the credibility of the A.E.C. was very low due to this lack of division of functions and responsibilities. It is indeed incomprehensible to me how two million dollars could be spent preparing an environmental report and not find any significant environmental damage from the LMFBR.

Having spent about six months and probably a hundred dollars on research on plutonium, specifically, and the fast breeder, incidentally, my conclusion would be just the opposite. But, perhaps, I look on plutonium as a threat to life and health and not necessarily as a source of abundant energy.

It has been about six months now since we were told of a leak of plutonium nitrate waste at the Kerr McGee Cimarron Plutonium Fuel Fabrication Plant at Crescent, Okla. This plant fabricates plutonium fuel pellets for the Fast Flux Reactor at Hanford, Wash. It was indeed a shock to find that we had a plutonium facility only 25 miles from our home, and that this extremely hazardous stuff had leaked from a drum, over the truck bed, and unto the ground. Thus, were we rudely introduced to the peaceful atom and some of its drawbacks.

Through talking to employees of the plant, and A.E.C. inspectors, reading the A.E.C. public records at the Guthrie Library, and through communications by phone and letters to A.E.C. officials, we have learned that this particular plant has been beset with leaks, fires, accidents, and violations of regulations. We are aware of four leaks of radioactive waste containing plutonium, two fires,

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one in which seven employees were exposed to airborne plutonium, several glove-box incidents, a case of two employees leaving the plant contaminated, a shipment of plutonium reaching Crescent on the back of a flat-bed truck, held in only with a chain, the plant operating for months without a criticality officer- all this in a period of less than four years.

We are deeply concerned that this plant was located in our midst with practically no public awareness, that it is in tornado alley, that there are 863,000 people within a 50 mile radius of the plant, that it is in a Zone 2 earthquake area, that it is a unique area with a low altitude jet stream of high winds, has flash floods, severe electrical, hail and dust storms, extreme temperatures, and is also a resort area. However, our local plant is only a microcosm of what to expect if we adopt the fast breeder as a main source of power. With the proliferation of plutonium sources, we can expect a proliferation of dangers and hazards.

Anyway, as a person living close to a plutonium plant, I know what it is to live with fear. Fear based not on ignorance, but on a knowledge of the fiendishly toxic and persistent nature of plutonium. When we have a tornado alert, I wonder if some of the drums of waste could be scattered or cracked open, and if the plutonium can be put to bed in time. I wonder about the fish kill that occurred on the Cimarron close to the plant. I wonder about the record flood they had in October, and what has happened to the liquid in the lagoons. I wonder about the many oil wells in the vicinity and the huge underground gas storage area near Crescent. I wonder whether we might have picked up a bit of plutonium in the windblown dust when we drove up to check out reports of the last leak. I think about the starkly dead trees just north of the plant, of plant per-

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personel who check the wells in the vicinity, and the state's chief radiologist, Dr. Dale McHard saying that our state has no instruments to measure plutonium. Dr. Arthur Tamplin has said that particles too small to be detected by sophisticated instruments could still be fatal if ingested into the lungs. We no longer go picnicing or fishing nearby on the Cimarron River, or take nature photographs on a friend's acreage several miles from the plant.

Death is not particularly fearful to me, but a lingering death of lung or bone cancer caused by plutonium is. As plutonium becomes more plentiful and the word spreads on the nature of the element, as it is sure to, the fear will spread in direct proportion. Because of the long time lapse between low level exposure to plutonium hot particles and the incidence of cancer, there could be an epidemic condition on our hands sometime in the future.

I am sure you are aware of the book by John McPhee called BINDING ENERGY in which the possibility of stealing or diverting plutonium and making it into atomic bombs was discussed. A television reporter for KWTU, Channel 9, Byron Harris, did a T.V. show on our local plant and how poorly guarded it was. Our friend, Mr. A. M. Morgan-Voyce, related that on a trip to England last summer, radical groups were distributing leaflets on how to make atomic bombs. With our population of over 200 million, there are bound to be some kooks, crackpots and malcontents who just might try it. Making bombs would be extremely difficult with the uranium fuel now used in nuclear plants, but would be much more simple with the plutonium fuel for the fast breeder. We have learned to our sorrow that hijacking of planes, an unheard of condition a few years ago, is now a very real possibility. One wonders what would be the situation

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in Ireland today if plutonium were available to the I.R.A. Of course, you wouldn't have to make bombs with it, all you would have to do is to put a dab in the air conditioning system of, say Congress or even the A.E.C. How would you assess the environmental effects of having another country obtain plutonium from us by underground operations. Any plutonium facility, whether it is a fast breeder, reprocessing plant, fabrication plant, or even a regular nuclear reactor is such a sitting duck in time of war, or is so vulnerable to sabotage or blackmail. This could cause unthinkable human misery. What hospital or doctor is going to treat a person or any number of people contaminated with plutonium. Talk about fear!

Plutonium and radioactive wastes come and go from the Crescent Plant by plane and truck. If the country is producing 10,000,000 lbs. a year by the year 2000, this material will be crisscrossing the country in ever increasing amounts. Nobody anywhere will be safe from an extremely serious accident. This is becoming an increasing concern of airline pilots and stewardesses. Perhaps we would be lucky and not have a plane crash involving plutonium, but it is extremely foolhardy to depend on good luck forever. It is lucky that the 1969, \$75,000,000 fire the Rocky Flats Plutonium Plant didn't burn through the roof and contaminate thousands of acres. It is not so lucky that off site contamination due to contaminated oil has increased the air concentrations of plutonium around the plant to above the A.E.C. acceptable standards.

In 1966, the Enrico Fermi Fast Breeder near Detroit had a near meltdown, with the result that the plant is permanently shut down, at a loss of \$150,000,000. What is to be done with that radioactive concrete pyramid? Certainly it isn't improving the environment

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just sitting there. In 1961, the experimental fast breeder at Idaho Falls blew a plug sending 3 men to a gruesome death. According to the New York Times, Russia recently had some kind of accident with their fast breeder. Because of the high heat of a fast breeder reactor, and the great toxicity of plutonium, fast breeders are to regular reactors as lightening is to lightening bugs. Without the vast outlay of money from the federal government, this $5\frac{1}{2}$ billion dollar venture would have been given up long ago.

We abolished slavery in this country a hundred years ago. It is highly ironic that we are now setting up a system of future slavery, because we are placing in bondage future generations to look after our radioactive wastes. We seem to have two choices, that of condensing the wastes into extremely hot radioactive chunks, or less concentrated and more bulky liquid wastes. We have yet to devise a container to contain this stuff for very long. Consider the miserable record at the Hanford facility which has only been storing wastes for 30 years. The last leak of 115,000 gallons wasn't discovered for 51 days. Plutonium wastes stay radioactive for a quarter of a million years. It would be nice if we could just dump it into the ground and forget about it, but that just can't be done, because of the possibility of leaking into underground water, earthquakes, radioactive material getting into the atmosphere or food chain. If the price of perpetual guardianship of wastes were included in the price of nuclear power, it would be indeed high.

Have you ever seen a KEEP OUT FOREVER sign. Due to the long persistence of plutonium, having a half-life of 24,360 years- contamination on human terms is essentially permanent. Dr. John Gofman

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has said, "Manufacture of plutonium 239 and its widespread use in nuclear electric power may represent man's most immoral act."

Since the widespread use of the LMP⁴⁹ would have serious side effects, I see it as similar to drug addiction. Would our society be able to shut them off, if we saw that they were harmful, or if we had a bad accident. Or would we have become so dependant on this type of power that we would be forced to continue even though the populace lived in perpetual fear.

When an irresistible force meets an immovable object, you have an indescribable catastrophe. When our increasing demand for energy (irresistable force) meets and immovable object (the environment) we have an indescribable catastrophe- especially if we go to the plutonium fuel economy and the fast breeder.

How can any sensitive person or society justify taking these kinds of chances with life on earth. Perhaps man's fatal flaw has been the size of his brain. If he were more intelligent, he could foresee the consequences of his actions. If he were less intelligent he couldn't have brought to fruition this nightmarish possibility. Perhaps plutonium is man's way of self-destructing because of this fatal flaw.

If we value the democratic form of government, we should consider the possibility of becoming a police state. With large quantities of plutonium around, it will be a matter of survival to increase security and military protection to keep it from getting into the wrong hands. Freedom will be more and more restricted, and people will be told less and less about what their government is doing.

I wish to urge my government to change its priorities from the fast breeder to other forms of cleaner and safer energy- such as

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solar, tidal, wind, geothermal, possibly fussion, and, in the meantime, making every effort towards cleaning up our coal. We should also embark on a national policy of wise use of energy and energy conservation.

Gene Younghein

SOME LARGER TRUTHS ABOUT PERFECTION, PLUTONIUM, AND PRICE

This paper is addressed to the U.S. Atomic Energy Commission and the Environmental Protection Agency as a protest to the AEC's environmental review of the plutonium-fueled fast breeder reactor program.

The primary thesis presented here is that the decision on the program's acceptability to the long term well being of Americans is an ethical and moral issue. Being such an issue, the AEC review procedure is not structured to provide full public disclosure and a public forum over an adequate period of time to deal with such monumental ethical matters. Further, this thesis will point out the various attitudes, forces-at-work and questionable assumptions that prevail in the federal and private nuclear power entities that cause most of their personnel to be unqualified to make important ethical decisions pertaining to the public well being.

The author has an engineering background- understands and appreciates high technology. He asks each AEC employee to carefully consider his higher responsibilities and priorities. They could be Creator, fellow-humans, nature, and self in that sequence. Another way of stating this is conscience, ethics, constitution, government, employer, etc.

PERFECT VS IMPERFECT

There are two very real truths that are the keys to understanding the motivations behind the opposing contentions of experts in the nuclear safety controversy, and in determining the probability of their objectivity. They are the citizens' tools for a common sense approach to dealing with seemingly overpowering expert opinions;

1. Perpetually Perfect Performance or PPP - Many nuclear scientists, engineers and advocates consciously and subconsciously assume PPP to be a reality in their nuclear safety systems and procedures.

2. Nature abhors perpetually perfect human performance (Nature Abhors Perfection) or NAP - Many environmentalists and a few key nuclear scientists are acutely aware of human fallibility as well as a wide range of random variations in natural phenomena that challenges nuclear safety.

Perpetual Perfection- A Closer Look

The PPP concept has a convincing image of reality- created, propelled and perpetuated by a powerful set of forces which, by our traditional values are as acceptable as "fresh apple pie with ice cream." Consequently few citizens see the Faustian aspects in the pact that these forces have with nuclear power: especially with plutonium fuel development. Let us identify and describe the effect of some of these forces:

Ego

The highly educated professionals take a natural and honest pride in their scientific, engineering, and technical discipline. It is indeed such professional pride and technical ingenuity that has been so fruitful to our industrial progress. Because many of their results have been so difficult to achieve and are so highly sophisticated, requiring genius or near genius talent, a false sense of their infallibility has developed. Consequently it is almost psychologically impossible for any but a few people in the nuclear field to conceive that they can't engineer a perfect solution to any threat- that their careers aren't in the highest service to mankind.

Is is a case of individuals who, highly ethical and moral in conventional

terms, have specialized so intently that they are incapable of recognizing their own degree of tunnel vision and the possible consequences thereof on society.

This ego aspect also extends through the entire system, from the Joint Congressional Committee on Nuclear Energy, through the AEC and the manufacturers of nuclear power systems. The fabricators and reprocessors of nuclear fuel, the utility companies, all their bankers and stockholders, yes, even educators and writers of educational materials are mesmerized. They reinforce their mutual egos and tend to create an elitist value system: all important final decisions shall be made by technical experts, preferably without arousing notice or participation by the laity.

All are naturally prone to preserve the image of quality in their personal judgment and integrity. They are sincere in wanting the best system, the best for America. Consequently, it is natural for most to have a mental blind spot in respect to safety hazards. Any hint of a real but unacknowledged danger in nuclear power or plutonium fuel concepts, for example, is a genuine threat to their job security, professional careers, and personal integrity. Many of the experts are personable, community-minded leaders, friends, and neighbors. This is the effect of ego and it is a very real force behind PPP concepts.

Economic Momentum

A vast investment of federal funds in research and development over several decades in nuclear power is involved as well as 40 billion in private capital. Over five billion is currently committed to development of the plutonium fast breeder reactor. With this high level of economic and vested interest pressure, there is a predominant motivating

principle at work: economic feasibility or profit. Again, this single-mindedness has historically and traditionally been a great asset to our industrial progress and economic affluence.

Energy Crisis Syndrome.

The developing shortage of clean conventional energy resources is obvious. We make assumptions without much thought, however, that our previous rates of growth in electric power consumption, doubling every ten years, are valid and can and should be sustained. Many citizens also make quite invalid assumptions that nuclear power is the only alternative, and, hence, that plutonium fuel should be used. The high rate of energy consumption and waste has little relevance to values that comprise genuine and meaningful aspects of the quality of life or progress.

Consequently, in a crisis atmosphere, the clear-headed reasoning and public debate so essential to sound decisions may be cut short by expediency. Expediency in nuclear power has inherent potential hazards unlike anything our society has experienced.

Eggs in One Basket

Cleansing of conventional coal mining, processing and burning operations by more innovative and sophisticated methods, or coal gasification, has been postponed by lack of economic motivation and research funding. Almost no modern nation, for example, has tolerated such a longstanding scandal in coal mine safety as has the U.S.A. Further, it has been repeated, if not more so, in uranium mining.

The irony is that the problems of coal are of tinker-toy level compared to fantastic problems and the uncharted areas of plutonium power. It is

almost ludicrous to relate the long range hazards of plutonium to those of coal, however, coal should be only an interim to something safer and better. General Motors has announced, per Time Magazine, that they have found a practical method of removing 90% of the sulfur from the cheapest coal and will go full speed ahead. With coal we can improvise better techniques very rapidly-- no big deal.

THE PREDOMINANCE OF IMPERFECTION

Let us examine now the common sense case for the opposite concept: NAP (Nature Abhors Perfection). We have an overabundance of convincing evidence of its inherent truth. The entire history of human endeavors constitutes ^{ir}refutable testimony to this. It is, in fact, in the more complex areas of technology that the best evidence exists. For, example, man has never been able to make PPP a reality in his complex submarines, ships, aircraft, or spacecraft. Failures have frequently occurred in the conceptualization, design, construction, operation or maintenance phase. However, those conventional machines and systems have an almost child-like innocence and simplicity compared to a plutonium-fueled liquid metal fast breeder reactor.

An Age of Innocence

In the non-nuclear period, especially the pre-plutonium period, failures of man's systems had consequences that were acceptable. For example, in the worst technological disaster, the crash of an airplane, the consequences were tragic to be sure, however, not more than several hundred families were involved, liability was limited, the wreckage was cleaned up in a matter of days, business as usual prevailed shortly near the crash site, and the worst social and emotional scars faded away within a few years. A vital difference about such risks was that they were

common knowledge: we took the risks voluntarily.

A strong characteristic of the more innocent pre-plutonium age was that in each such tragic disaster the consequences were still relatively small and short lived, so that "learning from mistakes" was a viable approach. Consequently, all the force of ego, etc. was tolerable. In the plutonium age, the adequacy of the best scientific knowledge and the most technical skill is often surprisingly inadequate because of voids of basic knowledge. Consequently "learning by doing" has grave human risks in the nuclear age.

The consequences of one major failure, or the long range cumulative effects of numerous small incidents in the plutonium age are mind boggling. Small traces may be dangerous. Thousands to millions of people may be affected obviously and immediately, or insidiously after a latency period. Further, not just their lives and lifetimes are involved, but for thousands of generations to follow (one thirtieth of a million of an ounce of plutonium 239 can cause cancer and it remains hazardous for over two hundred thousand years.) In this nuclear-plutonium age, the citizens are being forced to accept the risks largely without consent or a full disclosure of the potential danger. A study by Dr. Arthur Tampa for the Natural Resources Defense Council indicated current standards may be 115,000 times too lax.

SNAFUs

The fallacy in the "PPP" plutonium concept is nowhere more evident than in the currently emerging nuclear industry. For example, several years ago, the AEC hailed the proposed storage of nuclear waste in old salt mines under Lyons, Kansas, as their most significant achievement since fission. However, within a year or so the plan developed into a technical

debacle and was scrapped. The reality came to light largely because an amateur or non-nuclear expert, the Kansas State Geologist, asked enough unanswerable questions.

Again in July 1973, the AEC ordered ten nuclear power plants to reduce operating power because of unresolved hazards in fuel and core safety. The whole topic of safety in emergency core cooling systems was again brought to light largely by efforts outside of the AEC top management, and the nuclear power industry.

The saga of radioactive waste leakage of hundreds of thousands of gallons at Hanford, Wash., is a story of AEC's poor management. Further, as demonstrated in the AEC monthly record of operations and by an account in the Wall Street Journal of May 3, 1973, the operation of new larger nuclear power plants is plagued with deficiencies in design, quality of material and construction, plus blunders in operation. The eighteen oldest nuclear plants were able to produce only 62% of rated power due to their unreliable performance.

Again, in the operation of the plutonium fuel fabrication facility north of Oklahoma City, the AEC inspection reports on file in public records clearly documents fires, spillages, leakages, worker over exposure, regulatory violations, losses of plutonium - later accounted for- and lack of management concern.

NAP (Nature Abhors Perfection). is also at work in the conceptualization, organization, and operation of the administrative, legislative and regulatory phases of nuclear power. Further, all the PPP(Perfect Perpetual Performance) forces tend to sustain them and resist their

evaluation or improvement. Examples are the Joint Congressional Committee on Nuclear Power with its tunnel vision, and the AEC with its inherent conflict between promotion and safety. Ironically, the informed responsible citizen has had to seek protection from those charged with the mission of protection, usually via court action.

DANGER - NATURE AND MEN WORKING

The random variations of nature produce phenomena such as earthquakes, floods, tornadoes, tidal waves, hurricanes, etc, and all work against the most carefully engineered plans by man. Many natural forces are so great as to defy realistic engineered solutions.

POTENTIALITY PRINCIPLE

There is a corollary to Newton's classic Third Law of Physics(i.e. for every action there is an equal and opposite reaction) "For every potential for good there is an equal potential for evil." Or, "the greater potential for good, the greater potential for evil."

Nuclear power and especially the LMFBR is the most compelling example of this principle. On the one hand, plutonium has the potential for being the greatest of blessings to mankind, a cornucopia of perpetual, clean, esthetic and economical energy. On the other hand, plutonium has the potential of the greatest evil ever-- widespread abandonment of vast areas of cities and cultivated areas, contaminated air, water, food, high infant mortality, higher incidence of lung and bone cancer, cold dark homes and dead appliances because of an over-dependence on nuclear power that proved to be so fiendishly unsafe that all breeder reactors were forced to shut down. A monumental disgrace could befall all associated with nuclear power. Again, the potentiality principle: the greater potential good from highly specialized expert knowledge,

the greater the potential harm from "tunnel-vision" and short sightedness. The risks are just too great. Dr. John Gofman said, "The development of plutonium and its use for electric power may be man's ultimate act of immorality."

RIGHT TO KNOW

Norman Cousins said in the Saturday Review/World of October 23, 1973, "Governments are not built to perceive larger truths. Only people can perceive great truths. Governments specialize in small and intermediate truths..."

Dr. Alvin Weinberg, Director of Oak Ridge National Laboratory, has acknowledged the valuable contribution of dissenting non-experts to better nuclear safety. Further, he said, "Amateurs have always been the great Messiahs of the World."

Only the people are capable of understanding the human and moral aspects that are the greater truths. But, the missing ingredient in reaching the larger truths is the public's right- to- know. The AEC, the nuclear industry, and the many vested interests have been highly secretive, and, only recently, somewhat more open, but still not frank.

The National Environmental Protection Act, however, demands full public disclosure. With such gigantic economic political, professional, governmental, and energy-crisis forces at work, can a participatory democracy and its people function satisfactorily in such a highly technical issue as plutonium fuel? We think the people can. We must, or face the possibility of an enduring tragedy and long-lived scandal.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Ilene H. and Gaylord A. Younghein
3900 Cashion Place
Oklahoma City, Oklahoma 73112

Dear Mr. and Mrs. Younghein:

Thank you for your letter of April 15, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement for the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. AEC responses to your comments are also enclosed. More detailed information concerning your comments and concerns on Plutonium Toxicity is presented in Section 4.7 and Appendix II.G of the Final Statement.

The attachment to your letter titled "A Case Against the Fast Breeder Reactor and the Plutonium Economy," expresses concern over a number of LMFBR safeguards-related matters:

- (1) the adequacy of current safeguards; (2) the possibility that plutonium might be stolen by erratic individuals or foreign agents; (3) the relative ease of making bombs with LMFBR fuel; (4) the threat of plutonium being used as a radiological weapon; (5) the vulnerability of nuclear facilities to acts of war; and (6) the possibility that future safeguards requirements will seriously restrict the freedom of individuals.

Your concerns have been carefully considered in preparing revised safeguards information for the Final Statement. Please see Section 7.4.7.6 for information related to your first area of concern; Section 7.4.3 for your second; 7.4.6 for the third; 7.4.5.1.2 for the fourth and Section 7.4.4.1 for the fifth. The sixth item is covered in Section 5.4.2.

Your interest in the LMFBP Program and comments on WASH-1535 are appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical And Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Comments
2. Final Environmental Statement,
LMFBP Program (WASH-1535)

Enclosure 1

AEC Staff Response to Comments
by Ilene H. and Gaylord A. Younghein

1. Comment

Radioactive Wastes (page 6 of enclosure - A Case Against)

It was claimed that mankind is enslaving future generations by obligating them to look after our radioactive wastes, that we do not yet have a container that will contain these wastes for very long (as shown by the Hanford waste tank leaks) and that if the cost of perpetual care of wastes were added to nuclear power costs, electricity from nuclear power plants would be very costly.

Response:

As noted in the Final Statement in Section 4.6.1, "the near-term waste management program that has been adopted by the AEC for high-level wastes calls for retrievable surface storage for safekeeping until a safe and acceptable ultimate disposal method has been selected and tested." There are enough promising ultimate disposal concepts presently being evaluated that the prospects for developing an acceptable ultimate disposal method within a period measured in decades is highly probable. Thus, it is not anticipated that future generations will be burdened to any significant extent.

The Hanford waste tank leaks are for the most part unrelated to the question of commercial high-level waste management. The Hanford wastes are the result of the production of plutonium for military purposes. The Hanford waste tanks were suitable only for temporary storage. Current Federal regulations require that commercially-generated liquid high-level waste must be converted to a solid material within five years after separation in the fuel reprocessing step. Five solidification processes have been developed and demonstrated. Safe methods of storing and caring for the waste after it is solidified and encapsulated are discussed in Section 4.6 of both the Draft and Final Statements.

When short-term liquid storage is part of the commercial waste management plan, corrosion resistant alloys will be used for the primary containment barriers (tanks) and more than one barrier will be used (e.g., tanks installed in lined vaults). The probability of leaks will thus be very low, the probability that a sizable leak could go undetected will also be very low (the leak will be trapped and detected in the vault) and these factors combined with the short-term storage (5 years or less) make the probability of uncontrolled large leaks extremely small. Analyses of possible paths to the environment for radioisotopes from waste management operations have not shown any instance where a serious public health hazard resulted. Current studies at AEC laboratories indicate that even the most exotic and costly high-level waste disposal schemes would add no more than a few percent to the cost of nuclear power. This is largely due to the fact that although the cost of disposal may be high relative to the quantity of waste, the quantity of waste is small.

2. Comment

(page 7 of enclosure - Some Larger Truths):

The Hanford waste tank leaks were cited as an example of AEC's poor management.

Response:

It was anticipated from the beginning of the Hanford Project (during World War II) that there might be high-level radioactive waste leaks from the Hanford tanks. The Hanford site was originally selected because of the soil conditions and the dry desert climate which provided for excellent retention of any liquid leaks in the soil immediately adjacent to the leak. The leaks from the Hanford waste tanks have not resulted in the exposure of any member of the public. Furthermore, the probability that any member of the public will be exposed to radiation in the future as a result of these incidents is essentially zero.

3. Comment

LMFBR Safety (page 6 of enclosure - Some Larger Truths):

"The consequences of one major failure, or the long range cumulative effects of numerous small incidents in the plutonium age are mind boggling."

Response:

The public consequences of all U.S. nuclear power related accidents which have occurred have been minor. A fundamental requirement of design (see Section 4.2.7.3) is that any single failure which might occur should not result in a serious risk to the public health and safety. The consequences of lower probability, more serious accidents that have been postulated to occur, even hypothetical ones, would not be in any sense "mind-boggling" (see Sections 4.2.7.7 and 4.2.7.8). The additional plutonium in an LMFBR does not grossly change radiation safety considerations, as compared with current water-cooled reactors; this point is addressed in Section 4.2.7.4.

4. Comment

(page 7 of enclosure - Some Larger Truths):

"Again in July 1973, the AEC ordered ten nuclear power plants to reduce operating power because of unresolved hazards in fuel and core safety. The whole topic of safety in emergency core cooling systems was again brought to light largely by efforts outside of AEC top management and the nuclear power industry."

Response:

On August 24, 1973 the AEC imposed temporary operating limitations on ten nuclear power plants pending receipt of additional calculations and data from the reactor manufacturer, following a review of earlier calculations. The limitations were not imposed because of any unresolved hazards but as an added precaution until calculational models could be further studied. The calculations themselves model conditions which assume many coincident failures of a wide variety of operating and safety systems. Many additional "safety margins" are also introduced in the calculations to cover all possible uncertainties. The August 24 order is a good example of the AEC's very cautious practice of providing additional margin whenever any uncertainty is discovered and does not represent a reflection on the safety condition of the reactors involved.

5. Comment

(page 5 of enclosure - A Case Against):

"In 1966, the Enrico Fermi Fast Breeder near Detroit had a near meltdown with the result that the plant is permanently shut down, at a loss of \$150,000,000. What is to be done with that radioactive pyramid? Certainly, it isn't improving the environment 'just sitting there.'"

Response:

The Fermi incident is discussed in the Final Statement in Section 4.2.7.5 and in detail in 4.2.7, Annex C. This accident, while it did lead to a lengthy and costly shutdown, was repaired and was not the cause of the plant finally being taken out of service. The plant is now being decommissioned.

6. Comment

(page 6 of enclosure - A Case Against):

"In 1961, the experimental fast breeder at Idaho Falls blew a plug sending 3 men to a gruesome death. According to the New York Times, Russia recently had some kind of accident with their fast breeder."

Response:

The accident referred to at Idaho Falls occurred at the SL-1 reactor which was an Army light water experimental reactor, not a fast breeder reactor. This accident resulted from an operator action which, though seriously improper, would not have resulted in an accident at any other reactor in existence in the country at the time, or built since. Although this was the most serious accident which has ever occurred in the U.S., in terms of consequences to people, it posed no hazard to the general public. The Russian "accident" is more

properly called a malfunction of a particular sub-system; it led to a steam generator sodium-water reaction. LMFBR systems are designed to safely accommodate this type of malfunction (refer to section 4.2.7.5.5).

7. Comment

(page 6 of enclosure - A Case Against):

"Because of the high heat of breeders and the great toxicity of plutonium, fast breeders are to regular reactors as lightning is to lightning bugs."

Response:

This analogy, although colorful, does not accurately reflect the similarities and differences between LMFBRs and LWRs. Some comparisons of these reactor types are presented in Section 4.2.7.4 of the Final Statement. It is shown therein that, despite some differences in features, each reactor type is designed for safe operation with full recognition of all its inherent physical characteristics. For example, light water reactors have negative void coefficients, and they use high pressure coolant. LMFBRs have positive void coefficients but use low pressure coolant. In both cases the overall power coefficient is negative, assuring an inherent resistance to reactivity transients. Thus, the safety of both LMFBRs and LWRs is on a comparable and fully acceptable level.

8. Comment

Alternative Energy Sources (pages 4 and 5 of enclosure - Some Larger Truths):

"Cleansing of conventional coal mining, processing and burning operations by more innovative and sophisticated methods, or coal gasification, has been postponed by lack of economic motivation and research funding. Almost no modern nation, for example, has tolerated such a longstanding scandal in coal mine safety as has the U.S.A. Further, it has been repeated, if not more so, in uranium mining.

"The irony is that the problems of coal are of tinker-toy level compared to fantastic problems and the uncharted areas of plutonium power. It is almost ludicrous to relate the long range hazards of plutonium to those of coal, however, coal should be only an interim to something safer and better. General Motors has announced, per Time Magazine, that they have found a practical method of removing 90% of the sulfur from the cheapest coal and will go full speed ahead. With coal we can improvise better techniques very rapidly--no big deal."

Response:

As indicated on p. A.2-65 of the Draft Statement, current plans call for spending about \$2.2 billion over the next five years on research and development involving the mining, combustion, and conversion of coal.

Current estimates of recoverable, proven reserves of coal in the U.S. range from about 150 billion tons to about 400 billion tons. Though some coal now classified as part of the more uncertain "resource base" will be transferred to the "recoverable reserve" category in the future as prices rise and exploration broadens, it is unlikely that if our energy growth rate remains high, our coal supply would last as long as our uranium supplies.

Aside from environmental considerations, the resource bases associated with coal-fired electrical energy generation and electrical energy generation by LMFBRs are not comparable. The LMFBR resource base is sufficient to last for centuries, while our coal resources may be depleted within one century, if required to provide increasing shares of non-electrical and, indeed, non-energy demands.

Though the U.S. underground coal-mine safety record is not yet equal to that of some other industrialized nations, the record has improved significantly since passage of the 1969 Coal Mine Health and Safety Act. Bureau of Mines records indicate that the number of fatalities per million (net) tons of coal mined has declined from 0.43 in 1970 to 0.22 in 1973, a reduction of almost twofold. The number of nonfatal injuries per million tons mined, however, declined by only 2% during the same period. This safety record improvement has been accompanied by a decrease in deep-mine productivity (tons produced per man day) of about 20%, from 13.8 in 1970 to about 11.0 in 1973. The Study Committee on Environmental Aspects of a National Materials Policy of the National Academy of Sciences and National Academy of Engineering has recently made the following recommendation:

"The Coal Mine Health and Safety Act of 1969 should be thoroughly and promptly reviewed with regard to its effects on the health and safety of the miners. Its provisions should be vigorously enforced with the aim of achieving substantial reductions in underground mine accident rates. The Federal government should support increased research and development in the technologies of economic underground mining and improved health and safety."*

It has been found that large-scale rapid improvisation in the coal industry is, in fact, difficult. Examples include the quite slow rates of introduction, to date, of automated deep-mine continuous extraction systems, of the safer and higher-recovery method of longwall underground mining, of reliable stack-gas scrubbing systems on large electric utility units, and of in-situ (underground) coal gasification. As the pace of R&D and of technology transfer quickens, it is hoped that this large industry will, in the near future, be able to incorporate improved technology more rapidly.

*Man, Materials, and Environment, p. 115, The M.I.T. Press, Cambridge, (1973).

The General Motors stack gas scrubbers installed on its power plant at Parma, Ohio have been in operation since March 1974. The unit's capacity of 40 MW is only one-tenth to one-thirtieth that of a modern utility unit. The current scrubber system cost is equivalent to an additional \$10 per ton of coal, an increase of about 40%. While this small experimental prototype is promising, further testing on larger units over a longer period of time will be required to demonstrate its feasibility for large utility plants. Such results may be forthcoming from the joint GM-EPA study to refine the process and to reduce the costs. It is also noted that the incremental cost incurred by scrubbing that is reflected in General Motor's total product cost is undoubtedly a small fraction of the incremental cost of a utility's product (electrical energy) that is associated with current stack-gas scrubbing systems.

HARVARD UNIVERSITY

DEPARTMENT OF PHYSICS

CYCLOTRON LABORATORY
CAMBRIDGE, MASS. 02138

April 16, 1974

U.S. Atomic Energy Commission
ATT: The Secretary
Washington, D.C. 20545

Dear Sir:

I have recently received a copy of the draft Environmental Statement for the LMFBR program.

Time, and a recent family problem, prevent my commenting in detail. However, I find three glaring deficiencies.

First, in the discussion of alternative nuclear systems to the breeder, no mention is made of CANDU reactors. These work well (87% availability vs. 65% of U.S. reactors) as used by Ontario Hydro. There exist a number of papers including one by W. Bennett Lewis for the Royal Society of Edinburgh, on a U^{235} Th cycle for this reactor which would nearly breed.

With the increased uranium supplies that now seem likely, and the increased cost of the LMFBR, these U/Th cycles must be considered as a possible mechanism of marking time pending a decision in the future - by which time fusion may work.

Second, the hazard of diversion of plutonium to critical uses is greater for an LMFBR than for other systems. The recent book by Wihlrich and Taylor (Ballinger Press, April 1974) emphasizes this. There seems only a small discussion of nuclear parks, whereby transportation is limited. Yet these are vital to alleviate the problem.

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Third, no mention is made, or response given, to the two obvious economic problems of LMFBF; one is that sodium is opaque and a bolt dropped down would be lost to sight; two, the sodium/steam heat exchanger is very important. Heat exchangers usually leak and a leak here would shut down the plant. This presently keeps PFR (Donneray) off line. Maybe these problems are not as bad as they would appear to an outsider - but that should be carefully explained, since they are so obvious.

I hope these comments are helpful.

Yours sincerely,

A handwritten signature in dark ink, appearing to read "Richard Wilson", with a stylized flourish at the end.

Richard Wilson
Professor of Physics

RW: jk

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Professor Richard Wilson
Department of Physics
Harvard University
Cambridge, Massachusetts 02138

Dear Professor Wilson:

Thank you for your letter of April 15, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. This letter responds to the specific issues you raised.

With regard to your concern about alternative nuclear systems, the AEC did not discuss certain systems, specifically the CANDU (Canadian-Deuterium-Uranium) concept, because it was decided to limit the treatment of alternative nuclear technologies in the Statement only to systems now operating or considered promising and capable of penetrating the U.S. nuclear power market. The AEC has, of course, over the years evaluated and conducted research on a number of reactor concepts, some of which have been selected for further development and some of which have been found unpromising and therefore not warranting further support. The Heavy Water Cooled and Moderated Reactor concept has in the past been relegated to this latter category. Nevertheless, re-evaluations of various reactor concepts are occasionally conducted as new developments occur or new information becomes available, and in the case of Heavy Water Reactors (HWRs) the most recent review was completed on April 5, 1974. It was concluded at that time that construction of HWR plants (of the CANDU type) in the U.S. during the next decade does not merit serious consideration. The reasons for this conclusion are summarized below, and a copy of the evaluation report is enclosed for your information.

The evaluation concluded that there appear to be no fundamental technical problems that might delay the construction of HWR plants in Canada or other nations with similar economic and licensing structures. Nevertheless, there are several technical and economic factors that make this system much less attractive in the U.S., and for these reasons U.S. utilities have not chosen HWRs and are not expected to do so in the near future. The primary factors militating against HWRs are licensability and cost. The former includes problems relative to containment design (not entirely compatible with the existing U.S. regulatory approach), tritium production and release (due to the use of heavy water as the coolant), and emergency

core cooling (the geometry and orientation of HWR cores is significantly different from that of the Light Water Reactors (LWRs) prevalent in this country, and would require extensive analysis and R&D to verify satisfactory emergency cooling). The economic factors mitigating against HWRs include higher capital costs (several percent or more relative to LWRs), and higher fuel cycle and deuterium costs (see enclosure 1).

A major advantage of HWRs is their good fuel utilization - they are, under the assumptions in the evaluation report, 170% more effective with respect to uranium requirements than LWRs, and about 40% more effective than the High Temperature Gas-cooled Reactor (HTGR). Fuel utilization of all three reactor systems (HWR, LWR and HTGR) can be improved considerably over present values and, as you noted, the HWR can be designed for nearly break-even breeding on the Uranium 233-Thorium fuel cycle. This fuel cycle is also utilized by the HTGR, which is now entering the commercial area as an advanced converter, and by the Light Water Breeder Reactor (LWBR), which is under development by the AEC as discussed in the enclosed Environmental Statement. A major problem in successful achievement of breeding in a CANDU type reactor would be the requirement for low fuel burnup to prevent fission product poison accumulation in the reactor. Resulting power costs would be increased substantially, making this system even more economically unattractive in the U.S. than it appears to be at present. The economics of CANDU reactors is discussed further in the enclosed report, where the several reasons for not pursuing HWRs are examined in more detail.

With regard to your comment regarding the hazard of diversion of plutonium to critical uses, the AEC recognizes that the safeguarding of nuclear material is a major concern to the public and also one of the major problems in developing and implementing an LMFBR power economy. We believe these problems can be solved, and the subject is discussed at length in Section 7 of the enclosed Statement, which has been extensively revised in response to comments received on the Draft Statement. Please see Section 7.4.6 for information related to the comparative safeguards aspects of the various nuclear fuel cycles and Section 7.4.9.4.2 for discussion of the safeguards aspects of nuclear parks.

Your observations regarding "...two obvious economic problems of LMFBR; one, that sodium is opaque and a bolt dropped down would be lost to sight; and two, that the sodium/steam heat exchanger is very important,..." have both been considered in the preparation of the Final Statement. These matters are indeed recognized as problem areas, but both are believed amenable to engineering solution. They are discussed in Sections 4.2.3 and 4.2.7 of the Final Statement.

We hope that the above information and the enclosures are sufficiently responsive to the points you raised. Thank you again for your comments and for your interest in the LMFBP Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. Evaluation of the Potential of
Heavy Water Reactor Plants in
the United States (Phase 2)
2. Final Environmental Statement,
LMFBP Program (WASH-1535)

APR 5 1974

EVALUATION OF THE POTENTIAL OF
HEAVY WATER REACTOR PLANTS IN THE UNITED STATES (PHASE 2)

1. INTRODUCTION

The following discussion provides the detailed results of an evaluation of the potential of Heavy Water Reactor (HWR) plants in the U.S. Initial thoughts resulting from this evaluation were drafted on December 12, 1973 and submitted to Commissioner Anders on December 18, 1973. Since then, further work has been performed and the informal comments received on the initial transmittal have been addressed. Additional discussions with knowledgeable engineers representing the manufacturer, architect-engineer, utility and national laboratory points of view, as well as the results of the review of cost sensitivity and fuel utilization analyses performed by the Oak Ridge National Laboratory have been considered.

2. TECHNICAL STATUS OF HEAVY WATER NUCLEAR PLANTS

2.1. BASIC HEAVY WATER REACTOR TECHNOLOGY

Basic technology for heavy water (D_2O) moderated and cooled reactors has been demonstrated by the Canadians. There appear to be no fundamental technical problems that might delay the construction of such plants in Canada. The four 500 MWe Pickering plants (operating with D_2O moderated and cooled reactors) are reported to be achieving high plant factors. Because of a valid U.S.-Canadian Cooperative Program Agreement the U.S. has potential access to the existing technology.

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2.2. TECHNICAL PROBLEMS IN INTRODUCING HWR PLANTS IN THE UNITED STATES

2.2.1. LICENSABILITY

During the past several years the designs of light water reactor (LWR) plants in the U.S. have been upgraded to satisfy evolving quality standards and regulatory guides and criteria. Since the basic HWR plant design is different from the LWR design, the existing U.S. standards and regulatory guides and criteria do not apply directly. These would have to be modified or developed as required for the HWR design. While a precise evaluation of changes which would be needed to allow the Canadian HWR plants to be licensed in the U.S. is not possible, a number of major design issues can be foreseen:

2.2.1.1. The containment design probably would not be acceptable. For instance, the four existing 500 MWe Pickering reactors have a joint containment barrier which does not appear to satisfy the criterion of basically passive containment of a double ended pipe rupture accident hypothesized for U.S. plants. Instead, for this maximum accident, containment over-pressure would be prevented by activation of a venting valve in a pipe leading to a vacuum and quenching building. A vacuum pump which is normally in operation to maintain a vacuum in this building would have to be shutdown to prevent release of possible fission products to the atmosphere. Reportedly, the critical vent valve has been operationally tested only at 1/4 scale because of difficulties in testing it at full size under prototypic conditions of the hypothetical accident.

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2.2.1.2. Tritium release is of concern in the LWR plants where a major portion of its generation is due to the minute quantities of D_2O in the primary circuit cooling water. In HWR plants this appears to be a much more serious problem, which, on the basis of available information, has not been fully addressed or resolved. Relatively high partial pressure of tritium in D_2O increases the potential for tritium leakage through seals and for its diffusion through thin metal barriers. As a result, efforts to minimize tritium release to the environment would be needed and a development program probably would be necessary.

2.2.1.3. The existing HWR plant designs undoubtedly would have to be modified to satisfy criteria corresponding to the single failure criteria and redundancy requirements which have evolved for the U.S. LWR plants.

2.2.1.4. A great deal of analysis and research and development has been undertaken in the U.S. to demonstrate the adequacy of Emergency Core Cooling Systems (ECCS) in LWRs. Since HWR cores have a different geometry and are oriented horizontally this effort would not be fully applicable. Additional ECCS analyses undoubtedly would be necessary for HWRs and might lead to R&D requirements and plant design changes.

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2.2.2. SIZE EXTRAPOLATION

The largest operating HWR unit has a 508 MWe net capacity and 750 MWe Bruce HWR units are under construction. So far the Canadians have not committed a larger plant, whereas the U.S. LWR manufacturers have sold several 1300 MWe plants.

There appears to be no fundamental obstacle which would prevent size increases of the HWR and it has been reported that conceptual design of a high capacity plant is in progress. Nevertheless, the Canadians have opted for construction of eight 750 MWe units rather than for construction of fewer larger capacity units at the Bruce site.

The HWR header construction and refueling scheme present problems which it is probably preferable to minimize through construction of multi-unit plants. In-core pressure tubes must be individually fed with coolant in such a way as not to interfere with equipment access for on-line refueling performed at both ends of the core. To the first approximation, for a capacity increase from 750 to 1300 MWe, the area of the head forging would increase about 70 percent, substantially increasing the complexity of the reactor.

2.2.3. DESIGN OPTIMIZATION

The existing HWR plants are optimized for Canadian labor and capital cost conditions and are designed for maximum simplicity of the fuel cycle (i.e. for operation with natural uranium). As a result of power

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cost optimization, the U.S. Heavy Water Reactor Program which was cancelled in 1967, had focussed on an organic cooled reactor with slightly enriched fuel. If U.S. manufacturers would decide now to adopt the D_2O cooled and moderated Canadian design, they would try to minimize changes in the proven plant. However, since the reactors would have to be saleable, it appears major design changes would be necessary to make these plants more economically competitive under U.S. conditions.

Thus, very likely, U.S. manufacturers would again opt for slight uranium enrichment which would remove the severe constraints facing the Canadians in the use of neutron absorbing core construction materials. This design step would tend to reduce capital costs by simplifying construction, facilitating improvement of steam conditions (thereby reducing capital costs of the conventional part of the plant), and by making it easier to extrapolate power capacity to the high level offered by LWR manufacturers.

2.2.4. ADDITIONAL TECHNICAL CONSIDERATIONS

There are additional issues which could be of concern to a utility purchasing a HWR plant. Because of limited worldwide sales the cumulative operating experience of HWR plants will remain small for a considerable time. Thus, there may be lingering concerns as to reliability, particularly with respect to: (a) A serious incident with the on-line

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refueling system. It can be postulated that a failure of this system with a partially extracted fuel element would be very serious and costly because of potential presence of fission products and unaccessibility, (b) An incident involving a costly major loss of D_2O (although insurance might be available for protection from this occurrence).

HWR partial load operation and shutdown recovery are influenced by a xenon poisoning problem. Resultant operating characteristics are different from those with which U.S. utilities are familiar. Although there probably are ways to solve the problem, it would have to be addressed in detail.

An offsetting element favoring HWR plants may be the potential of on-line refueling for bringing about relatively high plant factors. A determination of whether HWR plant factors higher than achieved by light water plants are indeed attainable (while satisfying all long-range maintenance and inspection requirements for the plants and their refueling systems) requires extrapolation to U.S. conditions and accumulation of much more operating experience than now available.

3. ECONOMIC CONSIDERATIONS

3.1. CAPITAL COSTS (EXCLUSIVE OF D_2O)

As discussed in Section 2.2.2., it is necessary to compare the Bruce-Pickering HWR now offered by Canadians, with the advanced LWRs now offered in the U.S. For such a comparison, the cost differential

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(HWR excess cost relative to LWR) per kilowatt of installed capacity might be broken down approximately as follows: (a) 40 \$/KW due to the greater HWR reactor and plant complexity and lower construction efficiency under U.S. conditions (based on best weighted judgment of information in the literature, and presumed involvement of numerous U.S. business entities instead of the relatively small Canadian design and construction group), (b) 30 \$/KW due to the upgrading needed to satisfy U.S. standards and regulatory requirements (based on estimated costs of recent upgradings carried out in LWR plants), (c) 80 \$/KW due to the plant size discrepancy (based on the assumption that this differential is the same as the one derived from Reference 1 for an equivalent LWR plant size difference). Thus, the total estimated differential adds up to a penalty of about 150 \$/KW for the HWR plant, or about 3 mills/Kw-hr in levelized power cost. This differential may be compared to the figure of 145 \$/KW given in Reference 2, transmitted by the Consolidated Edison Company of New York, Inc. (See Table 1, Approximate Comparative Cost Data for 1980 Operation, in the attached Appendix 2). This reference mentions, but does not include in the total, any allowance for construction conditions in the U.S., and for the required plant upgrading to satisfy U.S. quality assurance and Regulatory needs. On the other hand, for the HWR plant it does include heavy water and one half initial fuel inventory costs, probably about 40 \$/KW.

Although the above estimated cost differentials are based on the best available data, such large total cost differences per unit capacity

do not properly reflect the potential of HWR plants in the U.S. To make a more valid comparison, a detailed design and cost estimate of an optimized high capacity plant, satisfying all U.S. requirements and conditions, is necessary. Without it, however, it is possible to weigh several basic considerations which include: (a) the inherently larger size of HWR plants; (b) their greater design complexity; and (c) the presence of additional systems required for handling D_2O . Taking into account these factors, and prevailing U.S. conditions, the present judgment is that ultimately there would remain a capital cost penalty of several percent or more, equivalent to at least 0.5 mills/Kw-hr.

3.2. FUEL CYCLE AND D_2O COSTS

In making an economic comparison of HWR and LWR reactor fuel costs, one can consider that the cost of D_2O separation in heavy water plants basically offsets the cost of uranium separation in light water plants. Thus, a broadly defined HWR plant fuel cycle cost can be obtained by lumping the D_2O interest charges with the fuel costs. On this basis, the HWR-LWR fuel cycle cost differential remains small for a relatively wide range of assumptions.

It can be assumed that the near-term uranium ore prices and the cost of separative work will increase, favoring the HWR plants. At the same time the D_2O costs may also be expected to rise, somewhat counterbalancing this effect.

As part of this evaluation, the Oak Ridge National Laboratory staff was requested to perform fuel cycle cost sensitivity studies. The price of uranium ore, separative work and D_2O , as well as the fixed charge rates were varied over a wide range of values. The results of this analysis are presented in Table 2 of Appendix 1. The best present judgment for conditions which might prevail 10 years from now points to prices of 15 \$/lb U_3O_8 , 50 \$/^W/SWU, 90 \$/kg of D_2O (see Appendix 3 for comments on D_2O production costs), and a 16 percent yearly interest charge. Under these circumstances, as seen in Table 4 of Appendix 1, HWR plant energy costs might be 2.60 mills/KW(e), versus 2.53 mills/KW(e) for a LWR. It may be concluded that there is little likelihood of a significant differential developing in these fuel cycle costs before 1984-1985.

4. FUEL UTILIZATION

A major advantage of heavy water moderated reactors is their good fuel utilization. In the course of this evaluation, the Oak Ridge National Laboratory has supplied gross comparative estimates of fuel utilization for present LWR, HWR and High Temperature Gas Reactor (HTGR) plants. The results are listed in Table 5 of Appendix 1. It is seen that the heavy water plants may be considered nearly 170 percent more effective with respect to uranium requirements than the light water plants, but only about 40 percent more effective than the HTGR.

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The HWR-HTGR fuel utilization differential cannot be considered important. As noted in Section 2.2.3., if U.S. manufacturers were to utilize the Canadian design, they probably would be forced by economic considerations to switch to a slightly enriched system, with a poorer uranium utilization factor. Fuel utilization of all three reactor systems considered (HWR, LWR and HTGR) can be improved considerably over the present values and they all can be designed for break-even breeding on the uranium 233-thorium fuel cycle.^{3/} A light water breeder is presently under development in the U.S. In the near term it is likely that the conversion ratios and the fuel utilization of all present plants will tend to increase due to increased ore prices and changes in other fuel cycle costs. However, this trend probably will evolve from economic considerations rather than from policies to improve fuel utilization.

5. OVERALL CONSIDERATIONS AND SUMMARY REVIEW

This review indicates that construction of HWR plants in the U.S. during the next decade does not merit serious consideration. Canadian HWR nuclear plants of current design cannot be built in the U.S. without modification and the resolution of a number of technical questions, including safety-licensing issues. This effort would severely tax the already extended U.S. manufacturing and technical manpower resources in the nuclear field. Furthermore, no significant overall fuel cycle cost advantage (as defined in Section 3.2.) can be expected for the Canadian plants, and the capital

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charges would be considerably higher than for plants being offered by U.S. manufacturers. Indeed, for the next 10 year period, there appears to be insufficient motivation for introducing HWRs in the U.S., even if one neglects the anticipated HWR-LWR capital cost differential.

The validity of the conclusions is reinforced by the Canadian experience in marketing HWR plants outside of their country. Except for those countries where special considerations such as the simplicity of the natural uranium fuel cycle make HWR plants attractive, there have been no major HWR plant sales. For example, following a recent review of available options the British reportedly have again not selected the HWR CANDU reactor. Although the British have devoted a considerable development effort to the steam generating heavy water reactor (100 MWe SGHWR), it is understood they have concluded that direct extrapolation of this system to a 1000 MWe plant is not technically justifiable.

U.S. utilities and manufacturers do not appear interested in the HWR system, presumably because of negative evaluation results. Recent correspondence relating to an analysis by the Consolidated Edison Company of New York, Inc., is attached as Appendix 2. It notes (paragraph 2, page 2, of the letter from W. W. Lowe to L. H. Roddis) that if their cost estimates are even approximately right, CANDU technology could not produce economically competitive power for the U.S. market, unless plants are built in Canada, with the low capital fixed charge rates typically applicable to government-owned facilities in Canada.

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While the HWR plants are much more efficient from the fuel utilization point of view than the currently commercial LWR plants, the U.S. presently has adequate alternatives without recourse to the HWR reactor. One of these, the HTGR system, presently is favored by U.S. utilities because of potential additional benefits, including consonance with direct cycle power extraction and heat rejection through dry cooling systems.

For the long term (beyond 10 years), depending on the success of the development of the LMFBR, HTGR and Light Water Breeder Reactor, the HWR system may appear attractive. Under certain assumptions, this system eventually could become of interest. However, to firmly establish its competitive position would require drastic changes in the overall situation such as: (a) major disappointment in the HTGR system, or (b) a major reduction of D_2O production costs by some process (e.g. laser technology) which would not similarly reduce the cost of uranium separation.

Under such circumstances a reevaluation could be in order. First it would be necessary to develop an optimized design and cost estimate of a HWR plant for application in the U.S. This would require a major design effort with Canadian cooperation by a U.S. nuclear plant manufacturer. The extensive involvement of the AEC regulatory staff would also be needed to assure that this design could be licensed in the U.S.

For the near term, there remains the possibility of a cooperative effort with the Canadians to build HWR plants in Canada, and to contract for the long-term U.S. purchase of the energy from these plants. Plants could

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be built in Canada according to existing designs, possibly under relatively favorable capital cost conditions. The U.S. could perhaps obtain additional energy at a reasonable cost, and the Canadians would achieve greater economic benefits than would be possible from direct sales of uranium ore. Such an arrangement was proposed last summer by Acres, Ltd., and reportedly was tabled by the Ontario legislature.

Some U.S. utilities are understood to have made contacts with the Canadians to briefly explore the above possibility. However, no indication of serious utility interest in such an arrangement was found. One utility, located on the Canadian border, has reported informally that Canadian environmental constraints would be stringent and that the overall result of their investigation of this approach was negative.

Attachments:

1. Appendix 1
2. Appendix 2
3. Appendix 3
4. List of References

APPENDIX 1

ORNL SUPPORTING STUDY

Estimated Energy Costs and Fuel Utilization
for CANDU Heavy Water Reactors and U.S.-
Type Light Water Reactors

L. L. Bennett

February 7, 1974

At the request of the Division of Reactor Research and Development, AEC, energy costs and fuel utilization were estimated for CANDU-type pressurized heavy water reactors and for U.S.-type light water reactors (PWR used as basis). This memo describes those estimates and presents cost sensitivities for selected items, such as uranium, separative work and heavy water costs.

1. Data Sources

Data for light-water reactor fuel cycles were based on typical PWR mass balances using recycle of self-generated plutonium. Equilibrium cycle costs were calculated.

CANDU data are based on current natural uranium fuel cycle, with no reprocessing of the spent fuel. (Canadian cost estimates indicate little or no economic incentive for plutonium recycle under near-term conditions.) Reactor characteristics and costs data were derived from References 4 through 7.

2. Base Fuel Cost Estimate

The fuel cycle costs were estimated for PWR and CANDU-PHW plants, using a base set of cost parameters. The base values and energy costs are presented in Table 1 for present conditions, and in Table 2 for estimated upper values during the next decade.

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3. Heavy Water Cost

In addition to the nuclear fuel costs, the heavy water reactor has costs associated with the inventory and upkeep of its heavy water

Typical design characteristics for 500-MW(e) CANDU-type reactors are as follows:

Heavy Water Inventory: 0.55 kgs/kW(e)

Heavy Water Makeup*: 0.8 kg/hour (2 gms/MWh(e) @ 0.8 PF)

These values lead to the following cost estimates:

D₂O Inventory (\$80/kg; 14%/year): 0.88 mills/kWh(e)

D₂O Upkeep (\$80/kg): 0.16 mills/kWh(e)

Total D₂O Cost 1.04 mills/kWh(e)

4. Discussion of Results

4.1 LWR Costs

The costs calculated for light water reactors are thought to be in agreement with costs currently being experienced by utilities operating LWRs. The detailed breakdown in Table 1 allows for conveniently estimating sensitivity of LWR costs to cost of U₃O₈ and separative work, which are the two costs most likely to increase in the future.

* Losses plus equivalent loss rate due to downgrading of D₂O in system.

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4.2. CANDU COSTS

The fuel cycle cost estimated in Table 1 appears to be in agreement with Canadian estimates. For instance, Reference 8 states without giving detail, "The fuel performance has been generally up to expectations, and has confirmed the estimated cost of 0.9 mills/kWh."

The cost associated with heavy water inventory and upkeep are higher in this memo than in References 4 through 8, because we have used a higher cost for heavy water (based on Division of Production and Materials Management staff estimates) and higher interest rates prevalent in the U.S.

Estimated costs of U.S. production of heavy water are in the range 35 to 40 dollars per pound (\$77-88/kg). Cost data in References 4 through 8 use heavy water costs in the range \$0-55/kg. These values appear unreasonably low for future costs using current heavy water production methods and considering that energy costs are a large fraction of the total D₂O costs.

Since the heavy water charges (at \$80/kg) contribute more to CANDU energy cost than does the fuel cost, the cost of heavy water production is a key variable in the total cost of energy from CANDU reactors.

5. Sensitivity Analysis

The sensitivity of total cost to the values used for certain cost variables were studied. The variables included:

U_3O_8 price

Separative work price

Heavy water price

Fixed charge rate

Results are presented in Table 3 and Table 4. It is seen that lumped D_2O fuel cycle costs in 1984 are estimated to be about the same for H_2O and D_2O plants.

6. Fuel Utilization

Table 5 presents comparative fuel utilization factors which were obtained for recent designs of HTGR, CANDU-PHW, and LWR. Plutonium recycle has been assumed for all the plants, although at present the fuel of CANDU plants is not reprocessed. This gives a representation of the future energy potential of the plutonium and U-235 remaining in the discharged fuel.

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Table 1. Cost Parameters and Energy Costs
for PWR and CANDU-PHW Power Plants
(Present Conditions)

	PWR		CANDU	
	<u>Basis</u>	<u>mills/kWh(e)</u>	<u>Basis</u>	<u>mills/kWh(e)</u>
<u>DIRECT COSTS</u>				
Fuel Fabrication	\$75/kgU	0.26	\$30/kgU	0.48
Fuel Shipping	\$10/kgU	0.03	0	0
Fuel Reprocessing	\$40/kgU	0.14	0	0
Uranium Feed	\$8/lb U_3O_8	0.43	\$ 8/lb	0.33
Separative Work	\$36/SWU	0.47	0	0
$U_3O_8 \rightarrow UF_6$ Conv.	\$2.50/kgU	0.05	0	0
Plutonium Credit	\$9.30/gm Pu_F	0	0	0
Subtotal		1.38		0.81
<u>INTEREST COSTS</u> 14%/year				
Fabrication		0.05		0.07
Shipping		0		0
Reprocessing		- 0.03		0
Uranium Feed		0.12		0.05
Separative Work		0.11		0
$U_3O_8 \rightarrow UF_6$ Conv.		0.02		0
Plutonium		0.10		0
Subtotal		0.37		0.12
TOTAL		1.75		0.93

Table 2. Cost Parameters and Energy Costs
for PWR and CANDU-PHW Power Plants
(Estimated Upper Values of Sensitivity Parameters
During Next Decade)

	PWR		CANDU	
	<u>Basis</u>	<u>Mills/Kwh(e)</u>	<u>Basis</u>	<u>Mills/Kwh(e)</u>
<u>Direct Costs</u>				
Fabrication	\$75/kgU	0.26	\$30/kgU	0.48
Shipping	\$10/kgU	0.03		0
Reprocessing	\$40/kgU	0.14		0
U ₃ O ₈ Feed	\$15/lb.	0.81	\$15/lb.	0.62
Sep. Work	\$50/SWU	0.65		0
U ₃ O ₈ → UF ₆ Conv.	\$2.50/kgU	0.05		0
Plut. Credit	\$9.30/gm	0		0
Subtotal		<u>1.94</u>		<u>1.10</u>
<u>Interest Costs (16%/year)</u>				
Fabrication		.06		.08
Shipping		0		0
Reprocessing		.03		0
U ₃ O ₈ Feed		.26		.11
Sep. Work		.17		0
U ₃ O ₈ → UF ₆ Conv.		.02		0
Plutonium		.11		
Subtotal		<u>.59</u>		<u>.19</u>
Total Fuel		2.53		1.29

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Table 3. Sensitivity of LWR and CANDU
Costs to Selected Parameter Values

Parameter	Mills/kWh(e)				
			CANDU		
			<u>Fuel</u>	<u>D₂O</u>	<u>Total</u>
<u>1. U₃O₈ Price, \$/lb</u>					
* 8 }	1.75	0.93	1.04	1.97	
15 }	2.23	1.26	1.04	2.30	
50	4.64	2.93	1.04	3.97	
100	8.08	5.30	1.04	6.34	
<u>2. Separative Work Price, \$/SWU</u>					
* 36 }	1.75	0.93	1.04	1.97	
50 }	1.98	0.93	1.04	1.97	
75	2.38	0.93	1.04	1.97	
<u>3. Heavy Water Price, \$/kg</u>					
25	1.75	0.93	0.33	1.26	
50	1.75	0.93	0.65	1.58	
* 80 }	1.75	0.93	1.04	1.97	
100 }	1.75	0.93	1.30	2.23	
<u>4. Fixed Charge Rate, %/year</u>					
10	1.64	0.90	0.79	1.69	
* 14 }	1.75	0.93	1.04	1.97	
18 }	1.86	0.96	1.29	2.25	

* Base Case

} Expected Range During Next Decade

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Table 4. Summary Comparison

(Case A Represents Present Conditions; Case B Represents
Values Used for 1984 Conditions)

	<u>Case A</u>	<u>Case B</u>
U_3O_8 Cost, \$/lb.	8	15
SW Cost, \$/SWU	36	50
D_2O Cost, \$/kg	80	90
Interest Rate, %/year	14	16

Fuel Plus D_2O Costs, mills/kwh(e)

	<u>Case A</u>		<u>Case B</u>	
	<u>PWR</u>	<u>CANDU</u>	<u>PWR</u>	<u>CANDU</u>
Fuel	1.75	0.93	2.53	1.29
D_2O	0	1.04	0	1.31
Total	1.75	1.97	2.53	2.60

Table 5. Comparative Fuel Utilization

	<u>CANDU-PHW</u>	<u>HTGR</u>	<u>LWR</u>
	<u>(Pu Assumes</u>	<u>(U233 Assumes</u>	<u>(Pu Assumes</u>
	<u>Recycle)</u>	<u>Recycle)</u>	<u>Recycle)</u>
<u>U₃O₈ Requirements, ST/MW(e)</u>			
Initial Core	0.246	.395	.548
Annual Feed *	0.065	.089	.179
Net 30-Year	2.205	3.065	5.918

* At 0.80 Annual Plant Factor.

APPENDIX 3

D₂O PRODUCTION COSTS

It appears that a drastic reduction of D₂O costs has the potential to make the D₂O reactor system attractive in the U.S. and therefore, this issue was carefully evaluated with the help of the Division of Production and Materials Management staff. The conclusion is that the projected D₂O costs for the 1980-1985 period are 25 to 40 percent higher than the 1968 costs, i.e., about \$35 to \$40 per pound. These costs could be higher than anticipated since power costs constitute 50 to 60 percent of the production costs in the Savannah River type D₂O plants.

At present, there is no U.S. D₂O production capacity for possible D₂O nuclear plants. Production facilities, therefore, would have to be built and these could be put on line in about four years. If built in the near future, they would most probably be of the H₂S - H₂O exchange type presently operated at Savannah River.

Introduction of modifications and improvements to D₂O production plants is relatively difficult and risky as shown by Canadian experience at Glace Bay. Initially, Canada invested about \$100 million into this salt water plant, also based on the H₂S - H₂O exchange process, and ended up with an unworkable system requiring complete renovation which will nearly double the initial investment.

The enclosure to the letter of November 16, 1973 from Dr. Benedict to Messrs. Smith and Pastore mentions the possibility of a breakthrough in

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D₂O separation technology using a laser technique. Laboratory efforts are in progress on D₂O and uranium separation techniques using laser technology (see, for instance, statement of Exxon Nuclear Company during Phase II hearings on Uranium Enrichment before the Joint Committee on Atomic Energy, October 3, 1973 and Press Release R-496 of November 28, 1973) and eventually these efforts could have some application to large scale D₂O separation techniques, but this is not a serious alternative at this time.

In this context it is significant to note that laboratory centrifuge separation experiments were in progress nearly 20 years ago and there still is no commitment in the U.S. to a large scale uranium separation plant of this type. Thus, anticipation of a drastic reduction of D₂O costs through new separation techniques appears unrealistic at this time.

LIST OF REFERENCES

1. RRD Sensitivity Analyses Performed January 22, 1974 with the Concept III Computer Program.
2. Letter from L. H. Roddis, Jr., Consolidated Edison Company of New York, Inc., to E. E. Kintner, dated November 15, 1973 (Enclosed as Appendix 2).
3. A. M. Perry and A. M. Weinberg, "Thermal Breeder Reactors," Annual Review of Nuclear Science, Volume 22, 1972, pages 317-353.
4. L. W. Woodhead, et al., "Commissioning and Operating Experience with Canadian Nuclear-Electric Stations," A/CONF. 49/P/148.
5. D. L. S. Bate, et al., "Costing of Canadian Nuclear Power Plants," A/CONF. 49/P/149.
6. R. G. Hart, et al., "The CANDU Nuclear Power System: Competitive for the Foreseeable Future," A/CONF. 49/P/151.
7. L. R. Haywood, et al., "Fuel for Canadian Power Reactors," A/CONF. 49/P/156.
8. K. L. Smith, "Recent Progress with Canada's Nuclear Generating Stations," AECL-4357, January 1973.

SHIRLEY'S ENTERPRISES

ROUTE 2 BOX 121F
BLUE RIDGE, GEORGIA 30513

Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs
US Atomic Energy Commission
Washington, D.C. 20545

Dear Sir:

I wish to thank you for the five books of drafts of environmental statements on LMFB. I was appalled at the scope, and I do not have the resources to rebut in such magnitude. A letter will have to suffice.

If the AEC is planning to build the LMFB because they have the money and power then it will be built, but over the protest of millions, because I have found no one outside the Utilities Companies and Government Agencies, who want this much radiational hazard in proximity to their friends and loved one.

Dr. Ray stated that nuclear plants and facilities were not attractive targets for saboteurs and blackmailers, I disagree. One surface to surface missile smuggled into our land piece by piece and aimed at a LMFB or the high-level wastes storage facility could bring devastation to the entire eastern seaboard. Is it absolutely essential a nuclear catastrophe has to occur to convince the AEC to do what the citizens want? Not to operate nuclear power plants.

More people died last year than live babies were born, the TVA had surplus electricity, they made fifty-six millions of dollars surplus, yet they are building and putting on the grid, nuclear plants like we were in a population explosion. This can only benefit industry, not persons.

I am enclosing a copy of my statement on the Licensing of the Sequoyah Plant- As I wish it included in my statement on the LMFB Environmental Hearing.

You gentlemen are operating from a position of credulity- Crime, sabotage, kidnapping, blackmail, are ever increasing. The consequences to the perpetrators are completely disregarded by them. They do not care. This will increase the cost of boiling water by nuclear reactors by more defense of radiological wastes, more defense of transportation of same. Defense of high-level waste management facilities. All to be paid by the tax payer- me.

In a true Democracy you would have the people vote to approve or disapprove this action- But this will never come to pass, because the results are not in doubt.

Sir, anything that so threatens the environment and people, that five books has to be drafted to present facts to the people should not be built.

Sincerely,

Roy Dycus
Roy Dycus

SHIRLEY'S ENTERPRISES

ROUTE 2 BOX 121F
BLUE RIDGE, GEORGIA 30513

Directorate of Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Docket Nos. 50-327
and 50-328

April 17, 1974

Subject: Sequoyah Nuclear Plants
Units 1 and 2

Gentlemen:

If the law of the land tried each of you for murder if any person died from any circumstance resulting from the operation of this plant, you could not grant a license to operate Sequoyah Nuclear Power Plant, if you believed:

- A. That a C-130 aircraft carrying military equipment was going to crash into this facility or
- B. A SAC bomber loaded with nuclear bombs would crash into this plant or
- C. A meteor would rupture the heart of the reactor or
- D. A member of the Symbionese Liberation Army was aiming a surface to surfact missile from any point within a thirty-five mile radius, and demanding the USA tender 500,000,000 dollars to the poor or they would fire same or
- E. A fanatical gang was to hijack a container of the radiological waste-and if their blackmail was not met, would release and poison a major water supply of a large city. You would not grant this license. But this you do not believe. So you will grant this permit even if each person that is capable of writing, sent a letter of protest. You still would grant this permit.

Gentlemen, I wish to go on record saying this is the greatest fraud perpetrated on the American people, you gentlemen of the AEC have never totaled the cost of thousands of years managing high level radioactive wastes, the costs of rebuilding storage facilities as they decay, increased inflation for thousands of years, you gentlemen have not added this into the costs of the operations of nuclear power plants. If you had, you would have to reveal to the American people that nuclear energy is the most expensive energy ever conveyed by man. You will grant this license gentlemen because you have to fulfill our Bible "Evil men and seducers shall wax worse and worse, decieving and being decieved."

SHIRLEY'S ENTERPRISES

ROUTE 2 BOX 121F
BLUE RIDGE, GEORGIA 30513

-2-

We are being decieved, you are licensing Trojan Horses filled with hidden enemies of the American citizens. The final environmental statement for Sequoyah Nuclear Plants is filled with errors (example-The statement reports residential costs of KWH are less than 2 cents per KWH) my last electric bill shows I paid 3.8 per KWH-this shows beyond a doubt only industry will recieve benefits, not us.

Not one person have I asked wants nuclear power plants licensed. Never in our history have so few imposed their way upon so many who were protesting-I guarantee when the nuclear crisis is over, the names of men who license nuclear plants will live in infamy. Dr. Ray's will be as Pontius Pilate.

Man is not biologically adaptable to radiation-yet by this very act you absolutely assure more radiation will be forced upon me and my fellow citizens, I protest this inhuman act with all my being.

You in the environmental statement refuse to consider a Class 9 accident from happening yet the military had to discharge men in the nuclear section for drugs, I refuse to believe you would feel safe with a pot smoker at the controls of Sequoyah, all this to boil water--

You will grant this operating permit, overeveryones protest, but I am going to do all in my power to have the Price-Anderson Act repealed-then we will see how long TVA will run nuclear plants.

Sincerely,

Roy Dycus
Roy Dycus

sad

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Roy Dycus
Shirley's Enterprises
Route 2, Box 121F
Blue Ridge, Georgia 30513

Dear Mr. Dycus:

Thank you for your letter commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Environmental Statement is enclosed for your information.

Your letter indicates the belief that nuclear facilities would be attractive targets for saboteurs and blackmailers, and expresses concern over the magnitude of the costs of effective safeguards.. Safeguards-related concerns similar to your own have been expressed in a number of other letters commenting on the Draft Statement. You may wish to review these letters and the AEC responses thereto which are appended to the Final Statement. The AEC takes these concerns seriously, and has greatly expanded the scope and depth of treatment of the subject of safeguards in the Final Statement. With regard to the particular concerns you mentioned, please see Section 7.4.3 for information related to the AEC's present characterization of the nature of the threat against nuclear facilities, and Section 7.4.9 for information related to the costs of future safeguards measures.

It is recognized that substantial additional effort will be required to develop and implement the type of expanded safeguards program that will be necessary if plutonium comes into widespread commercial use. This would occur with the advent of plutonium recycle in Light Water Reactors, and with the later introduction of the LMFBR. However, there is ample time to develop this program, and the AEC is confident that an adequate level of safeguards can be achieved.

Mr. Roy Dycus

2

The final comment in your letter suggests that the considerable bulk of the Draft Statement is a measure of the threat posed by the LMFBR, and that the LMFBR "...should not be built." In preparing the Draft and Final Statements, the AEC has made every effort to exclude extraneous information. Unfortunately, the complexity of the subject and the many requests by commentators for still more detailed treatment of the issues precludes brief presentation. We are hopeful that your reading of the Final Statement will alleviate some of the concerns you have expressed.

Thank you again for your comments and for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

AtlanticRichfieldCompany . International Division
515 South Flower Street
Mailing Address: Box 2679 - T.A.
Los Angeles, California 90051
Telephone 213 486 3511

April 17, 1974

Office of the Assistant General
Manager for Biomedical and
Environmental Research and Safety
Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Gentlemen:

I would like to thank you for giving me the opportunity to review your March 1974 draft of the Liquid Metal Fast Breeder Reactor Program. Since I received the 5 volumes at the end of March and have been extremely busy performing my tasks at Arco, I was forced to concentrate on volumes 1, The Summary and Background, and 4, Alternative Technology Options. To augment my limited knowledge of the latest technological achievements in the nuclear field, I assembled as much recent literature on the subject that time would permit. I did this not only for knowledge, but to gain perspective on the subject matter by diversifying my sources of information.

My comments on your environmental statement will be grouped into two basic categories: (1) the contents and structure of your material presented and (2) my evaluation of the LMFBR program from an allocation of resources viewpoint.

(1) Contents of Material Presented

From an environmental standpoint, I believe you correctly approached the problem of assigning probabilities to a most uncertain sequence of events, such as a breakdown in the fuel supply/disposal mechanism, a reactor malfunction, or similar occurrence. It is inevitable that in any system mechanical/human breakdowns will occur, but to single out this particular program as being innately more susceptible to mishaps than the LWR nuclear system or HTGR system would seem inappropriate.

The technological documentation, especially that related to nuclear fusion and MHD generation systems, was particularly informative, as was the material on oil shale and synthetic hydrocarbons manufactured from coal.

The economics presented, especially related to all tentative fuel costs, was excellent. A consideration, however, is the potential

April 17, 1974

Page 2

elasticity of energy demand relative to price. Recent supply cutbacks precipitated by the Arab embargo has indicated a willingness in the consumer to restrict energy consumption where feasible to minimize rapidly escalating costs.

As the U.S. enters the era of ever-increasing energy costs, and basic energy saving measures are implemented, e.g. mass transit, smaller cars, direct burning of a premium fuel, such as natural gas, per capita energy consumption in the U.S. could begin to level off. That occurrence alone could make the need for an alternative energy source, such as the LMFBFR, much less urgent. Current proved domestic fossil fuel and U_3O_8 reserves, at current consumption rates, could last the United States well into the 21st century without precipitating excessive price increases. To the degree that foreign energy producers, especially the Middle East oil producers, escalate their prices, further additions of energy reserves will be "proved-up".

(2) Resource Allocation

Recent press releases and the numerous assertions in your Environmental Statement that the LMFBFR is the optimum choice for governmental research, indicates that the AEC is prepared to devote most of its resources, both financial/manpower, to develop an LMFBFR that is commercially feasible at the earliest possible date. It is this aspect of the program that I feel best able to evaluate, and to question.

To be specific, I do not question the need for an alternative system to extend our finite energy reserves but question whether or not an agency such as yours, which has access to far greater financial/manpower resources than any other organization of this kind in the world, should concentrate so heavily on what could be termed an intermediate technology.

Alternatively, your statement and various other AEC documents I have received indicate substantial progress in laser-fusion technology. Various forecasts indicate that commercial reactors of this type should be available by the year 2000, but most likely could be available sooner given appropriate priority. Therefore, assuming massive injections of resources into either program will greatly accelerate progress towards achieving a commercial nuclear reactor, and, as your agency has repeatedly stated, that fusion is virtually the ultimate in nuclear technology, should not massive resource injections be at least evenly divided between the relatively proven LMFBFR and the more uncertain, yet ultimate, fusion energy technology which apparently could lie in the near future.

I do not want you to misinterpret this reasoning as advocating a dependence on foreign energy sources, especially Middle Eastern petroleum which have in the past so greatly benefited the industry of which I am a part, for indeed they would then be entirely self-serving. Rather, I am advocating the near-intermediate term development of an energy resource which has maximum resource potential but will have minimal (of all feasible energy resources) influence on environment, and, if properly developed, can be brought on stream far before serious depletion of domestic fossil and uranium fuel resources.

April 17, 1974
Page 3

I would greatly appreciate further correspondence on your development activities, especially in the fusion area, and will continue to familiarize myself with all aspects of nuclear technology.

Very truly yours,

A handwritten signature in cursive script that reads "Richard James Chamberlin". The signature is written in dark ink and is positioned above the typed name.

Richard James Chamberlin
Special Projects Analyst

RJC:jk

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Richard James Chamberlin
Special Projects Analyst
Atlantic Richfield Company
International Division
515 South Flower Street
Box 2679-T.A.
Los Angeles, California 90051

Dear Mr. Chamberlin:

Thank you for your letter of April 17, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the other enclosure to this letter for specific responses to your comments.

We appreciate your taking the time to make your views known to us and hope that this response and the enclosures answer any remaining questions you may have. Your favorable comments on the documentation of technologies, the probabilistic treatment of sequences of events, and the treatment of economics are also appreciated. In regard to probabilistic treatment of accidents, please refer to Section 4.2.7 of the Final Statement for a discussion of LMFBR Safety.

Thank you for your comments and for your interest in the LMFBR Program.

Sincerely,

A handwritten signature in cursive script, reading "James L. Liverman", is written over the typed name and title.

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

ENCLOSURE I

AEC STAFF RESPONSE TO SPECIFIC COMMENTS
BY MR. RICHARD J. CHAMBERLIN

1. Comment:

"The economics presented, especially related to all tentative fuel costs was excellent. A consideration, however, is the potential elasticity of energy demand related to price. ... per capita energy consumption in the U.S. could begin to level off. That occurrence alone could make the need for an alternative energy source, such as the LMFBR, much less urgent."

Response:

Your point on elasticity of demand is well taken and the Nation's recent experience in the energy crisis is a case in point demonstrating that there is considerable elasticity in demand. Experience since the easing of the crisis however, points to another facet of this elasticity vs. price equation. With the passage of time, the public, as well as the economy in general, tend to adjust to changes in price structures and demand tends to rise again closer to the original level representing the life-style to which the people are accustomed and which they would like to maintain. Very often adjustments are made in other areas of the overall living standard in an effort to return to the original status quo. Thus, any energy conservation measure which is not backed by continuous stringent enforcement measures or clearly required by actual energy shortages is not likely to be as fully effective as one might like.

It should be noted that reductions in total energy demand do not necessarily imply corresponding reductions in electrical energy demand. In fact, relatively accelerated electrification may result. Energy conservation may emphasize the use of available and environmentally acceptable energy sources. Conservation of highly mobile fossil fuels may require electrification of ground transportation and residential energy uses. In general, optimum allocation of fuel resources and minimization of environmental impact may require increased electrification and commensurate increase of central station power generation utilizing abundant, clean fuels. Thus, while the AEC fully endorses a strong energy conservation program and believes that it can result in appreciable energy savings and a reduced rate of increase in per capita energy consumption, it does not believe that complete reliance on full achievement of energy conservation goals is a prudent course for the Nation to take. The AEC continues to feel that development of promising energy technology options including the LMFBR should

continue so that the Nation has all the electric energy generation options available which it might need.

You are referred to Section 11 for analyses of the impact of energy conservation measures on the cost-benefit aspects of the LMFBR. This section examines the economic benefits of LMFBR availability for several energy demand projections. Energy demand projections for the standard cases were derived from the interacting historic trends of population, GNP, total energy demand, and electrical energy demand (Sections 2 and 11). Additional cost-benefit cases were computed for variations in the base energy demand projection. In terms of the year 2020 energy demand, the alternate cases considered variations of a twenty-percent increase and decrease, and a fifty-percent decrease. The latter case is indicative of a projected energy demand assuming successful energy conservation measures. It should be noted that the cases examine the cost-benefit relationships due to national power generation economics. The cases do not include incremental costs or benefits resulting from mechanisms necessary to reduce the energy demand or from the effects of the reduced energy availability on the economy.

You are also referred to Section 6C for a discussion of various energy conservation measures that might be pursued.

2. Comment:

"Current proved domestic fossil fuel and U_3O_8 reserves, at current consumption rates, could last the United States well into the 21st century without precipitating excessive price increases. To the degree that foreign energy producers ... escalate their prices, further additions of energy reserves will be 'proved-up'."

Response:

It is certainly correct that reserves would last well into the 21st century if consumption were suddenly to level off at current rates. There is no evidence, however, that this is happening, and it is not at all clear that prices would cease climbing if a leveling were to occur. The rise in oil and coal prices began before the Mid-east oil embargo precipitated even steeper increases and forced reduction in U.S. petroleum consumption. Uranium selling for about \$6 per lb. U_3O_8 a year ago is selling today at \$15 per lb. U_3O_8 for delivery in 1980. Such increases are partly due to mismatches in supply/demand, partly due to environmental and occupational safety strictures imposed by society, and partly due to general escalation and other factors peculiar to the industries involved. You are referred to Sections 6A.1.1.2 and 6A.2.1.2 of the Final Statement for detailed discussion of coal and uranium resource availability.

In any event, it is clear that these industries are preparing for increased, not level or decreased, energy demand. Exploration for oil, gas and uranium in the U.S. (and the rest of the world) will probably reach all time highs this year, as will activities to exploit lower grade resources, such as the oil shales. In this context, the breeder's capability to place an upper limit on the total amount of natural uranium required to support an expanding nuclear power economy seems worthy of emphasis.

3. Comment:

"... I do not question the need for an alternative system to extend our finite energy reserves but question whether or not any agency such as yours which has far greater financial manpower resources than any other organization of this kind in the world, should concentrate so heavily on what could be termed an intermediate technology," also "... your statement and various other AEC documents I have received indicate substantial progress in laser-fusion technology. Various forecasts indicate the commercial reactors of this type should be available by the year 2000 but most likely could be available sooner given appropriate priority ... should not massive resource injections be at least evenly divided between the relatively proven LMFBR and the more uncertain, yet ultimate, fusion energy technology which apparently could lie in the near future."

Response:

In answer to the first part of your comment, the LMFBR is not being developed as "an intermediate technology." The LMFBR, when it is successfully developed and proves to be economically competitive and environmentally acceptable, will have the potential for meeting a large part of our future electrical energy requirements for centuries. The LMFBR would only become an "intermediate technology" if an energy technology option superior to it both economically and from an environmental standpoint is developed. A number of candidate technologies have been proposed, including thermonuclear fusion, solar, and geothermal energy as well as others which might have these potential attributes and these have been reviewed in Section 6. However, their successful development remains to be demonstrated and until one or more of these technologies become established, the designation of the LMFBR as an intermediate technology is not warranted, except in the broadest of time scales.

In order to respond to the second part of your comment, a brief discussion of the nature of R&D programs and their funding at different stages of development is required. It should be noted that LMFBR technology is much more advanced than that of fusion (which incidentally consists of two programs, magnetic confinement as well as laser fusion). While the AEC first proved the feasibility of nuclear

breeding in the 1950's and a demonstration breeder plant is now being designed and built for operation in the early 1980's, controlled thermonuclear fusion is yet to be demonstrated on a laboratory scale. The more advanced engineering stage of LMFBR technology requires greater amounts of funding for the construction of full size demonstration plants and test facilities, whereas R&D on nuclear fusion, being more in the laboratory stage, requires a commensurately lower level of funding in order to allow its development to proceed at an optimum rate. As research and development advances in both areas, funding of LMFBR will gradually decline and funding for fusion R&D will increase and surpass the annual expenditures for LMFBR. Eventually, if both programs are carried to successful conclusion, the total expenditures for each should be comparable. To illustrate this trend, you are referred to WASH-1281, "The Nation's Energy Future," December 1973. Tables 2.7, 2.8, and 2.9 on pages 30-32 give the recommended expenditures for each technology program for the 1975-1979 time period for operating, equipment and construction obligations. You will note that in this five-year period (which represents just the early stages of the fusion program) the recommended funding for fusion R&D increases from 31% (\$145 million vs. \$447 million) of the LMFBR funding to 80% (\$406 million vs. \$506 million). The total costs for developing the LMFBR are estimated to lie in the same range (\$8-10 billion) as the total estimated cost for developing either one of the two candidates for thermonuclear fusion (magnetic confinement or laser fusion).

ZERO POPULATION GROWTH

April 17, 1974

Dr. James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. Liverman:

In response to W. H. Pennington's letter of March 14, enclosed are my invited comments on the draft Environmental Statement for the Liquid Metal Fast Breeder Reactor program (WASH-1535).

My comments take the form of a paper entitled, "Antisocial Interventions Against the Proposed Liquid Metal Fast Breeder Reactor Program (Provisional Cost Estimates)." Please reprint it and my appended article, "Radioactive Malevolence," in the final draft of the Environmental Statement.

Permission to reprint "Radioactive Malevolence" has been requested from Samuel H. Day, Editor of Science and Public Affairs, and your office should receive that permission directly from him. Dr. Thomas B. Cochran also plans to append the article to his comments. It is immaterial to me whether it should accompany my comments or his in the final Environmental Statement, but I feel it is extremely vital that it be included.

Very truly yours,

L. Douglas DeNive
L. Douglas DeNive, Ph.D.
Vice-President

Enclosures

ANTISOCIAL INTERVENTIONS AGAINST THE PROPOSED
LIQUID METAL FAST BREEDER REACTOR PROGRAM
(PROVISIONAL COST ESTIMATES)

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April, 1974

Summary

This paper was submitted as an invited commentary on the draft Environmental Statement (ES) for the Liquid Metal Fast Breeder Reactor Program (WASH-1535), USAEC, March 1974. It gives provisional estimates of the minimum dollar costs to this country stemming from antisocial acts directly related to the presence of a substantial mixed LMFBR-LWR fission power deployment in the United States.

Various possible reasons for the neglect of violent and coercive behavior in the draft ES are considered, and found inappropriate. With conservative assumptions, it is forecast that each one hundred years of national commitment to electricity generation from atomic fission will give rise to not less than one and one-half trillion dollars in additional costs, due to malevolent exploitation of the nuclear industry.

Of a total estimated burden of \$1,687,705,760,000, roughly \$424 billion will be consumed by acts of war, \$133.7 billion in losses will be inflicted by terrorists, crime will exact a toll of \$130 billion, and compromise of the United States' relative international power position will cost about \$1 trillion.

It is observed that the \$50 billion cost saving promised in the draft ES from the first 46 years of the LMFBR program is small relative to the expected losses from accident or maleficence.

It is concluded that thorough coverage of the topic of malevolent interventions is absolutely essential for the final draft of the LMFBR Environmental Statement, and that if more optimistic prospects do not emerge from detailed study, that the LMFBR and associated LWR reactor programs be held in abeyance.

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This paper is submitted as an invited commentary on the draft Environmental Statement for the proposed LMFBR program (WASH-1535), USAEC, March 1974. It gives provisional estimates of the dollar and social costs to this country of antisocial acts directly related to the presence of a substantial mixed LMFBR-LWR power reactor deployment in the United States. In view of the startlingly high magnitudes of the figures derived herein, it is deemed absolutely essential that the final Environmental Statement (ES) include thoroughly detailed and justified estimates, or ranges thereof, on the same topics.

The draft ES makes no assertion that the probability of warfare, terrorism, or criminality is diminishing. The evidence appears to suggest the opposite. Terrorism and crime have become increasingly visible in recent years. Since the Declaration of Independence, the United States has been involved in shooting wars during 16% of its years. Since the end of World War II and the advent of nuclear weapons, the U.S. has been involved in shooting wars (Korea and Indochina) during 46% of its years. Presently looming quarrels over the division of planetary resources, and improvements in weapons delivery systems, offer no prospect for early improvement in the outlook for future war.

In this context, some possible reasons for the neglect of these topics in the draft ES will be considered, by way of introduction. One conceivable rationale for their omission is that the LMFBR program

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is deemed to involve no hazards additional to those associated with light-water reactors (LWRs). In view of the plutonium basis of the LMFBR fuel-cycle and the admitted special dangers of plutonium, such a suggestion would appear inapplicable. Moreover, the anticipated costs of malevolent actions against LWRs and their ancillaries have never been presented to the public in any official government publication. Thus the general problem of the expected costs of crime, terrorism, and warfare vis-a-vis fission powered electricity generating plants is addressed for the first time, to the author's knowledge, in the present study.

Another hypothesis to explain the absence of this topic in the draft ES is that the events to be dealt with are "not readily subject to quantitative description" (cf. p. 7-65). It may be replied that on a matter of this importance, estimates must be developed on the best available basis even in the absence of detailed theory which would permit more precise prediction. It is appropriate to base provisional estimates on assumptions which would receive wide acceptance as reasonable or conservative, and then to explore the sensitivity of cost figures thus derived to modifications in the assumptions. The major theme of this paper is to illustrate that readily derived and reasonable estimates of likely events, and their costs, compel the conclusion that the true price of fission-generated electricity is vastly higher than the representations of the draft ES.

Still another hypothesis is that consideration of hostile acts is not the concern or area of expertise of those proposing the LMFBR program, but is rather the responsibility of other governmental bodies such as those concerned with law enforcement and national security. This view would imply that suitable members of the Departments of Justice, Defense, and other agencies be assigned to develop forecasts,

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or ranges of forecasts contingent on various assumptions, for inclusion in the final draft.

A fourth viewpoint is that sufficient safeguards against anti-social interventions can be applied with an ongoing, post hoc approach, as sufficiently numerous incidents occur to establish levels for actuarial estimation. In this context it is well to note that a single deliberate radiocontamination incident could permanently evacuate a major metropolis. It thus represents a class of events which is best dealt with on a total-prevention basis. Ample precedent for such an approach resides in the U.S.'s development of strategic missile forces to totally deter an unacceptable nuclear attack from overseas.

Still other rationales for avoidance of the topic of radioactive malevolence are discussed in my paper of that name, which is attached as an appendix (1). These include the notion that the deployment of power reactors can safely proceed while the problem is being studied, unexamined faith in technological modifications such as increased safeguards and underground siting, reliance on human nature and social science, the unjustified expectation of adequate insurance coverage, and the objection that other power sources also present risks. All such arguments have specific flaws, and all do violence to a basic principle: That the anticipated costs and benefits of the program, and alternatives to it, should be presented to the public in as complete a form as possible prior to irreversible commitment. Society, which ultimately foots the bill for all the errors of technologists, should not be held hostage to their unquantified optimism.

The estimates which follow are quantified, and their assumptions apparent or readily deduced. It is certain that they can be improved;

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it is very unlikely that they can be reduced either in theory or in practice.

Warfare

It will be assumed that for the next century the United States will be at war 20% of the time, or less than half the observed incidence since the termination of the Second World War. It will be further assumed that, during half of the years in which we are carrying on hostilities, successful actions by enemy military forces (or their agents in this country) against U.S. nuclear industry will be totally prevented. For the remaining ten years per hundred, it is assumed that annually, a single 1000 MWe (megawatt-electrical) nuclear power reactor is directly destroyed by conventional explosives (bombing, missiles); a second is sabotaged, resulting in meltdown; and independently, a single large American metropolitan area is rendered uninhabitable by the deliberate dispersion of radioactive materials derived from fission-reactor fuel. Let us further assume that once per century, a single fuel-reprocessing plant (FRP), plutonium fuel fabrication plant (PFFP), or retrievable surface radioactive waste storage facility (RSSF) is explosively destroyed and its contents dispersed by wind. Thus, the minimum per-century costs expected from war damage to American fission power components may be estimated at 424 billions of dollars in present currency, as summarized in Table 1.

This perhaps surprising total is reached despite the conservative character of the assumptions as described above. Moreover, the listed costs do not presuppose the use of nuclear weapons by our adversaries. Medical costs are totally excluded, as are expenditures for decontamination (where possible) and later entombment and monitoring of rup-

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tured atomic power stations.

Table 1.

Cost of United States real property damage, per century, in present dollars, attributable to warfare in interaction with nuclear fission energy production (provisional estimates)

<u>Item</u>	<u>Cost</u>
Total loss of twenty 1000 MWe nuclear power plants @ \$500 million each ¹	\$ 10 billion
Civilian property damage from particulate and volatile radionuclide releases from ten exploded reactors, plus disaster services and relocation expenses @ \$10 billion per event	100 billion
Civilian property damage from volatile radionuclide releases from ten power reactor meltdowns, @ \$400 million per event	4 billion
Rebuilding on new sites of ten major American metropolises, @ \$30 billion each ²	300 billion
Civilian property damage resultant from explosive dispersion of radioactivity at one nuclear fuel reprocessing plant, plutonium fuel fabrication plant, or RSSF	10 billion
Total minimum war-related costs	\$424 billion

1. Radiocontamination at the sites is assumed to preclude salvage and re-use of reactor components.

2. Predicated on a depreciated (actual market value) estimate of real property per capita of \$12,000, and average displaced population of 2.5 million persons per event. The estimate is conservative in that no loss of personal property or commercial inventories is assumed. In actuality, radiocontamination would often preclude salvage or resale of such goods. An additional conservative factor is the disregard of nationwide disruptions to be expected from the loss of key cities, e.g., New York or Washington, D. C.

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Terrorism

Small groups of political extremists, or even individuals, are capable of dispersing radioactivity throughout large urban areas, forcing their abandonment temporarily or permanently.¹ Even with fairly prompt reoccupancy, major costs would be incurred through evacuation, temporary quartering expenses, idled productive capacity, neglect, and uncontrolled fires. Containers of long-lived nuclides such as plutonium could be blown up by conventional explosives, burned on rooftops, or dispensed as aerosols and dispersed by wind and vehicle traffic. A leaky container of plutonium-oxide powder could be attached covertly to the undercarriage of a public transit vehicle, and disseminate highly carcinogenic particles along a known route in a city. One pound of plutonium 239, evenly dispersed, could bring three square miles of land up to the contamination level (0.35 microcurie per square meter) set by the AEC for the determination of an "extraordinary nuclear occurrence" for transuranic alpha emitters (Regulation 140.84). Some experts familiar with plutonium believe that a more realistic level for public health concern is $0.01\mu\text{Ci}/\text{m}^2$, 35 times less, or an even lower value (2). About fifteen pounds of Pu-239 or 22 pounds of $^{239}\text{PuO}_2$ would suffice for the construction of a crude atomic bomb (3).

Table 2 summarizes the reasonably expected costs to America from terrorist exploitation of the nuclear power industry over one

1. Domestic political terrorists would presumably be loath to inflict lasting damage on the country which they are attempting to eventually take over and run. However, subversives aligned with a foreign enemy would be under no such felt restraint. Moreover, those who disperse radionuclides could greatly underestimate the duration of the effects of their deeds.

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century. Once again, conservatism underlies the bases for the estimates in Table 2. It is assumed that industrial safeguards succeed in preventing all attempts by terrorists to induce meltdowns of power reactors by sabotage during 96 out of each 100 years. In the remaining four years, sabotage-meltdowns are assumed to occur at the rate of one per year. Two major American metropolises, or their equivalent, are assumed to be contaminated to evacuation levels by terrorists each century. Two other major urban areas, one each fifty years, are assumed destroyed by nuclear weapons constructed or diverted by terrorists. Once per century, a fuel-reprocessing plant, PFFP, or RSSF is assumed to be explosively destroyed by terrorists. Smaller extremist acts of radiocontamination and other assaults on nuclear facilities are assumed to inflict losses, including decontamination costs, of \$1 million per annum. These assumptions give rise to the following summary.

Table 2.

Cost of United States real property damage, per century, in present dollars, attributable to terrorism in interaction with nuclear fission energy production (provisional estimates)

<u>Item</u>	<u>Cost</u>
Total loss of four 1000-MWe nuclear power plants @ \$500 million each	\$ 2 billion
Civilian property damage from volatile radionuclide releases from four power reactor meltdowns, @ \$400 million per event	1.6 billion
Rebuilding on new sites of two major American metropolises abandoned due to terrorist radiocontamination @ \$30 billion each	60 billion
Rebuilding on original sites of two major American metropolises destroyed by privately constructed or purloined nuclear weapons @ \$30 billion each	60 billion

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Table 2 (concluded)

Civilian property damage resultant from explosive dispersion of radioactivity at one nuclear fuel reprocessing plant, plutonium fuel fabrication plant, or RSSF	\$ 10 billion
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Smaller extremist assaults involving radioactivity, including decontamination costs, @ \$1 million per annum	100 million
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Total minimum terrorism costs	\$133.7 billion
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Crime

In contrast to terrorists' underlying desire for political change, the motivation of criminals may be assumed to be primarily for money. Thus criminals would seek control over radioactive materials mainly for extortion and to secure non-interference from law enforcement agencies.

Table 3 presents in summary form plausible minimum domestic costs from a century of criminal interventions into the nuclear power industry. On ES page 4.5-15, it is envisioned that, as part of the LMFBR program, as many as 576 kilograms of plutonium will be shipped as oxide in a single vehicle. The key assumption underlying the cost summary of Table 3 is that one such sizable shipment per century will be diverted to organized criminals, and retained subsequently at one or more unknown locations. At a later date, the assumption is made that it will be used to evacuate through radio-contamination a single major American metropolis. It is further assumed that this event convinces the federal government to make covert extortion payments to the criminal syndicate of \$500 million per annum. Some of the material is presumed to be sold to other criminals. This results in additional national costs due to black-

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mail, higher law-enforcement costs, and increased requirements for radioactive monitoring and decontamination of \$500 million per year. These costs, all of which could stem from a single sizable diversion, are given in tabular form:

Table 3

Additional costs to the United States economy, per century, in present dollars, attributable to criminal acts in interaction with nuclear fission energy production (provisional estimates)

<u>Item</u>	<u>Cost</u>
576 kg. Pu equivalent @ \$10/g	\$ 5.76 million
Rebuilding on new site of one major American metropolis abandoned due to criminal radiocontamination by plutonium	30 billion
Governmental extortion or ransom payments required to avert threatened further dispersions of plutonium @ \$500 million per year	50 billion
Additional annual costs of extortion payments, increased law-enforcement expenditures, increased radioactive monitoring and decontamination @ \$500 million per year	50 billion
Total minimum crime costs	\$ 130,005,760,000

Geopolitical Ramifications

Given the multi-national usage of fission power plants, the provisions of the present Nuclear Non-Proliferation Treaty will not prevent foreign nations from covertly stockpiling plutonium and other radioactive materials. The widespread transnational availability of these substances will no doubt give rise to a pattern of international relations analogous to the present welfare payment system in this country. Under this system, the haves donate a certain amount of their wealth to the have-nots, lest the have-nots commit larceny and other crimes to provide for their material wants.

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Similarly, poor nations, possessed of the means to evacuate or destroy Washington, D.C. conveniently concealed in a Georgetown attic, would be most likely to utilize that latent power to procure additional military and economic assistance from the United States. It may be countered that America's nuclear arsenal could demolish any smaller nation posing such a challenge. Yet it is equally certain that the nerve center of this nation, and perhaps several other American cities, would also be emptied if such an exchange occurred. The implication suggested by this analysis is that the development and circulation of ultratoxic materials in international trade creates a rough parity of power among all organized groups which have access to their use as weapons. Table 4 summarizes reasonable international-related costs to the United States per century incident to the proliferation of radiotoxins in a plutonium-based energy economy.

Table 4

Additional costs to the United States economy, per century, in present dollars, attributable to international pressures generated by the permeation of the global governmental power structure by readily concealable, storable, and transportable ultratoxic materials with long-lived biological activity

<u>Item</u>	<u>Cost</u>
Direct additional military and economic assistance to foreign nations, • \$8 billion per year	\$800 billion
Additions to U.S. arsenal necessary to deter unlimited radioactive extortion from other nations, • \$1 billion per year	100 billion
Additional cost of international nuclear materials accounting and safeguards (to U.S.); additional intelligence gathering and data analysis; • \$1 billion per year	100 billion
Total international-related costs	<hr/> \$ 1 trillion

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Table 5

Summary of per-century costs to the United States due to antisocial exploitation of the nuclear fission power industry, in present dollars

<u>Item</u>	<u>Cost</u>
Warfare	\$ 424,000,000,000
Terrorism	133,700,000,000
Crime	130,005,760,000
International adjustments	1,000,000,000,000
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Grand total (minimum)	\$ 1,687,705,760,000

Discussion

The foregoing estimates are admittedly tentative, but they are quite unlikely to prove to be too high. Because of the various conservative assumptions underlying them, and due to omissions of some costs, they are almost certainly too low. Four significant sources of additional expense, not included in the above analysis, are:

(A) Medical costs of caring for the additional illnesses and birth defects resultant from radiation exposure. (B) Costs of providing adequate uncontaminated food, water, and manufactured goods in a geography which must accommodate to numerous large and small areas of radiocontamination. (C) The psychological strain on the average citizen of adapting to such an environment, and the anticipation of yet further disruptive incidents. (D) The reduced efficiency and quality of governance to be expected when civil servants and legislators work under the special threat of radioactive extortion, or succumb to its corrupting pressures.

The minimum total cost of antisocial interventions involving radioactivity is for a single nation and century in excess of one

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and one-half trillions of dollars. By contrast, the entire construction cost of the 550 LMFBRs, 28 fuel reprocessing plants, and 28 fuel fabrication plants anticipated by the year 2020 could be borne by a lesser sum. One clear implication is that the true cost of fission-dependent electrical generating capacity is probably double what it has been thought to be. Another implication is that the \$50 billion discounted net cost saving expected from the LMFBR program over the interval 1974-2020 is insignificant relative to the approximately \$500 billion costs to be expected over that 46-year interval from malevolent acts and their sequelae (cf. pp. 1.7-8, 1.11-3). Irrespective of the details of the present study, such a \$50 billion savings could be vitiated by the cost of five major accidents spread over 46 years, an average of one \$10 billion mishap every nine years.

Conclusions

1. A detailed, quantitative, and fully justified discussion of the topic of antisocial interventions and their costs is essential for the final draft of the Environmental Statement on the liquid metal fast breeder reactor program.
2. Unless such a discussion can be founded upon premises that are both more defensible and considerably more optimistic than those which have been employed herein, the LMFBR program and its associated expansion of LWRs should be placed in abeyance. Such a suspension should be lifted only upon the clear attainment of massive reductions in the probability of human antisocial behavior, and/or similar reductions in the probability of lasting health damage resulting from exposure to ionizing radiation.

References

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2. Geesaman, D. P. Plutonium and Public Health. Paper delivered at the University of Colorado, April 1970, p. I-163.

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3. Taylor, T. B., quoted in "AEC Doubts A-Bomb Could be Homemade," Los Angeles Times, March 14, 1974; "Homemade A-Bomb Peril Cited," Washington, D.C. Star-News, April 7, 1974.

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RADIOACTIVE MALEVOLENCE

"The likely interaction of nuclear technology and the human predisposition to evil have been discussed here. It would seem that unacceptably great misuses of radioactivity cannot be prevented at acceptable cost in a world committed to fission energy. The conclusion generated by available evidence and theory is that we must look elsewhere for primary power sources. For the near future, some will disparage the clear indications that society is too immature to accommodate the nuclear presence. Others will hope for a 'moral breakthrough,' while a few will conspire to bring dire events down upon us."
L. Douglas DeNike, a clinical psychologist, is vice president of Zero Population Growth, Los Angeles.

The toxicity and persistence of radioactive substances has radically altered the power balance between large and small social units. It is now possible for a few persons to force the evacuation of entire cities through the dispersion of plutonium or high level reactor waste. These materials are rapidly increasing in quantity and availability, coordinate with the growth of nuclear power. Thus it would seem of the highest importance to scrutinize the safety of the nuclear industry from human maleficence.

Ionizing radiation causes tissue damage insensibly, persistently and at a distance. This imbues it with an unsurpassed threat value for criminal misuse. Recent violent crimes and terrorist atrocities suggest very strongly that a few persons will commit the most heinous deeds within their power. Their eventual employment of radioactive materials appears virtually certain.

Many believe that the irradiation perils inherent in the theft, storage or dispersion of radionuclides would automatically deter potential troublemakers. The facts of physics and psychology indicate otherwise. Evil-doers will learn that alpha and beta emitters, while deadly in the environment, require only lightweight shielding which would present no problems of bulk to thieves. Even spent reactor fuel and high level waste, which emit gamma rays and require massive shielding, could be seized in pre-packaged and portable form aboard a transport truck.

More simply, such a shipment could be destroyed by explosives detonated from a safe distance. On the psychological side, malefactors ignorant of radiation hazard, deliberately misled concerning the nature of their hijacking assignment, or fanatical for their cause could assume risks of radiation exposure inconceivable to an informed person.

In any human organization, the possibility exists for outright criminality or the negligent failure to safeguard against it. In the nuclear energy industry, several incidents have already occurred despite extraordinary precautions:

- In August 1971, an intruder penetrated past guard towers and fences to enter the grounds of the Vermont Yankee nuclear power plant at Vernon, Vermont. He escaped after wounding a night watchman.

- In November 1971, arson caused \$5 to \$10 million damage at the Indian Point No. 2 plant at Buchanan, N.Y., just prior to its completion. A maintenance employee was accused of the crime.

- In February 1973, the Atomic Energy Commission's former top security officer, William T. Riley, was sentenced to three years' probation. An investigation revealed that Riley had borrowed \$239,300 from fellow AEC employees and had failed to repay over \$170,000. He used a substantial portion of the money for race track gambling.

- In March 1973, a guerrilla band took temporary possession of a nuclear station in Argentina.

- In August 1973, 21 "extremely harmful" capsules of iodine-131 were stolen from a hospital in Arcadia, California.

A certain irreducible number of such events is bound to occur. As the Riley case illustrates, there are limits to employee testing, screening and surveillance. Moreover, no screening program will obviate the fact that during transient intervals normal people do abnormal things. Persons under pressure may experience dark moods which prompt bizarre or desperate schemes. For example, if a virtuous but unstable employee came to believe that the perils of nuclear energy had to be demonstrated to the public by a dramatic occurrence, he might become motivated to create that occurrence. Disgruntlement or boredom can lead to pointless vandalism or lapses in security precautions, increas-

than for females. It is interesting to note that the relative probability of leukemia in individuals less than 60 years of age has not changed substantially since 1950. For the over 60-year age group, however, it has increased markedly.

A special function has been derived to represent the mean probability of males and females within any age group contracting leukemia relative to the total probability estimated from all age groups for that sex ($\Sigma(P_m)/n$ and $\Sigma(P_f)/n$, where n is the number of age groups). These are presented in Figure 2 for males and females in each year from 1950 to 1970. If a linear relationship is assumed for the observed increase in both cases, estimates for slope of each curve show that current doubling time of the leukemia incidence rate for males is 10 years and for females, 30 years. The observed increases, however, particularly for the male, appear in part to be non-uniform.

If the actual curve of best fit is examined relative to the number of atmospheric tests [7] which have been conducted up to any particular point in time, an interesting similarity is evident. In the absence of full information on test yields, the total number of tests at any time may be taken to arbitrarily represent the total relative fallout effect on individuals in any population sub-group of the world. A comparison of the curves suggests the possibility of a cause-effect relationship. The ap-

For the over 60-year age group the relative probability of leukemia has increased markedly.

parent reduction shown for the rate of incidence since 1962 could result from the limited number of tests that have been held since the 1958 moratorium and conclusion of the 1963 Partial Nuclear Test Ban Treaty.

The significantly increased probability for leukemia in the over-60 age group is consistent with the concept that incidence results from an accumulated effect. Two points should be emphasized however. Although the rate of incidence of leukemia is increasing, the factors quoted are statistically weighted and the probability of an individual contracting leukemia remains extremely small. Second, the apparent increase in the rate of incidence of leukemia since 1950 may also be related to a number of other causes. For example, industrial activity, an increase in the use of x-rays, or changes in lifestyles may all be contributing factors.

Nonetheless, the present rate of increase would appear to be approaching a risk level which gives cause for further investigation. There is evidence to suggest that the increase may be related to radioactive causes. Some doubt must therefore exist that hitherto assumed negligible quantities of radiation are not, in the long term, biologically insignificant. Thus there is a need to clarify the significance of prolonged exposure to low-level radiation as a contributing factor in the increase in the incidence of leukemia.

NOTES

1. For a full list of publications on measurements of radioactive fallout in Australia, see "Report of the Atomic Weapons Tests Safety Committee" (Canberra, Australia: The Committee, Feb. 1971).
2. "Report of the Atomic Weapons Tests Safety Committee," May 1971.
3. "Environmental Effects of Producing Electric Power," Hearings before Joint Committee on Atomic Energy, Jan. 27-30 and Feb. 24-26, 1970, 91st U.S. Cong., 1st Session, Part 2, Vol. 2; and "Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences — National Research Council Advisory Committee on Biological Effects of Ionizing Radiation (the BEIR report), Nov. 1972.
4. A. M. Brues, *Science*, 128 (1958), 693.
5. National Radiation Advisory Committee, "Report to the Prime Minister" (Canberra, Australia: The Committee, Nov. 1965).
6. "Causes of Death," Commonwealth Bureau of Census and Statistics, Bulletins 1-8 (Canberra, Australia: The Bureau).
7. *World Armaments and Disarmaments*, 1972 SIPRI Yearbook (Stockholm: Stockholm International Peace Research Institute, 1972), p. 462.

Fig. 2—Relative probability for incidence of leukemia in any age group as a mean of the probabilities for every age group, 1950-1970 [6].

ing the chance of accident or malfeasance. Those with hidden aberrations may be blackmailed into nefarious complicity by the threat of exposure; even "pure" employees may be subverted with fabricated evidence. Thus, the nuclear energy field will continue to incur sudden unexpected losses due to the vagaries of human behavior.

Vulnerable Targets

Nuclear power plants are the most vulnerable military targets in any country that uses nuclear energy. Actions against such installations would be consistent with belligerent aims to inflict casualties, deprive an enemy of electric power and deprive an enemy territory, thereby reducing the need for occupation and retarding postwar recovery. Even if mutually declared non-targetable by the combatants, nuclear power plants might be ruptured adventitiously in wartime by unintentionally incapacitating cooling systems by bombing, say, dams. Hence in the next war involving a nuclear power nation, military actions are likely to cause major releases of radioactivity. Simple abandonment of nuclear power plants in war might lead to eventual catastrophic meltdowns if vital residual cooling systems were no longer attended by knowledgeable personnel.

Naval attacks could destroy coastal or offshore nuclear power stations. In this regard, the peak fission product inventory of a large reactor is sufficient to contaminate tens of thousands of cubic miles of water in excess of permitted AEC tolerance levels.

The greatest concentrations of long-lived radionuclides are stored in near-surface "tank farms" near fuel reprocessing plants. Conventional bombing of such areas would contaminate them sufficiently to preclude human approach and make it impossible to prevent further spread of massive quantities of radioactivity. One motive for such an attack would be to enjoin the enemy from utilizing his radioactive wastes for warfare. The presence of plutonium-239 in stored reprocessing wastes dictates that it be isolated from the environment for about 250,000 years. On the conservative assumption of one, two-year war per century in a given locality, plutonium-bearing wastes will remain military targets during roughly 5,000 years of actual warfare.

Political extremists might be drawn to nuclear sabotage, theft, terrorism and extortion. Because of the international character of subversive movements, lax nuclear precautions in a single nation constitute a threat to all. Even perfectly maintained domestic safeguards do not preclude smuggling: the southern border of the United States, for example, is crossed yearly by roughly 360,000 illegal entrants and daily by aircraft transporting marijuana.

The principal methods of subversive attack on nuclear power stations would involve incendiaries and explosives. Plausible approaches exist so that

determined insurgents could destroy a nuclear power plant without even entering it. For example, a logical target would be the cooling system, specifically the intake piping which runs hundreds of feet outside the plant to a large body of water. Saboteurs could drop improvised time-delayed depth charges onto cooling intakes from a small boat. With scuba equipment, underwater demolition activities could be carried out unobserved from the surface. Floating bombs introduced into cooling pipes could travel unimpeded to the screen-well located close to the power plant, where their detonation would send a shock wave through the plant's piping. If the attack succeeded in destroying all of the intake pipes or their pumps, means would be available to remove fission product afterheat for only about one day. During this interval, the AEC claims that adequate emergency measures could be taken to prevent a meltdown disaster.

The most vulnerable radioactive target would be the spent-fuel pool, in which used fuel assemblies age for several months prior to being shipped for reprocessing.

Aerial Attack

Assaults from the air might involve dropping incendiary or explosive substances from hijacked or rented aircraft. More desperate agents might load a plane with explosives and power dive into the plant. Attacks by berserk military aircraft are a remote but definite possibility, and these might be equipped with sophisticated munitions.

This brings to mind the large number of citizens who, through military training, possess sabotage skills. A retired Green Beret colonel has given secret testimony to the AEC that he could readily sabotage the San Onofre, California, nuclear power plant located 4,400 yards from the western White House at San Clemente.

Criminal Activity

The chief interest of criminals in nuclear power plants would be to gain control over radioactive materials, rather than to destroy the facilities. The private manufacture of atomic explosives is within the capability of many groups once they possess the requisite 11 pounds of plutonium-239. The serious implications of this fact have been discussed elsewhere.¹ Here it suffices to point out that inferior, but still usable for weapons, plutonium is produced in nearly every nuclear reactor. It is shipped from reprocessing plants as nitrate solution in lots exceeding 100 pounds.

Underworld fabrication of atomic bombs is more difficult and less likely than the simple use of stolen plutonium as a contaminant. Plutonium-oxide dispersion could raise lung cancer hazard to unacceptable levels throughout an entire city. The possessor of metallic plutonium need only expose it on the roof of a tall building to release oxide particles into the air by pyrophoric combustion. One pound of the metal thus dispersed could theo-

retically bring 110 square miles to worrisome radioactive levels, or 3 square miles to the level used by the AEC in determining an "extraordinary nuclear occurrence."² Such deposition could necessitate evacuation, extremely expensive decontamination or the permanent use of face-mask respirators.

Each 1,000 megawatt-electrical nuclear power plant annually produces over 80 million curies of long-lived gamma emitters. One percent of these could theoretically contaminate 500 square miles to levels that would require evacuation.³ Once known to possess such a deterrent, a criminal gang would be virtually immune from prosecution. Armed with plutonium or high level waste in storage, organized crime might demand federal assurances of non-interference with their operations. Punishment for non-cooperation might be the loss of Washington, D. C., as a habitable center. Nuclear thieves could demand large sums of cash, control over policy or special concessions from national governments. One can imagine the plight of an administration seeking to mediate the demands of several radioactive blackmailers—large or small in number, foreign or domestic, criminal or altruistic.

States and cities could be threatened with radio-contamination of essential public facilities: capitol buildings, city halls, police stations, hospitals, water and sewage treatment plants. Simple disposal of radioactive material down a toilet could create a sanitary emergency by shutting down sewage treatment facilities. Attacks on workplaces would pose the threat of extremely costly contamination of equipment, manufactured goods and foodstuffs. Such losses would not be covered by most property insurance policies, which specifically exclude damage from nuclear radiation.

Any location which attracts the bomber of today will attract the nuclear thief of tomorrow. Places of public assembly such as theaters, stadiums and transportation terminals would be likely targets for nuclear terrorists, blackmailers or hoaxers. In the future, any wealthy, powerful or well-known person could receive real or crank threats from those who claimed possession of radioactive substances. Public officials subject to grudge attacks would feel obliged to use radiation detectors to monitor their homes, autos, offices and mail. Once sizable quantities of nuclear material had been diverted to the underworld, no imaginable precautions would prevent its widespread criminal use.

Thieves of radionuclides could induce or coerce an ignorant person to subdivide them for resale. They could then be purveyed anywhere in the world, to anyone possessed of the asking price. In this regard, the Nixon administration's plan to export nuclear power technology to 19 nations presents grave risks. The foreign sale and subsequent diversion of nuclides potentially presents almost the same danger as the proliferation of nuclear weapons.

The kidnapping of a nuclear scientist is no more difficult than the procurement of special nuclear

materials. Even an extremely loyal employee might surrender top secret information were he, she or a family member to be abducted by ruthless criminals. To preclude misleading information, criminals might kidnap two or more experts, whose separately coerced accounts could be checked for consistency. Of course, the possibility of Ellsberg-type leaks or even voluntary collaboration of nuclear personnel with criminals can never be completely ruled out. Thus, the safety of the "atomic age" from criminal domination must be judged in light of the questions: Does security depend on secrecy? How likely is such secrecy to be permanently kept?

Hoodlums, domestic subversives or foreign agents may attempt to incriminate innocent third parties for acts of nuclear violence. By deliberate fabrication of clues, malefactors may hope to escape the blow of retaliation and divert the same onto a rival or suspect group. This possibility suggests special perils in connection with smoldering international conflicts. A small nation or faction might arrange nuclear power plant sabotage in the United States in such a way as to make another nation appear responsible. If the dispersal of several large amounts of radioactive materials of mysterious or misleading origin occurred in a short period of time, the nation might feel impelled to retaliate against its most visible enemy with a missile strike. The risks of error would be high, and the consequences, monumental.

Psychosocial Aftermath

One immediate evacuation-related problem, following a large radioactive spill, would be the evacuees' anxiety concerning their degree of radiation exposure. Facilities would be required to deal with hypochondriacal complaints of radiation sickness as well as the medical injuries of actual victims. Some exposed women may request therapeutic abortions. In the wake of the emergency, other issues would arise. A strong public demand, impossible to grant, might be to shut down all nuclear plants at once. Real estate values close to nuclear facilities, especially downwind, might be severely cut. Massive litigation and agitation for indemnification could be expected. Evacuees would have to be maintained, relocated and reemployed. Persistent contamination of substantial areas would necessitate bypass transportation routes, new water supplies and sources of agricultural commodities.

Never before have large inhabited zones suddenly become unusable without visible damage. The administrative problem of keeping people out of such areas might not be solved completely by the fear of radiation. Near the periphery of these areas, persons might attempt to loot and transport materials, some of which might be contaminated. Vagabonds and desperadoes, relatively unimpressed with official warnings, might take up residence within interdicted zones and mount forays therefrom. Thus, these fenced-off areas might pose continuing headaches.

Objections and rejoinders to the above are as follows:

1. *The limited value of quantitative studies.* To some, the foregoing statements would be valued only as preliminary to detailed quantitative studies of the probability and magnitude of damage to be expected from each type of radioactive maleficence. Precision in such studies is precluded by two basic considerations.

- The number, motivation and capability of nuclear malefactors will vary with economic, social and geopolitical conditions as well as with the "state of the art" of sabotage, hijacking, etc.

- The first instances of radioactive violence and their insuppressible media coverage will inspire imitative attempts that will make obsolete all pre-existing calculations of likelihood, as we have seen with aircraft hijackings.

The truly relevant questions for security analysis appear to be: Is each scenario possible, in the United States or abroad, assuming normal precautions versus adversaries undeterred by the possibility of capture, irradiation or even death? If it is possible, can it be rendered essentially impossible at a sustainable cost to industry and society?

The most promising approach to answers appears to be gaming analysis, in which offensive and defensive teams compete in simulation to probe the strengths and weaknesses of security systems and personnel.

2. *The limits of industrial safeguards.* Nuclear power plants' security systems include a superficially impressive array of physical barriers, armed guards, procedural plans and electronic surveillance. Such precautions no doubt go far toward prevent-

ing illicit acts by employees or interlopers. However, sophisticated attacks by aircraft could be opposed only by ringing each nuclear installation with surface to air missiles and interdicting overflight. In order to similarly protect cooling intakes, all boats and scuba divers would have to be kept at a safe distance. Even these expensive measures would not protect against military attacks.

The adequate safeguarding of radioactive shipments presents even less wieldy problems. Armed hijackers could in principle overpower armed guards and immobilize the cargo by shooting truck tires or derailling a train. The massive bulk of lead-lined spent fuel casks would not prevent spillage if explosives or thermite were used. The AEC's latest attempt to bolster transportation safeguards is altogether inadequate relative to attacks of paramilitary strength or greater.⁴

3. *The false panacea of undergrounding.* Underground emplacement of nuclear power plants unquestionably would augment their resistance to aerial attack and improve the containment of radiation following a major accident. Because of the shortage of top-quality geologic formations, undergrounding could approximately double construction costs and raise the price of nuclear electricity by 50 percent. Moreover, it would be uneconomic for each power plant to have its own nearby underground reprocessing and fuel fabrication facilities. In their absence, the hazards associated with long-distance transport of spent fuel would remain. If several power reactors were concentrated underground in a single area so as to justify having their own reprocessing plant, such a complex would be a tempting target for attack with nuclear weapons.

Cooling towers, Peach Bottom nuclear power plant in Pennsylvania.

A major percentage of electrical power might thus be lost in a single strike.

It is doubtful whether undergrounding, at whatever practicable depth, could positively exclude malefactors or prevent the atmospheric release of nuclides following attack or major accident. An underground nuclear power station would have to maintain several connections with the surface. Intruders still might enter, and the volatile 20 percent of fission products still might leave following rupture through elevator shafts, stairwells, air conditioning ducts and sizable freight entrances that are big enough to accommodate spent fuel casks.

The wartime advantage of undergrounding fades with the recognition that nuclear explosives could destroy even a greatly hardened site. A direct atom bomb hit on a surface nuclear power plant would actually result in less onsite contamination, since most of the material would be carried up to the stratosphere by the rising fireball. Once ruptured, any nuclear power plant would be eventually infiltrated by groundwater, whose percolation would carry radiation into the large body of water that supplied the plant's cooling.

4. *The unjustified reliance on human scruples.* Conscience might prevent all but one in a million persons from committing radioactive atrocities. That would still leave 3,800 people in the world who could endanger most of the others. However, circumstances enable normal human beings to rationalize vicious deeds. An attacker either subjectively dehumanizes his victims, invokes the right of vengeance or justifies his behavior as part of a larger noble cause, such as "ending the war."⁵

5. *The false hope of prevention through social science.* It has been suggested that physical or psychological profiles might be constructed to identify potential nuclear criminals. Such profiles have been of some value in screening possible airline hijackers at the ticket counter or boarding gate. However, future atomic felons do not so cooperatively present themselves for advance scrutiny. Thus, any screening instrument would have to sift, at great expense, major segments of the population. Probably even a very large net would not catch all the fish. The validation of the screening procedure would be a major undertaking in itself. In a free society, no prior restraint could be placed on those identified in the screening as high risks.

6. *So far, so good.* Reliance on a good past record ignores the automatic multiplication of malfeasance opportunities as the nuclear industry proliferates. Moreover, new technological innovations may pierce formerly impenetrable barriers. The remote-controlled drone airplane, which could put a crude guided-missile capability in criminal hands, is an example.

7. *The false hope of insurance.* As AEC estimates of possible damage in a radioactive release have risen to \$17 billion, utilities' total liability for a single nuclear power plant disaster is limited by the Price-Anderson Act to less than \$600 million.

Private insurance against radio-contamination is largely nonexistent, and the present annual limit of Small Business Administration disaster loans is \$4.3 billion.

8. *The fallacy of comparative risk.* American society accepts the 57,000 fatalities and 2 million disablements that annually result from U.S. highway travel. Are radioactive disasters acceptable by comparison? Auto accidents are not subject to sudden orders-of-magnitude increases; casualties from radiation are.

No other risk presents the prospect of long-term incapacitation of sizable inhabited land areas and watersheds, injecting an element of uncertainty into all planning for land use.

No other hazard poses a distinct threat to the health and genetic integrity of future generations.

No other hazard, save that generated by the international nuclear industry, quietly undermines our entire system of national defense by making the United States vulnerable to anonymous attack from within.

Since 350,000 Americans die annually from cancers, perhaps additional cases of radiation-induced cancer would be inconsequential on a percentage basis. However, since one out of four U.S. citizens is presently destined to contract cancer, we should not be eager to add unpredictably large doses of carcinogens to our environment.

Another comparative-risk argument invokes the threat to industrial civilization in the absence of an inexhaustible energy source, presumably provided only by nuclear fission. Granted that a long-term power source is indispensable, potentially infinite energy may be obtained yet from the varied effects of the solar beam, the Earth's heat, and the fusion of light atoms.

NOTES

1. Ralph E. Lapp, "The Ultimate Blackmail," *New York Times Magazine*, Feb. 4, 1973; Robert B. Leachman and Phillip Althoff, eds., *Preventing Nuclear Theft: Guidelines for Industry and Government* (New York: Praeger, 1971).

2. This level for transuranic alpha emissions is 0.35 microcuries per square meter, as given in USAEC Rules & Regulations Section 140.84, Nov. 28, 1970.

3. Gamma deposition of 1,400 curies per square mile would deliver a first-year dosage of about 50 rem. This is ten times the annual maximum permitted to atomic workers in restricted areas.

4. U.S. Atomic Energy Commission, Nuclear Fuel Cycle Division, "Fuel Cycle Safeguards," Nov. 6, 1973.

The minimum number of armed guards that must accompany shipments of special nuclear material (SNM) in a railroad car or separate vehicle remains at two. The still-required prominent identification numbers on top of the vehicle enable easy identification by searchers and also enable easy identification and pursuit by aerial attackers.

The general theme of the transportation rules is to withstand small assaults with pistols but not to withstand, let alone repel, significant armed attacks. A single armed guard monitors transfers of SNM.

5. R. Nevitt Sanford and Craig Comstock, eds., *Sanctions for Evil* (San Francisco: Jossey-Bass, 1971).

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Dr. L. Douglas De Nike
Vice President
Zero Population Growth
Los Angeles Chapter
1720 Pontius Avenue, Office 205
Los Angeles, California 90025

Dear Dr. De Nike:

Thank you for your letter of April 17, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information.

Your paper "Antisocial Interventions Against the Proposed Liquid Metal Fast Breeder Reactor Program, (Provisional Cost Estimates)" assesses the consequences of successful theft in terms of property damage with costs expressed in dollars. The assessment is based on assumptions that two major metropolises, or their equivalent, will be contaminated to evacuation levels each century, and two other major urban areas will be destroyed by nuclear weapons constructed or diverted by terrorists, one each fifty years. Smaller extremist acts of radio-contamination and other assaults on nuclear facilities are assumed to inflict losses, including decontamination costs, of \$1 million per annum. It is further assumed that once each century a shipment of 576 kilograms of plutonium will be stolen by criminals, used to force evacuation through threat of radio-contamination of a single American metropolis, and form the basis for extortion payments by the federal government and other costs totaling one billion dollars per year. The cost totals based on these and other similar assumptions are presented in the discussion as "the minimum...for a single nation and century."

Dr. L. Douglas De Nike

2

It is noted that the assumptions used in the assessment are offered without justification or foundation. A wide range of assumptions would be equally defensible, including some that would result in negligible costs. Projections into the future are tenuous even when based on copious historical data. When the data is sparse or, as in this case, practically non-existent, any projection is qualitative and highly uncertain. It is concluded that such projections should not be incorporated into cost-benefit analysis, and this policy was followed in preparing the Final Statement.

Although the inability to predict the consequences of future anti-social acts precludes their use in cost-benefit analysis, the development of future AEC safeguards will take into account the need to provide levels of protection commensurate with the potential consequences of credible anti-social acts, other than acts of war. Section 7.4.8 of the Final Statement describes in detail the approach to development of future safeguards.

Protection of U.S. nuclear facilities against wartime attack is the responsibility of the defense establishment and the armed forces. While such an attack might occur, it is not possible to predict the probability or frequency of this occurrence. As pointed out in Section 7.4.4.1 of the Final Statement, it is believed that the overall consequences of a massive strategic attack would mask any incremental effects resulting from nuclear facility damage.

We appreciate your interest in AEC safeguards activities and the LMFBR Program, and trust that the Final Environmental Statement, which contains an expanded discussion of safeguards matters, will alleviate your concerns on this subject.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WASHINGTON, D.C. 20250

April 22, 1974

Mr. J. L. Liverman
Biomedical and Environmental
Research and Safety Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Liverman:

This is in response to your letter of March 14 to Dr. Fred H. Tschirley regarding the Draft Environmental Statement, WASH-1535, Liquid Metal Fast Breeder Reactor Program.

The general tone in many sections of this statement leaves one with the impression that steps can be taken to protect the environment. Yet, little is said regarding the specific steps that will be taken. One specific example of this appears on page 4.2-80. Another example appears on page 4.2-83. It would be much better if the statement showed specifically what is going to be done to protect the environment.

Sincerely,

H. L. Barrows
Acting Assistant Administrator
National Program Staff

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. H. L. Barrows
Acting Assistant Administrator
National Program Staff
Agricultural Research Service
United States Department of Agriculture
Washington, D.C. 20250

Dear Mr. Barrows:

Thank you for your letter of April 22, 1974 on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information.

Regarding the concern of the Agricultural Research Service that little is said regarding the steps that will be taken to protect the environment, it should be noted that steps taken for future LMFBR power plants will depend greatly upon the nature of the plant site and the specific plant design, especially the type of cooling system selected. In addition, as stated on pages 4.2-2 and 4.2-3 of the Draft Statement:

"Each LMFBR power plant will be licensed according to this established procedure, which requires that the electric utility owner and operator of the plant submit to the AEC a Preliminary Safety Analysis Report (PSAR) and an "Applicant's Environmental Report -- Construction Permit Stage." The PSAR must contain evidence that the proposed plant can be built and operated without undue risk to the health and safety of the public. The Environmental Report must include detailed analyses of potential environmental impacts that might result from construction and operation of the plant; it must also present considerations of other factors as required by NEPA. These documents are reviewed by the AEC, and suitability of the plant on the proposed site is judged from the standpoints of safety and environmental impact."

Mr. H. L. Barrows

2

Thus, it is seen that the measures that will be taken to protect the environment will be determined on a case-by-case basis for future LMFBR power plants.

We hope this information is sufficiently responsive to the points you raised. Thank you again for your comments and for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

JAMES J. BARKER

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Telephone 516 WE 1-6151

SPECIALTIES

Nuclear Technology

Heat and Mass Transfer

Isotope Separation

Theoretical and Economic Analyses

MEMBER

A.N.S., A.I.Ch.E., A.C.S.

A.A.A.S., N.Y.A.S.,

Tau Beta Pi

Sigma Xi, Phi Lambda Upsilon

April 22, 1974

Office of the Assistant General Manager
Biomedical and Environmental Research and Safety Programs
U.S.A.E.C.
Washington, D. C. 20545

Re: WASH-1535

Dear Sirs:

1. I think it is unfortunate that more time was not allowed for review of the draft statement. My comments are therefore hurried and not as complete as I would like them to be.

2. I think it is unfortunate that the question of uranium resources was dismissed so readily on the basis that the LMFBR can function on the available tailings from the diffusion plants. I suspect that the uranium resources of this nation are manyfold larger than the current official estimates. Since larger resources would have an important bearing on the economic crossover time, a less frenetic schedule for LMFBR development could be adopted if it could be shown that more uranium exists within our borders. I also, incidentally, find it difficult to understand why, if uranium is available cheap (or cheaper) elsewhere in the world, we cannot exchange separative work or other technology or goods or services for uranium which we could stockpile here in the U.S.; thereby conserving our uranium resources. Project Independence is not incompatible with stockpiling; in fact, I think quite the reverse is true.

3. I believe that the radiation dose rates are unreasonably low, and therefore uneconomic, in comparison with the dose rates from natural and other man-made radiations. The distribution of the dose rates does not make sense to me, either. The dose rates and the dose from the plants should increase, whereas that from the transportation segment is relatively too high. Making the LMFBR less economically attractive is not a sensible direction in which to move, in my opinion, and a more economic distribution of doses is called for.

Yours truly,

James J. Barker

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. James J. Barker
Consulting Engineer
10 Walden Avenue
Jericho, L. I., N. Y. 11753

Dear Mr. Barker:

Thank you for your letter of April 22, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information.

Your comments on uranium resources suggest that you may have overlooked information presented in sections 8A.1.1.2, 8A.1.1.6, 8A.1.1.8 and in Appendix III B to Chapter 11 of the Draft Statement. This information has been augmented in the Final Statement and will be found in sections 6A.1.1.2, 6A.1.1.8, 6A.1.1.9 and 11.2.3. In brief response to your specific points, we believe that the foreign uranium supply/demand situation will be tight and that it would be unwise to rely heavily on imported uranium for future U.S. requirements. The ultimate availability of uranium from relatively high grade resources in the U.S. is, of course, uncertain. Based on the information currently available, however, we believe it is at least prudent to pace LMFBR development on the assumption that high grade resources will not be overly abundant and that lower grade resources may prove to be environmentally and economically unacceptable.

With regard to your comment on dose rates, it was not our intention to obtain uneconomic and/or unreasonably low radiation dose rates. Rather, model LMFBR plant radioactive waste management systems were described which are thought to be economically feasible and realistic and to produce radiation doses that would be as low as practicable. Use of nuclear energy centers would greatly reduce the radiation dose due to the transportation segment by the transportation of spent fuel between reactors and reprocessing plants, and of fresh fuel from fabrication plants to reactors.

Mr. James J. Barker

2

We hope this information is adequately responsive to your comments.
Your interest in the LMFB Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFB Program (WASH-1535)

Mr. Hamilton Treadway

P.O. Box 88
Augusta, W. Va. 26704
15 April 1974

Office of the Assistant General Manager
for Biomedical and Environmental Research Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Subject: Comments on the Liquid Metal Fast Breeder Reactor
Program, Draft Environmental Impact Statement, WASH-1535

Gentlemen:

Attached hereto please find three copies of subject comments.

Due to the limited amount of time available I have not been able to prepare my comments in the detail which this important document deserves. I have outlined the substance of my comments in broad terms so that the Commission, with this general guidance, can make the technical studies and detailed calculations which are necessary to complete the comparisons required for the final draft of the Environmental Impact Statement. The importance of preparing the comparisons I am recommending, in the form and manner and using the techniques I am recommending, can not be over emphasized. These studies will provide the basis for a sound national evaluation of the program, permit assessment of the place of the LMFB program in both the R&D and the energy supply mix and will allay those questions regarding the program which proved so troublesome to the Courts in the action which resulted in the order to comply with NEPA at this time. I urge the Commission to consider these comments and recommendations carefully in preparing the final draft.

Previous commitments prevent me from being present at the hearing on 24 April 1974. I shall be out of the country until about 16 May 1974. At that time I shall be glad to furnish such additional information as I can which may prove helpful in preparing the final EIS on this important program.

Yours very truly,

Hamilton Treadway

Hamilton Treadway
Attorney-at-Law

LIQUID METAL FAST BREEDER REACTOR PROGRAM

Comments on Draft Environmental Impact Statement, WASH-1535

1. Statement of Scope of Comments

The draft Environmental Impact Statement, hereinafter referred to as EIS, WASH-1535, was prepared as a result of the decision of the U.S. Court of Appeals, D.C. Circuit in *Scientists Institute for Public Information, Inc. v Atomic Energy Commission*, dated 12 June 1973.^{1/} The Court's opinion is not completely clear as to what it expected the environment impact statement to cover and accomplish. In its summary statement, the Court says:

"....Taking into account the magnitude of the ongoing Federal investment in this program, the controversial environmental effects attendant upon future widespread deployment of breeder reactors should the program fulfill present expectations, the accelerated pace under which this program has moved beyond pure scientific research toward creation of a viable, competitive breeder reactor electric energy industry, and the manner in which investment in this new technology is likely to restrict future alternatives, we hold that the Commission's program comes within both the letter and spirit of Section 102(C)^{2/} and that a detailed statement about the program, its environmental impact, and alternatives thereto is presently required".^{3/} The draft EIS does not provide that.

In its opinion it recognizes many factors including sizeable irretrievable commitments of resources, a radical change in the manner in which our entire nation produces electricity, unique and unprecedented environmental hazards, the possibility that these will be less harmful than existing fossil fuel generating plants, the slowing down of the development of other new technologies and the controversy surrounding the commitment to pursue the LMFR program as a solution to the energy supply problems of this nation.^{4/} While emphasizing that it was not in its opinion questioning the wisdom of the program, it leaves the inference that its wisdom would be tested by requiring full disclosure to the public and to other entities within the government of all environmental effects likely to stem from agency action.^{5/} The draft EIS falls short of this.

The EIS is massive. In the limited time available for review and comments it is difficult for it to be digested and thought through by a single mind. It is clear from a reading thereof that this has not as yet been done. This is necessary before a final draft is issued if it is to accomplish the objectives of NEPA and the Court's decision.

^{1/} EIS, WASH - 1535 p 1.1-4

^{2/} National Environmental Protection Act, 42 USC Sec. 4331 hereinafter referred to as NEPA

^{3/} Slip opinion, page 2.

^{4/} Slip opinion page 35.

^{5/} Slip opinion page 37.

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NEPA is forward looking. It substituted vision and foresight for 20/20 hindsight. It is the effects that can be foreseen by looking at the consequences of today's actions and the alternatives thereto which must be examined and held up to public inspection. NEPA introduced a beautiful tool into the planning process for Federal programming. That it has been honored more in the breach than in its use does not lessen its effectiveness and importance when properly used. The heart of that planning process is the investigation of the alternatives. That investigation must be as thorough as the investigation and formulation of the program which the Agency seeks to implement. The cost-benefit analysis provides a basis for evaluating the program and the alternatives thereto. That analysis takes a central position in the EIS. In order that one may review the cost benefit analysis it must be presented in a manner which permits the reviewer to sit in the same position as those who made the analysis. He must be able to follow it step-by-step so that he can assess the reasons for the conclusions reached on each element and also determine whether any elements have been omitted or have been given too little or too much consideration. It follows that the alternatives must be given the same detailed treatment as the program the Agency seeks to implement; in this case the LMFB program. EIS, WASH-1535 seems to recognize this need. It falls short of that objective or has failed to present the information in a manner which readily demonstrates the detailed consideration given the many alternatives. As previously noted within the time limitations all alternatives can not be reviewed in detail. Our comments will, therefore, be confined to one of these to demonstrate what should be done with respect to each before a final EIS is issued.

The draft EIS seems to contain many assumptions which may or may not have been evaluated in detail before they became conclusions on which the draft was based. The number of these assumptions throughout the test is extremely large. Comments can only be made on some of these so that their status may be clarified in the final draft. It is hoped that comments of other interested parties will be sufficiently diversified in this respect to cover substantially all of these assumptions so that the final EIS will provide greater clarity with respect to each.

There are many conclusions drawn in the report seemingly as truisms and often without factual support. More careful cross-referencing would help clear up some of the problems in this respect when the final draft is prepared. Other suggestions herein will also help clarify this aspect of the problem in the final draft.

The most glaring example of a misleading conclusion is the statement in the summary that fossil fueled plants burning coal, oil and gas are fully developed. Nothing could be further from the truth. It is correct that the pulverized coal cyclone furnace has been brought to a high state of development and commercial operation. It, however, is incapable at present of burning high sulfur high Btu coal at acceptable levels of sulfur, NOx, and ash emissions. Research and development on a range of auxiliary systems to provide adequate pollution control effectively to the steam generators is still in progress. It is conclusions of this type which have lead the preparers of this draft to adopt projections that fall short of reality in testing the LMFB program under the standards set by NEPA.

6/ EIS, WASH-1535, p 1.8-1
 7/ EIS, WASH-1535, p 1.8-5

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2. The Purpose of the EIS

This brings us to the core of the problem. Is it the purpose of this EIS to analyze the effect of the LMFBR program on the environment? Is it the objective to determine the place of the LMFBR in the mix of future sources of electric energy? Is this an assessment of its environmental impact as a research and development project or is it an assessment of the environmental impact of the development of a new industrial complex?

In one way or another the EIS seems to attack all of these questions. It appears unfortunately to draw a straight line from the assumption that the breeder reactor is the major long term solution to our energy supply to the conclusion that it is the best solution to those problems. This Assumption and conclusion are the ones which give the most trouble. Actually the breeder reactor is one of a mix of energy conversion devices which will constitute the long range solution to our energy needs. The EIS should have been prepared to help more accurately pinpoint its point of entry and exist in the mix. Instead it starts with the assumption that the time schedules established in 1968, prior to the adoption of NEPA, are still controlling. Those decisions and the commitments based thereon have not been tested by the standards imposed by NEPA. That must be one of the objectives of the final draft of the EIS. WASH 1535 does not accomplish this.

The LMFBR program is still a research and development program. Its place in the supply of this country's energy needs should be determined by a cost-benefit analysis comparing it with each and every energy production and conversion research and development program in a manner to permit the evaluation of the place, if any, of each in the complexities of the mix both with respect to the probabilities of each becoming a certainty at some point in time and the internal rate of return to the economy which each will generate. The evaluation of the availability of each as to time must also take into account the national goal of energy self-sufficiency at an early date and may substantially affect the point of entry of LMFBR in the mix. Determination of the internal rate of return of each research and development program should lead to the most economical use of our resources considering both the internalized and externalized costs generated by each. This is sound economics. It reduces the probability of a mistake in the planning process that would be economically catastrophic in the years ahead. It is not only possible but probable that when this evaluation is made, sans foregone conclusions, LMFBR may find its place in point of time usurped by energy conversion processes which are both more readily available and less costly. This is not to say that the LMFBR program may have no place in the development of energy supply sources in this country, but it does say that its place should be determined in an orderly manner making use of the best tools now available for that purpose.

3. Assumptions

a. Load Estimates

Perhaps the assumptions which should first be reexamined are those relating to the load estimates, particularly after 1990. The forecasts used in the study are taken from a previous projection made by AEC.^{8/} As indicated

^{8/} USAEC, Nuclear Power 1973-2000, Report WASH-1139(72), 12/72.

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It is, like many others, based on projections of energy use per capita and population. As shown in Figure 9.1-1¹⁰ it is of the exponential form. This is subject to considerable question. Long range growth is more likely to follow a curve of the form of

$$y = \frac{K}{1 + m e^{F(x)}}$$

which is the well known S curve where the value of y becomes asymptotic to some limit K at some future time x. There are good reasons why the growth of the use of electricity should begin to approach some limit in this country about the year 2020. There is general agreement now that the population will level off about that time, a prediction the author made in late 1936 in a study for the Illinois Commerce Commission. There is also good reason to believe that average per capita usage will also approach a maximum level by that time. It is suggested that the maximum system capacity required to meet this country's peak demand at that time will be in the order of 4000 to 4500 Gigawatts. Price elasticity may bring this limit as low as 3750 Gigawatts. These reduced requirements would substantially affect the mix of energy conversion methods required to meet the demands. On the other hand, if a complete electric economy ultimately shakes out of the present energy situation, the maximum system capacity requirements could reach 8000 to 10000 Gigawatts by 2020. In that event it may be desirable to speed up the fusion research program in preference to concentrating now on a more intermediate approach. It may also be desirable to speed up other options, such as MSBR. It is, therefore, desirable that the EIS explore several possible upper limits on electric growth rather than the single load projection used in the draft statement.

b. The Outlook for Fossil Fuels

The future mix of fossil fuels is inescapably in error. It assumes that the use of natural gas to generate electricity will gradually increase until about 1980 before declining. This is doubtful. An end use control policy is now evolving for this precious natural resource. Enlightened conservation should soon preclude its use as a boiler fuel including electric generation. Natural gas should probably cease to be used for this purpose by 1980 and its role in the generation of electricity thereafter should be negligible.

There should also be a gradual decline in the use of oil to generate electricity. Economics, scarcity, preferential uses and technological changes should reduce its role in energy conversion mix rapidly after 1980.

This leaves coal as the principal expanding fossil fuel source both immediately and in the long run. As soon as the present artificially induced shortage of this abundant fuel shakes out its availability and cost will make it the most significant fossil fuel source in the generation of electricity, provided we solve speedily the problems of clean combustion. Five to six massive coal fueled generating complexes should develop east of the Mississippi and perhaps an equal number in the Western States. Once a new generation of pollution free plants are built to produce electricity from coal its use in the generation mix will expand rapidly. That expansion is essential to energy

9/ EIS, WASH-1535 p. 9.1-1
10/ EIS, WASH-1535 p. 9.1-2

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self-sufficiency in this country. The availability of a new generation of coal fueled energy conversion plants is much closer than the draft EIS assumes. It is the failure to examine thoroughly the position of coal in the mix which leads to a questionable conclusion in the cost-benefit analysis. The fallacies in the conclusions are unfortunately buried in the cost-benefit technique used in the draft EIS.

c. Energy Sources Mix

The several assumptions that lead to the final conclusion regarding the position of the LMFBR in the energy mix are the most questionable of all. The assumptions used in earlier studies are picked up and used without serious re-examination. No consideration is given to the probability of greatly expanded use of coal if research and development results in both lower cost steam generation facilities and lower cost coal production. No consideration is given to the possibility of locating large electric generating complexes in the great coal fields with either extra high voltage AC or DC transmission corridors to the load centers although these seem to be among the more probable alternatives. Most important, however, is the failure to test this research and development project, i.e. the LMFBR, against the other research and development projects to determine the place of each in the future energy mix. This is what the final EIS must focus upon. By way of illustration the remainder of these comments will focus on one of these research and development programs which is now much nearer to commercial operation than the LMFBR.

It must be emphasized at this point that assumptions and conclusions which consider that nuclear generation is the only viable alternative in the electric energy mix and that the only question to be resolved in the cost/benefit analysis is how much will be supplied by LMFBR fueled generating plants are highly questionable.

It is also important to point out here that this hypothesis and the conclusions reached provide no solution for the immediate energy problem, do not consider the stimulus of the realignment of fuel prices on solving the immediate problems and fail to recognize the affect of a solution to the immediate problems on the long range mix of energy conversion methods. These factors should be fully considered in the final draft of the EIS.

4. A Viable Research and Development Alternative - Fluidized-Bed Combustion

Of all of the research and development programs now in one stage or another of implementation the fluidized-bed furnace and steam generator is the most advanced. Most of the research work has been completed and the experimental furnace has been operated successfully under laboratory conditions demonstrating capability to meet the air pollution emission limitations utilizing high sulfur high Btu coal as a fuel. A prototype unit is under construction. Conceptual designs of a steam generator comparable in size to the proposed experimental LMFBR installation are available.^{11/} The EIS gives only passing recognition to this fact in a one paragraph statement regarding its possibilities.^{12/} The fluidized-bed combustion program is much farther advanced than the LMFBR program. If given appropriate emphasis at this time in the research and development picture the first large scale steam generator could be in full commercial operation prior to 1980 and a whole new generation

^{11/} OCR, R&D Report No. 36, Contract No. 1401-000-1-478 Public Utilities Fortnightly, 14 March 1974, Vol. 93, No. 6 p:36, 38

^{12/} EIS, WASH-1535, Vol. IV, p A2-17

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of fluidized-bed electric power plants utilizing high sulfur, high Btu bituminous coal located in the major coal producing areas near the mines could be contributing to the energy self-sufficiency goals of this country by the mid-1980's. It is accordingly necessary that the final EIS include a new cost/benefit analysis comparing these programs.

This is the only R&D program now nearing fruition which offers a reasonable prospect of resuming the downward trend in the cost of steam generators for the electric utility industry. It is also the only one which is likely to involve a minimum of sulfur removal problems in the stack gas because almost all sulfur is removed in the furnace bed. Fly ash removal and coal cleaning problems are minimized. By locating large generating complexes in the coal fields fuel transportation is reduced and ash disposal and surface restoration are facilitated.

The important thing in this cost/benefit analysis is that it be completed in detail on a year by year basis so that each assumption and each conclusion can be reviewed, alternates considered and the optimum mix determined. Instead of discounting each of the costs and benefits entering the future stream at an assumed interest rate, which may or may not be realistic in the future, the internal rate of return should be calculated for each program from the complete stream of costs and benefits for each year in the period from 1974 to 2020.^{13/} Each program will have a different internal rate of return under this method of economic evaluation. This will give a relative national profitability ranking for each research and development program. In making this analysis the critical variables in each program should be subjected to sensitivity testing by varying these critical variables through a range of optimistic, most probable, minimum or pessimistic. This would give a range of internal rate of return values for each program. If each is fully documented the final ranking of each program both as to national profitability and time phasing of its entry and exit in the mix will be facilitated and the probability of a gross error in the choice will be lessened.^{14/} The information thus developed should provide comparisons of these R&D programs which can be readily evaluated by all parties.

^{13/} The internal rate of return is determined by calculating that discount rate at which the present value of the costs and benefits for the program are equal; i.e. the discount rate at which the difference between present value of the costs and the present value of the benefits is zero.

^{14/} In any national planning effort a massive mistake can be disastrous to the economy as a whole. The mistakes already made in the energy field adequately demonstrate this. In the final EIS every effort must be made to minimize this possibility.

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5. Other Research and Development Alternatives.

Since there are several other research and development alternatives which may also be competitive as to time, economics and environmental risks and burdens, each such project should be evaluated in the same manner and by the same techniques as suggested in paragraph 4 above for the fluidized-bed combustion of high sulfur, high Btu coal. The final EIS should then provide the developmental guidance for all energy research programs that is today almost totally lacking.

6. The Final EIS

The foregoing recommendations are directed to the preparation of a final EIS which will provide the guidance sought by the court. It is realized that the recommended cost/benefit technique is different than that which has been adopted by the Atomic Energy Commission in its guidelines for the preparation of such studies. Those guidelines may provide a sufficiently accurate result for the purpose of issuing a construction permit where the alternatives under consideration are capable of cross-comparison without probable large scale oversights. Such is not the situation in preparing cost/benefit studies of energy conversion research and development programs where the only thing in common is their electrical output. The inputs are totally different, widely separated as to time, economics and probable fruition. Thus different techniques are essential to produce a meaningful result. The cost benefit analysis plus the environmental risks and burdens analysis recommended herein would then meet the needs of this particular EIS. The EIS would then provide the information which is necessary to permit the public, through its elected and appointed representatives, to determine that mix of energy supply systems it considers most desirable and most likely to meet this country's energy requirements on a timely basis, effectively and efficiently, within an economy of abundance and self-sufficiency. This is the question which NEPA provided the means of answering but in responding to NEPA it is essential that one use the correct tools, in this case the tools which will provide an effective means of ranking all of energy conversion research and development programs in a manner to permit their evaluation on the basis of national priorities.

Hamilton Treadway
Attorney-at-Law

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Hamilton Treadway
Attorney-at-Law
P. O. Box 88
Augusta, West Virginia 26704

Dear Mr. Treadway:

Thank you for your letters of April 15 and April 25, 1974 which provided comments on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. The other enclosure to this letter provides further information on the points you raised.

Your interest in the LMFBR Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement, LMFBR Program (WASH-1535)

ENCLOSURE I

AEC STAFF RESPONSE TO SPECIFIC COMMENTS
BY MR. HAMILTON TREADWAY

1. Comment:

The Draft Environmental Statement does not comply with the U.S. Court of Appeals opinion regarding the necessary scope and depth of treatment of the LMFBR Program, its environmental impact, and alternatives thereto.

Response:

Although the AEC appreciates the substantial thought and effort that have obviously gone into the preparation of your comments, we are unable to agree with your initial conclusions that the Draft Statement does not provide detailed information on the LMFBR Program, its environmental effects, and alternatives. The AEC has made every effort in the Draft Statement to set forth all relevant information and to indicate where new information is needed or under development. This effort included 50 man-years of AEC and AEC contractor activities and the expenditures of approximately \$1,800,000. We believe that the Draft Statement was an extremely comprehensive examination of the anticipated environmental effects of the LMFBR Program and that it was fully in compliance with the National Environmental Policy Act of 1969 and resulting government guidelines and court interpretations for the preparation of environmental statements. At the same time, the AEC recognizes that many questions were submitted on the Draft Statement (see Appendix to the Final Statement). We have attempted to answer these questions as completely as possible in the response to these letters and through appropriate revisions to the text of the Final Statement. We hope that a reading of the material therein will satisfy you that our evaluations have been complete and fully responsive to the issues raised.

2. Comment:

"The cost-benefit analysis provides a basis for evaluating the program and the alternatives thereto. That analysis takes a central position in the EIS. In order that one may review the cost benefit analysis it must be presented in a manner which permits the reviewer to sit in the same position as those who made the analysis. He must be able to follow it step-by-step so that he can assess the reasons for the conclusions reached on each element and also determine whether any elements have been omitted or have been given too little or too much consideration."

Response:

The assumptions, major results, and findings resulting from parametric studies of important factors and conclusions have been included in Section 11.2. The AEC feels that the bases for conducting the cost-benefit analysis have been thoroughly presented and that reviewers have all relevant information available.

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3. Comment:

"...a misleading conclusion is the statement in the summary that fossil fueled plants burning coal, oil and gas are fully developed."

Response:

We agree that a successful outcome of current R&D in the areas of pre-, co-, and post-combustion coal treatment and of fluidized-bed combustion and binary cycle development will lead to future fossil-fueled power plants that will be significantly more efficient and environmentally acceptable than the average plant of this type now in operation. (See Section 6A.2.1.3 for discussion of this point.) It should be noted, however, that the competitive position allocated to fossil fuels in the cost-benefit analysis was not pessimistic. Fossil fuel price projections were conservatively low. The highest coal cost utilized in the cost-benefit analysis (50.9 cents/million Btu after the year 2005) in the Draft Statement is about 10 cents/million Btu less than the March 1974 average coal cost.*

Fossil fueled power plant penetration in the cost-benefit studies was constrained to a level higher than would be indicated by sensitivity studies which allowed unconstrained nuclear-fossil competition. It is improbable, at least at this point in time, that future technological improvements could compensate for the accelerating high cost of fossil fuels.

4. Comment:

"The EIS should have been prepared to help more accurately pinpoint its (the LMFBR's) point of entry and exit in the mix. Instead it starts with the assumption that the time schedules established in 1968, prior to the adoption of NEPA, are still controlling... The LMFBR program is still a research and development program. Its place in the supply of this country's energy needs should be determined by a cost-benefit analysis comparing it with each and every energy production and conversion research and development program..."

Response:

As discussed in Section 11, there are two major factors affecting the need for the LMFBR and the timing as to when it will be needed for entry into the energy economy. These are the availability of uranium resources and the availability of alternative technologies for producing electricity. If further exploration fails to identify significant amounts of sufficiently high grade uranium resources, and assuming mining of low grade resources

* Electrical World, July 15, 1974, p. 8.

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such as shale is environmentally as well as economically unacceptable, then depletion of usable uranium reserves could occur by the end of the century--unless a breeder reactor economy is established.

Thus, there is a real need on this basis not to delay the LMFBR. Similarly, as discussed in Sections 6 and 11, there is no assurance that environmentally acceptable alternative energy sources based on essentially "limitless" fuel, such as solar energy and nuclear fusion will be available when needed (if at all) i.e., by the time that uranium ore costs, availability or environmental constraints would preclude continued reliance on non-breeder reactors. The current status of these technologies and experience in developing new complex energy sources strongly indicates that neither solar energy nor fusion can be expected to supply significant amounts of electricity until after the turn of the century, if then. Some time after that, if these technologies are successful, it may become feasible to "phase out" breeder reactors. In the meantime, as discussed in the enclosed Final Statement, there is a time window in which LMFBR's will be essential if the Nation's energy requirements are to be met.

With regard to your comment on cost-benefit analyses, it is not feasible to compare research and development programs in the cost-benefit analysis approach. Rather, it is necessary to project the successful commercial introduction of an alternative energy production system with appropriate justified cost data and allow the cost-benefit analysis procedure to determine the extent and rate of introduction of that particular energy production system into the existing energy production mix. This was done for all existing energy production systems including fossil fuels, converter reactors, and hydroelectric power and for the LMFBR based upon several projected dates of its introduction and upon its expected costs. The results are provided in Section 11.2. As discussed above, other alternative energy production systems are not projected to be introduced in significant quantities to make a meaningful contribution to the results of the cost-benefit analysis, nor are there sound projections of cost data available for them. They therefore were not treated in detail. However, a segment of the projected energy demand in the period through 2020 was reserved for unspecified energy production system to account for contributions from unspecified sources.

5. Comment:

"The future mix of fossil fuels is inescapably in error. It assumes that the use of natural gas to generate electricity will gradually increase until about 1980 before declining. This is doubtful. An end use control policy is now evolving for this precious natural resource. Enlightened conservation should soon preclude its use as a boiler fuel including electric generation. Natural gas should probably cease to be used for this purpose by 1980 and its role in the generation of electricity thereafter should be negligible.

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There should also be a gradual decline in the use of oil to generate electricity. Economics, scarcity, preferential uses and technological changes should reduce its role in energy conversion mix rapidly after 1980."

Response:

The assumptions in Chapter 9 of the Draft Statement concerning use of natural gas (somewhat less than a 10% increase between 1972 and 1977-78, and a decline thereafter) were based on several factors and are supported by several of the references listed in that chapter. The aggregate of these factors tends to indicate that the most likely future role of oil and gas in electrical generation would be characterized by a rapid decline in new plants fueled by oil or gas, but that existing and planned plants would continue to use these fuels over their normal lifetimes.

The AEC agrees that natural gas and oil are precious and scarce resources which have much greater value in uses other than as electric utility boiler fuels. We also support as rapid a conversion as possible of existing and planned electric generation capacity from the use of these fuels to alternatives. In fact, reduction in the use of natural gas and oil as fuels for electrical generation is now a national policy, as stated by the President in his energy message to Congress on October 8, 1974. Unfortunately, shifting of existing capacity from gas and oil to coal is not a simple task, not only technologically but from the viewpoint of obtaining assured supplies of coal which can be burned in an environmentally acceptable manner. The phasing out of oil and gas as utility boiler fuels is likely to be a gradual process which is not amenable to sudden shifts, even when severe emergencies such as last year's oil embargo make such changes desirable. Nevertheless, this changeover is a necessary activity and should be pursued to the maximum feasible extent.

The future mix of fossil fuels is uncertain, depending upon how quickly the changes can be made. However, the mix assumed in Chapter 9 was intended to serve more or less as an arbitrary reference mix on which to base the cumulative impact calculations, and the conclusions of Chapter 9 vis-a-vis the net impact of the breeder economy are not affected by the assumed relative contributions of coal, oil, and natural gas.

6. Comment:

"Once a new generation of pollution free plants are built to produce electricity from coal its use in the generation mix will expand rapidly. That expansion is essential to energy self-sufficiency in this country.

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The availability of a new generation of coal fueled energy conversion plants is much closer than the draft EIS assumes."

Response:

As was indicated on pp. A.2-41 and A.2-42 of the Draft Statement, there is a general consensus that many of the new developments related to "a new generation of coal-fueled energy conversion plants" can be operating commercially by 1980, and certainly by 1985. Considering the constraints on the availability of necessary capital, manpower, equipment, and water, it is difficult realistically to project a commercial-status date earlier than 1980. Finally, it is clear that coal can be burned in a more environmentally acceptable way than it has been in the past; though "pollution free plants," mentioned on p. 4 of your letter of April 15, 1974, are difficult to envision, at least in this century.

7. Comment:

"There are good reasons why the growth of the use of electricity should begin to approach some limit in this country about the year 2020." The peak demand will depend on assumptions in population growth and other factors." It is, therefore, desirable that the EIS explore several possible upper limits on electric growth rather than the single load projection used in the draft statement."

Response:

The econometric model utilized for the base energy demand projection is described fully in Section 11.2.3 of the Final Statement. (The model did include the lower population projection which assumes the population will reach a stationary level in about 70 years.) In addition to the base electric energy demand several alternative energy demand curves were analyzed. The cost-benefit analysis has been performed over a range of +20 to -50 percent of the base case electrical demand in the year 2000. The resultant electrical energy requirements were therefore assumed to range between 7.1 and 11.7 trillion Kwh in the year 2000, and between 13.8 to 33 trillion Kwh in the year 2020. The lowest energy demand projection is commensurate with successful energy conservation as described in Section 6C.6 in the Final Statement. This case corresponds quite well to the low capacity projections to which you refer on page 8 of your letter.

8. Comment:

The fluidized-bed furnace/steam generator R&D program is quite advanced (certainly more so than the LMFBR program), is less costly and potentially

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hazardous and more flexible than the LMFBR, and can meet all primary and secondary air pollution regulations when using high-Btu, high-sulfur coal.

Accordingly, the fluidized-bed combustion program deserves a higher priority, amounting to a crash effort to complete development of the various concepts under study. If this is done, a large demonstration unit could be operating by early 1976, and the first large commercial units could be in operation in established bituminous coal fields by 1978 (letter of 4/25/74) or prior to 1980 (letter of 4/15/75).

Response:

A summary of the fluidized-bed combustion concept is presented in Section 6A.1.2.3 of the Final Statement, where it is indicated that technical feasibility has been demonstrated, that the process can utilize low-grade coals, that the potential for large reductions in SO_x and NO_x emissions is significant, and that pressurized systems may achieve thermal efficiencies of 45%. As far as electrical-energy generation is concerned, an additional major advantage, relative to conversion of coal to fuel oil or to power (low-Btu) gas, is that the cycle (coal mine to bus bar) efficiency is significantly improved by avoiding the inefficiency of converting coal in alternative fuel processes, which is typically about 30%.

Work in this area is active and rapidly accelerating. The Subpanel V report, titled "Coal and Shale Processing and Combustion Energy R&D Report," October 27, 1973, prepared as a contribution to WASH-1281 (ref. 47 of the Draft Statement), notes the following:

- a. This program is one of the major alternatives.
- b. Such boilers will meet all environmental standards.
- c. Projected ultimate thermal efficiencies are promising: 40% (atmospheric system) and 47% (pressurized system).
- d. The U.S. balance of payments would be improved in the likely event that this technology were exported to foreign countries, especially those with poor quality coal reserves.
- e. Limestone and dolomite for sulfur acceptance during combustion of high-sulfur coals is available in large quantities through most of the U.S.
- f. Federal funding involvement is necessary, and an "accelerated/ orderly program" was estimated to require (through Fiscal Year 1980) a total of \$368 million, which would probably lead to full commercial availability in 1981.

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- g. Developed fluid-bed boilers should capture at least 25% of the market for new coal boilers; this rate of implementation would result in minimum installed capacities of 3000 MWe in 1985 and 40,000 MWe in the year 2000. Using a common-basis costing procedure, it was estimated that for a 600 MWe plant operating at a 70% load factor, the capital cost and electrical energy generating cost of a fluid-bed boiler plant would approximate 85% and 93%, respectively, the corresponding costs of a conventional-boiler power plant.
- h. The primary barriers to implementation are: sorbent regeneration and sulfur recovery, for the system variants involving regeneration; demonstration of high-temperature, high-pressure particulate-removal technology for pressurized systems; and demonstrating the operability on a large scale of the integrated boiler systems.

A National Fluidized Bed Program has been established in the Office of Coal Research (Dept. of the Interior). Because of its concern with SO_x and NO_x emissions control, the E.P.A. recommended a Fiscal Year 1975 ^x program in this area totalling \$9.75 million. In addition, the Interior Department's Office of Coal Research recommended for Fiscal Year 1975 a sum of \$34.0 million for its Direct Boiler Combustion Program. This program includes development of atmospheric fluidized-bed boilers (ultimately to 800 MWe), of pressurized fluidized-bed boilers (to 500 MWe), and supportive laboratory and process-development-unit research. The total funding for Fiscal Year 1975 should, therefore, be 43 to 44 million dollars, an increase of about 140% beyond the FY 1974 total of \$14.2 million. In addition, the Interior Department (Energy Research Program of the U.S. Department of the Interior Draft, February 1974) projects a total funding requirement in the subject area for the next five years (FY 1975 through FY 1979) of \$342.4 million. This funding, if provided, compares favorably with the \$368 million recommended by Subpanel V for an "accelerated/orderly program" through FY-1980.

We are in essential accord with your comment and feel that the program plan recommended will lead to fluid-bed boiler power plants becoming an important contributor to the Nation's electrical power generation capacity in the 1980's, though probably three to four years later than suggested in your letters. This does not imply that other energy generation systems, including nuclear fission reactors, will not also be needed.

9. Comment:

"The important thing in this cost-benefit analysis is that it can be completed in detail on a year by year basis so that each assumption and each conclusion can be reviewed, alternates considered and the optimum

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mix determined. ...The internal rate of return should be calculated for each program from the complete stream of costs and benefits for each year in the period from 1974 and 2020."

Response:

The AEC LMFBR Program is reviewed on a regular basis by the Office of Management and Budget and the Joint Committee on Atomic Energy. Detailed cost-benefit analyses of the LMFBR Program have been prepared.* The Final Statement, which also includes cost-benefit studies, contains the rate of return (~ 15%) for the LMFBR Program under base conditions in Section 11.2.3.3.3.

*1. USAEC - Cost-benefit Analysis of the U.S. Breeder Reactor Program
WASH-1126 (April 1969).

2. USAEC - Updated (1970) Cost Benefit Analysis of the U.S. Breeder Reactor
Program WASH-1184 (January 1972).

April 21, 1974
 HARVARD UNIVERSITY
 THE BIOLOGICAL LABORATORIES
 16 DIVINITY AVENUE
 CAMBRIDGE, MASSACHUSETTS 02138

Assistant General Manager for Biomedical and Environmental Research and Safety Programs
 U. S. Atomic Energy Commission
 Washington, D. C. 20545

Dear Sir,

I have been examining the Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor Program, and I have the following comments to offer.

The several volumes of the draft statement offer an impressively wide range of information on the LMFBR and on alternative forms of energy production, present and potential. However, in my opinion, the information is so presented as to be slanted in favor of the LMFBR and against possible alternatives. In fact the fast breeder is by far the most hazardous, and the most potentially polluting, means of producing energy on a large scale, among all the possibilities that are open to us. My own primary concern, as a medically trained biochemist, is with the enormous toxicity of plutonium. There is universal agreement that it is one of the most toxic substances known. Moreover the recent report by Arthur R. Tamplin and Thomas B. Cochran on "Radiation Standards for Hot Particles" (Natural Resources Defense Council, Washington, D. C., Feb. 14, 1974) produces strong evidence that the present tolerance standards for plutonium and other similar alpha emitters are far too permissive. They claim that the maximum permissible lung burden should be reduced by a factor of 115,000. I would not claim competence to pass any judgment on this exact figure, but the evidence that extremely small hot particles have a significant possibility of inducing cancer in a small region of lung (or other) tissue immediately surrounding the particle seems to me highly persuasive. More research is obviously needed, but the wise course, in the absence of definitive information (which will take a long time to obtain) is to assume that the danger is very real, and make our standards of radiation exposure much more strict accordingly.

A liquid metal fast breeder reactor of about 1000 MWe capacity will contain something of the order of a ton of plutonium-239. The potential cancer-inducing dose, for inhaled particles (probably in the form of PuO_2) may be of the order of a microgram. It is therefore obvious that the plutonium in the reactor must be kept rigorously out of contact with the outside world, and especially with the biosphere. Furthermore this must be true, not only while the plutonium is in the reactor, but throughout its transportation to and from the processing and reprocessing plants, and during the long period, of the order of hundreds of centuries, that will be required for the storage of radioactive wastes. Since the half life of plutonium-239 is approximately 24,000 years, and since safe storage must be over a period of at least 20 times the half life, the required period is around half a million years. This is of the order of a geological epoch; two or three periods of extended glaciation, and of subsequent retreat of the glaciers, have been experienced by the earth during the last half million years. The fact is that the problem of storage of radioactive wastes is still unsolved; there have been many proposals, but none that is really safe or satisfactory, even for the periods of about 700 years that would be required for storage of radionuclides such as strontium-90. I consider it irresponsible to plan a huge system of future nuclear fission power plants, when the problem of storage of wastes is still unsolved, and there is no real solution in sight.

Apart from storage, the problems of safe transportation of materials rich in plutonium involves all sorts of hazards. These are discussed in the draft environmental statement, but they are played down in a manner that I consider deceptive. The hazards are of two general kinds: (1) ordinary human carelessness, and (2) theft and sabotage. As to (1) I think it is only realistic to figure on a substan-

To Assistant General Manager, A.E.C.

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tial amount of carelessness and error in the handling of these materials. If many hundreds, or perhaps a few thousands, of breeder reactor power plants come into operation within the next fifty years, as the A.E.C. envisages, tens of hundreds of thousands of people are going to be involved in shipping, handling, and storing these materials. Some of these people are going to make mistakes, and as the operation gets larger and comes to seem more like a matter of routine, the number of mistakes will gradually increase. Last year more than 115,000 gallons of highly radioactive material leaked out of one of the storage tanks at Hanford, and the leak was not discovered for more than 50 days. There had been other serious leaks at the Hanford plant before that. If this sort of thing can happen now, when the development of nuclear energy is still in an early stage, how many such errors can we expect if the program is a hundred fold larger than it is today. To err is human, but when the errors involve leakage of plutonium they become simply intolerable.

As to point (2) above, I believe that the hazards of theft and sabotage are very great; far greater than the Draft Environmental Statement admits. We live in an era of war and violence. Sabotage of an intact nuclear power plant may be difficult to carry out, but bold and determined fanatics, who are willing to sacrifice their lives, can accomplish destruction under circumstances that would seem inconceivable to most rational people. The Arab terrorists who recently killed 18 people in a northern Israeli town, and knowingly sacrificed their own lives in doing so, are I believe forerunners of many other similar people, some of whom will direct their hostility against the United States. Furthermore some of them will have the ability and determination to train themselves highly in the necessary technical skills that will enable them to deal with the special problems involved in attacking nuclear power plants.

The dangers of theft of plutonium during shipment will also be extremely serious. The plutonium from a breeder reactor will be much more enriched than in reactors of the type currently in use, and it could be made into weapons grade material with only a moderate amount of chemical purification. I am certainly no expert in this field, but I know that some physicists who are experts are very worried indeed about the possibility of theft of plutonium, followed by clandestine manufacture of nuclear weapons. If this prospect is real, it is indeed appalling.

Finally I think that the draft Environmental Statement, although it gives a great deal of information about alternative forms of energy production, tends to play down their significance and promise in an unjustifiable way. In spite of all its drawbacks, coal can provide for our energy needs for quite a long time to come. Its mining and its use must be subject to much stricter environmental safeguards than in the past; this will raise the price of coal substantially, but we must be prepared in any case for a rise in the cost of energy in the years to come. While relying temporarily on coal, as well as what oil remains, we should push ahead with the utmost vigor on development of nuclear fusion, solar energy, geothermal energy, and other techniques that are less polluting than nuclear fission. We should also institute a far reaching program of energy conservation, and efficiency in the use of energy. The breeder reactor should probably continue, as one research project among many; but its widespread use on a commercial basis should be considered only a last, rather desperate resort, that we might fall back on if all else fails. I do not believe for a moment that all else will fail.

I enclose the page proofs of an article on the hazards of nuclear fission power that I have written for a new international journal "Environmental Conservation". It deals in more detail with some of the points I have discussed in this letter.

Yours sincerely

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I apologize for my personal typing in this letter. I am about to leave for Europe and had to type it while my secretary is away.

Hazards of Nuclear Fission Power and the Choice of Alternatives

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ENERGY NEEDS AND NUCLEAR FISSION

Power from nuclear fission has been widely regarded as the chief future source of energy. The progressive depletion of the world's supply of oil, and still more of natural gas, is now in sight; and the continued utilization of coal on a large scale presents formidable technical and ecological problems. These issues have been sharpened by the partial cut-off of oil supplies to Europe and the United States from the Arab countries in October and November 1973. Voices urging a rapid development of nuclear fission power are becoming more numerous and urgent. At the same time, those who are primarily concerned with human health, and with the protection of the environment from contamination, are increasingly alarmed by the hazards of pollution from nuclear fission. The conflict has become particularly acute in the United States, where the *per caput* consumption of energy is far higher than anywhere else in the world, but similar issues are soon bound to arise in other countries.

People who stress the need for a vast programme of nuclear fission-plants, for example in the United States, point out that the consumption of electric power in that country has been doubling every decade for the last 30 years. They forecast a continued doubling in each of the two coming decades, regard this increase of power consumption as an essentially irresistible trend, and claim that nuclear fission is the only agency capable of meeting the need. Their opponents claim that the hazards of large-scale nuclear fission operations are intolerable, that there are other forms of energy production—solar energy, geothermal energy, and quite likely nuclear fusion—that could be developed to supply needed energy with far less pollution than nuclear fission would involve. They also point out that the people of the United States use energy with great extravagance, and that the use of energy can be substantially reduced, in many ways, without the sacrifice of vital needs.

I belong to the latter school. I shall argue here the case against building more nuclear fission-plants, and in favour of energy conservation and the development of alternative sources of energy. I shall try to make no claims that are not justified by known facts; but the reader should be aware, from the beginning, of my point of view.

Eminent scientists are to be found on both sides of this controversy. Thus Glenn Seaborg (as indicated by his statements while he was Chairman of the U.S. Atomic Energy Commission) favours the building of nuclear fission power-plants as a major source of energy; Hannes Alfvén (1972) opposes it. Ordinary citizens ask how it is possible for supposedly objective scientists to draw opposite conclusions from the same set of facts. Some people have learned to distrust science, and scientists, because of such disagreements, but in doing so they misunderstand the nature of the problems.

A decision on building nuclear power-plants cannot be made intelligently without the knowledge of a great many scientific facts, but it is essentially a political and social decision. The range of relevant facts is enormous; it encompasses not only data from physics, chemistry, biology, engineering, and meteorology, but also other less 'hard' data from the whole realm of human history and experience. Reliable scientific data are essential for making wise decisions, but the relative importance of different categories of facts is a matter of judgment, where honest men can differ passionately.

My own judgment concerning the hazards of nuclear power is deeply influenced by my general estimate of human nature and behaviour, and by my reading of history. People have to operate nuclear power-plants, no matter how much automation we introduce. People are forgetful, often they are irresponsible, and quite a few of them suffer from deep-seated irrational tendencies to hostility and violence. One need not be a student of psychoanalysis to be aware of these facts; one need only read the newspapers.

Also, as a student of history, I am haunted by the long record, extending over centuries and millennia, of the rise and fall of human societies, and of the collapse of social orders that had seemed stable and enduring—resulting in the periodic recurrence of dark ages in which the level of technology declines and communication between different parts of the world declines with it.

I believe that the confident advocates of the safety of nuclear power-plants base their confidence too narrowly on the safety that is possible to achieve under the most favourable circumstances, over a limited period of time, with a corps of highly trained and dedicated personnel. If we take a larger view of human nature and history, I believe that we can never expect such conditions to persist over centuries, much less over millennia.

THE FAUSTIAN BARGAIN

One of the ablest and best informed advocates of the nuclear fission power programme, Alvin Weinberg, Director of the Oak Ridge National Laboratory, has stated our choices in terms of what he calls a 'Faustian bargain' (Weinberg, 1972). Mankind can receive an unlimited supply of energy from nuclear fission, which, he says, 'when properly handled is almost non-polluting.' In return for this great gift we must maintain incessant vigilance to guard against leaks and accidents, and we must maintain 'longevity of our social institutions' to a degree that is probably unparalleled in history. Weinberg believes that we should accept the bargain. I hold, on the contrary, that this, like the original bargain made by the legendary Dr Faustus, is a pact with the Devil, and that we should resolutely refuse it (Edsall, 1972).

Use of nuclear fission energy involves a vast complex of operations—the mining of uranium, its chemical purification, the installation of the fuel rods in the reactor, and the safety precautions in the design and operation of the reactor itself; also the periodic removal of the intensely radioactive fission products from the reactor, their transportation by rail or truck to a reprocessing plant, and finally their storage. This storage has to be in suitable containers and in places where it is supposed that they can be safely left for periods of the order of 100,000 years, out of all contact with human or other forms of life. I shall point out below that there is no evidence that such places in fact exist. The hazards to mankind lie not only in possible leakage from the operating reactors themselves, or in the small but definite possibility of a catastrophic release of radioactivity; the hazards exist all along the line, from the initial mining of the uranium to the final—if indeed it is final—disposal of the envisaged huge quantities of radioactive waste.

THE BIOLOGICAL AND MEDICAL HAZARDS

Before discussing these various operations, consider what we know of the biological hazards of nuclear radiation. The upper extreme limits of exposure, for a nuclear fission power-plant, would be represented by a catastrophic release of a large fraction of the total radioactive material in the reactor. This is generally considered an extremely improbable but by no means impossible event, of which more is to be said later in this article. A study made for the U.S. Atomic Energy Commission (1957) attempted in great detail to estimate the possible effects of such an accident, for a reactor producing 500 megawatts of thermal energy. The accident was estimated, under the worst circumstances, to lead to the deaths of some 3,400 people, and injury to as many as 43,000. Property damage, it was estimated, could run as high as seven thousand million (7×10^9) dollars, and there might be some restrictions on the use of land and crops, for variable periods, over areas which might be as great as 150,000 square miles (380,000 km²). We should note that the reactors now being planned are approximately six times as large as the one for which these calculations were made. Fortunately, no such accident has yet occurred, and all estimates of the magnitude of such disasters are no more than informed guesses. If such an accident did occur, however, it would presumably rank among the major disasters in the history of mankind.

At the other extreme we must consider the biological effects of low-level radiation, below or near the level of the natural radiation background to which we are all exposed. The most authoritative report on the effects of such radiation is probably that of a committee of the U.S. National Academy of Sciences, known for brevity as the BEIR Report (1972). The natural background radiation exposes an average inhabitant of the United States to about 100 millirem per year (mrem/yr),* of which somewhat less than half is due to cosmic rays. Persons living at high altitudes, as in Colorado, may receive natural doses twice as large as those at sea-level, or more.

At present the chief exposure to man-made radiation is from medical and dental x-rays. In the United States, where such uses are common, average exposure from this source may be two-thirds of that from the natural background. The importance of restricting such medical uses to essential purposes, and of carefully shielding all parts of the patient (especially the gonads) (apart from those that are actually being examined by

* The rem is a unit of dose equivalent. It is closely related to the rad, which is defined as a unit of absorbed dose equal to 0.01 joule per kg in any medium. To convert rads to rems one multiplies by certain factors depending on the relative biological effects of various types of radiation, but for present purposes we can treat the rem and the rad as roughly equivalent.

x-ray) is obvious; but this important point is only incidental to the problems that concern us here.

The BEIR Report (1972) discusses three major types of damage that arise from radiation—genetic damage, from gene mutations and chromosome aberrations; induction of cancer; and damage of various sorts during the early stages of development, to which the foetus and the young child are particularly susceptible. The Report, in accord with the judgment of the great majority of experts today, concludes that we must assume that there is no threshold value below which radiation does no biological damage; even the smallest increment of radiation in the environment must be expected to increase the statistical probability that a person exposed to it will suffer genetic damage, or develop cancer, or both. Direct experimental proof of this proposition is virtually impossible, as the expected effects are so small at very low radiation levels. Impossibly large populations would have to be studied, at very low levels, to obtain statistically significant results. Thus in practice by extrapolation we calculate the effects at very low levels from the observed effects at higher levels.

The BEIR Report concludes that the doubling dose for genetic abnormalities in Man probably lies in the range between 20 and 200 rem; that is, a lifetime dose of this order of magnitude, applied to the whole human population, would double the number of genetic abnormalities arising from all causes, including the natural background radiation. The present official limits for human exposure, as set by the Federal Radiation Council, are 170 mrem per year, or a total of 5 rem for a 30-years reproductive period. If the whole reproductive population of the U.S.A. (assuming 3.6 million births per year) received this dose, the report estimates that, at equilibrium after several generations, there would be between 500 and 9,000 additional serious, dominant, or x-linked, diseases and defects per year. There would also be between 1,100 and 27,000 additional cases of congenital abnormalities and constitutional diseases that are partly genetic; and there might be an increase, of the order of 5 per cent, of general 'ill health' in the population.

All these estimates, as the BEIR Report is careful to point out, are highly uncertain, being based largely on extensive studies on mice, with the tentative assumption that mice and Men are not very different in their sensitivity to radiation. Moreover, at the present time, our exposure to man-made radiation (apart from medical x-rays) is far below the 'allowed' figure of 170 mrem/yr. The report estimates it as about 4 mrem/yr from global fallout due to weapons testing, and as about 0.003 mrem/yr from present nuclear power-plants. With respect to radiation-induced cancer, the BEIR Report estimates that additional exposure of the U.S. population to 5 rem over a 30-

years period could cause an additional number of deaths from cancer of the order of 3,000 to 15,000 annually. Earlier, J. W. Gofman & A. Tamplin, in a series of articles (cf. 1972), had come to a similar conclusion, but had predicted a much larger number of additional deaths from the increased radiation; they estimated at least 30,000 and possibly as many as 100,000 deaths annually. Some scientists, and others, sharply criticized them at the time for claiming that such an effect existed at all; but the careful calculations of the BEIR Committee support their argument qualitatively, even though estimating a much smaller number of deaths.

Two things should be said, to avoid misunderstanding. The allowed total of 5 rem over a 30-years period, for man-made radiation apart from medical x-rays, is far above what people are receiving today, as pointed out above. Even if radiation levels rose, so that an appreciable fraction of the population were getting as much as this, the average exposure for the entire population would still be considerably less. On the other hand, any rise of radiation levels, even a very small one, will mean that some people will die of cancer who would not otherwise have died, just as the descendants of some people, who might otherwise have been normal, will suffer genetic damage. The effects will be detectable only statistically; we shall not be able to say 'This man (or woman or child) died because of the added radiation from such-and-such a nuclear power-plant.' Nevertheless we must face the fact that we are paying with human lives for whatever benefits we get from the source of the radiation. How do we strike a bargain, to equate the costs that we must pay with the benefits we get? This question is raised explicitly in the BEIR Report, whose authors conclude that an answer is far beyond their scope or competence. They urge, however, convincingly, that no increase in radiation levels is acceptable unless it can be shown unequivocally to yield benefits that justify it.

Dr E. J. Sternglass (1972 a), of the University of Pittsburgh, has claimed the existence of increased infant mortality in the neighborhood of nuclear power-plants, particularly in the directions (towards which the prevailing winds blow. There is indeed general agreement that the foetus and the very young infant suffer far more than the adult from a given dose of radiation; but a number of authors have sharply criticized the statistical evidence that Sternglass has presented. Some of the critics—see, for instance, Tompkins *et al.* (1972)—have produced data on infant mortality around several nuclear power reactors that are apparently in direct conflict with the views of Sternglass. Many arguments, with some further data, are presented in the papers and the discussions in the same volume of Le Cam *et al.* (1972). My own view is that Sternglass has not as yet made out a convincing case,

but that his contentions are sufficiently disturbing to call for careful further study by statistical methods and other forms of inquiry. As the following discussion indicates, I agree with the conclusion that the building of large numbers of nuclear fission-plants represents an unacceptable hazard for the future of mankind, even if we are to dismiss completely the evidence presented by Sternglass.*

Thus the operations of nuclear fission reactors present us, on the one hand, with the possibility of occasional catastrophic accidents, in which thousands, or hundreds of thousands, of people might be exposed, over a short time, to fatal doses of hundreds or even thousands of rems. On the other hand, as the number of nuclear fission-plants multiplies—the Atomic Energy Commission (AEC) contemplates the proposal that some 2,000 will be in operation in the United States alone by the year 2020—the total leakage of radioactivity may reach substantial levels, for which the people and other living organisations of the world will have to pay in increased deaths and disabilities. The risk that we shall have to pay a heavy price depends, not on the best performance of the most carefully shielded reactors under ideal conditions, but on the average performance of this prospective vast array of reactors, managed by fallible and sometimes careless operators, and subject to the hazards of sabotage and war.

THE FIRST STEP IN THE SEQUENCE: URANIUM MINING

Consider the first event in the total sequence of events in the production of fission power—the mining of uranium, and its residual products. Uranium miners are known to suffer from an increased risk of lung cancer from inhaled radon (for a critical evaluation see the BEIR Report, 1972); they are engaged in a hazardous occupation. After the preparation of purified uranium oxide from the ore, there remain great quantities of radioactive liquid wastes, as well as solid 'tailings.' In the Colorado River basin, for at least a decade in the 1950s, the liquid wastes were simply dumped into the streams that fed into the Colorado River. Thus the inhabitants who lived downstream were subjected to 2 or 3 times the officially permissible dose of radium (the dose limit set by the International Committee on Radiological Protection). As to the solid tailings, Holdren & Herrera (1971) stated that, at the time their book was written, some 30 million tons of tailings had accumulated; those at abandoned mills alone contained enough

radium to exceed, by a considerable margin, the maximum permissible body content of radium for every person on Earth. Most of the piles of tailings were beside rivers and streams, where they could wash into the flowing water. By an almost incredible blunder, some 3,000 houses in Grand Junction, Colorado, were built on land-fill and concrete made up of such radioactive tailings. The facts were not publicly revealed until 1970; for years before that, and since, the people of Grand Junction were breathing radon derived from radium (half-life 1,620 years) in the land-fill below their feet (Holdren & Herrera 1971).

This shocking episode was presumably not due to conscious criminal intention on the part of anybody; it was simply a manifestation of human carelessness and irresponsibility. Possibly some of the contractors knew what risks they were imposing on the people of Grand Junction, but chose to disregard them in order to increase their profits; but one need not make such accusations. Throughout history the operators of every type of technology have made disastrous mistakes from time to time; bridges collapse, trains collide, and airplanes crash, from sheer blunder and miscalculation—or from shoddy design. The people who built the mine tailings into the city of Grand Junction were guilty of the same human failings that have plagued mankind from the start. The difference lies in the potential magnitude of the consequences; if a few dozen, or a few hundred, people die in a plane crash, that is a tragedy; but it is a mere ripple in the onward flow of the affairs of mankind. If increased radioactivity permeates the environment, however, all mankind will have to pay the price, in increase of deleterious mutations and hereditary abnormalities, in increased cases of cancer, and in defects of development.

Certainly, in the handling of the liquid wastes and the tailings from the uranium mines, the dedicated supervisory priests whose watchful presence, according to Weinberg (1972), should be essential for prevention of damage, were in fact conspicuously absent. The nuclear scientists and engineers, who had so devotedly worked to develop safeguards for reactors and for many aspects of the nuclear industry, had not watched with comparable care over the mines and their products.

HAZARDS OF PRESENT NUCLEAR REACTORS: HEARINGS ON EMERGENCY CORE-COOLING SYSTEMS

A modern type of reactor may develop some 3,000 megawatts of thermal, or 1,000 megawatts of electrical, power. The corresponding level of radioactivity is of the order of 1.2×10^{10} curies, where 1 curie denotes 3.7×10^{10} nuclear disintegrations per second. These quantities are so huge that the radioactivity must be

*The book by Sternglass (1972b) describes his views and the controversies in some detail. I note it here, partly because it was the occasion for a very interesting and thoughtful review by Hoffman & Inglis (1972).

rigidly contained within the reactor system; even the escape of as little as one tenthousandth (0.01 per cent) of this amount to the outer environment would represent an unacceptable risk. It is of course supremely important that no major accident should occur in such a reactor. It could occur if the circulating cooling water were lost, so that rising temperatures in the intensely radioactive core would lead the whole structure to melt and collapse. This would probably lead to the release of intolerably large amounts of radioactivity. The AEC therefore requires that emergency core-cooling systems be installed on all reactors, to prevent such disasters.

Serious questions have been raised, however, concerning the safety of these systems, and these led to extensive hearings, beginning in January 1972, before a Hearing Board appointed by the AEC itself. Sixty citizens' groups, known as the Consolidated National Intervenors (CNI), raised questions concerned with reactor safety; and the Union of Concerned Scientists, of Cambridge, Massachusetts, served as the technical arm of CNI.

The hearings, the transcript of which ran to some 20,000 pages, centred on the safety and adequacy of the emergency cooling systems. The testimony at the hearings raised some extremely disturbing questions concerning reactor safety. These have been set forth particularly by Daniel F. Ford & Henry W. Kendall, of the Union of Concerned Scientists—first in a short article (1972), and then in a much more detailed report (1973). The hearing record shows clearly that some of the best-informed experts—for instance Dr William B. Cottrell, Director of the Nuclear Safety Program of the Oak Ridge National Laboratory; Dr P. L. Rittenhouse, who was in charge of the AEC's Fuel Rod Failure Program; and Dr Morris Rosen and Mr Robert Colmar, of the AEC Regulatory Staff—had grave reservations concerning the safety and reliability of the emergency corecooling systems in their present state. They expressed these concerns in their testimony, in spite of written instructions from the AEC to its witnesses to 'never disagree with established policy' (Exhibit 1013 of the hearings, quoted by Ford & Kendall, 1973). Dr Rittenhouse indeed 'read into the record the names of 28 individuals whose reservations concerning emergency core-cooling performance had influenced his own views concerning the serious unresolved problems in this aspect of reactor safety technology' (Ford & Kendall, 1973).

Moreover, extensive as the hearings were, the Hearing Board arbitrarily refused to hear testimony on matters that would appear to be highly relevant. Thus, they prohibited testimony concerning the possible causes of loss-of-coolant accidents, on the somewhat peculiar ground that, once the Commission had *postulated* the occurrence of such an accident,

consideration of causes was irrelevant. Likewise they refused to consider testimony on the probability that such an accident might occur, or concerning the possibility that the reactor system might fail in a manner different from the mode postulated by the AEC. For instance, the possibility that an accident might occur because of the failure of the reactor pressure vessel was ruled out from consideration as being (presumably) inconceivable, although it seems clearly a conceivable possibility. (Concerning these matters, see Chapter III of Ford & Kendall, 1973.)

This is only a much-abbreviated and incomplete statement of the many disturbing issues that emerged from the hearings. (Other disturbing aspects of the nuclear safety programme are discussed by Gillette (1972).) At the time when this article was submitted (November 1973), the AEC had announced no final decisions concerning the issues raised at the hearings. There are powerful forces, in Government and in industry, pressing for the rapid development of nuclear power-plants, and they are reinforced by the current sense of urgency for the development of new energy sources, due to the cut-off of oil from the Arab states to Europe and the United States. Nevertheless the AEC will fail in its responsibilities if it disregards the apparently grave deficiencies in the present emergency core-cooling systems, and proceeds to license reactors in haste.*

In any case, even if the emergency cooling systems could be shown to be adequate, fission reactors are dangerous. As the number of reactors increases, with a resulting great increase in operating personnel, the quality and sense of dedication of the operators is likely to decline; the number of leaks will surely increase, and the world-wide level of radioactivity will slowly rise. Virtually every form of technology has gone through periods of slow decline, as its operations have become routine and the operators have become careless or complacent. In the United States we have witnessed such a decline in the operation of our railroads over the last quarter-century. In periods of war and social disintegration, such disintegration of advanced technology may be far swifter and indeed catastrophic. Nelson Glueck (1960), for instance, has described the superb systems of water-use and conser-

* In late November 1973 the Union of Concerned Scientists released a detailed report (Ford *et al.*, 1973) on the nuclear fuel cycle and its hazards. In a press conference they, together with consumer advocate Ralph Nader, strongly criticized the AEC for what they considered its grave disregard of safety considerations in the development of nuclear fission. This brought a sharp reply from the new chairman of the AEC, Dr Dixie Lee Ray, who was quoted as saying of these critics: 'They have used innuendo and inaccuracies to build a case against nuclear power, largely on emotional grounds. We do not believe that the people will be fooled' (quoted in *Newsweek*, 10 December 1973, p. 138). This seems a pretty clear indication that the AEC intends to pursue its course in building nuclear fission-plants, regardless of the warnings of its critics.

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vation developed by the Nabateans, and continued by the Romans, in the Negev desert, and the collapse of this technology with the disintegration of the Roman empire. Nuclear technology is not immune to such future disintegration; and the effects of such a decline will not be merely local, as with the water of the Negev, but may liberate radioactivity so as to imperil mankind in general.

THE BREEDER REACTOR AND ITS DANGERS

It is proposed to replace the present uranium water reactors by fast breeder reactors which are hailed by the AEC as the great hope of the future. The breeder reactor seems at first sight to be a bargain, as it produces more fuel than it consumes, and holds out the prospect of providing mankind with practically unlimited supplies of energy; but its prospective dangers are immense. The proposed breeder would have a power density of the order of 400 kilowatts per litre—10 to 12 times that of the light water reactors now in operation. This heat-flux is to be carried off by molten sodium, flowing through the core at about 5 cubic metres per second, and emerging from the core intensely radioactive and at a temperature near 550 °C. The core of such a reactor is to contain about a ton of plutonium-239, one of the most toxic substances known, which is powerfully carcinogenic even in minute doses and persists with a half-life of 24,000 years.

The hazards of the present reactors will be multiplied many-fold in the breeders; an explosion in a fast breeder could make thousands of square miles uninhabitable for many years, and could endanger the lives and health of millions of people. Yet the AEC has proposed that as many as 2,000 such breeders may be built and in operation in the United States by the year 2020. As is pointed out in a searching critique by Lovins (1972), the projected breeder system by 2020 would require *daily* 100 railway cars loaded with casks of spent fuel, on their way to and from reprocessing plants (see also Tinker, 1973). The radioactivity of the spent fuel at the time of shipment from the reactor site, after a cooling-off period of 30 days, would be some 500 million curies for the fuel of a single reactor. The risks of accident during shipment, between the reactor and the processing plant, add another alarming dimension to the problem of nuclear safety.

THE DISPOSAL OF RADIOACTIVE WASTES

There is, in fact, no safe place known for the storage of the radioactive wastes that are produced in such huge quantities by reactors of the present type, and

will be produced, as indicated above, by the proposed breeder reactors. To achieve a safe period of storage, one must place these materials where they will be out of contact with mankind, indeed with the living world in general, for a period of the order of at least 20 half-lives of the radioactive material. For Plutonium-239, with its halflife of 24,000 years, the required period of storage is roughly half-a-million years. This is of the order of a geological epoch; the last glacial period, which buried much of Northern Europe and North America under ice, came and went in a far briefer time. How can we give assurance of safe storage, even for a few centuries, much less for half-a-million years?

In 1971 the AEC believed it had found such a safe place in underground salt-mines in Kansas, supposedly free from leakage of water and contact with the outside world. Within a year, geologists had shown that in fact the region was full of holes, and certainly was not safe for storage. The AEC then abandoned the plan, and no satisfactory alternative has yet been proposed.

Fantastic suggestions have been put forward. In 1972 James Schlesinger, then Chairman of the AEC and now Secretary of Defense in the U.S. Government, suggested in a speech that we might get rid of radioactive wastes by shooting them off in rockets to the sun. He did not say what would happen if some of them fell back to Earth by mistake, nor did he estimate the consumption of energy and of material for the rocket casings that this would involve. Others have suggested burying the radioactive wastes in the ice of Antarctica, where their heat would cause them to melt their way down until they hit bottom (Zeller *et al.*, 1973); but in fact we do not know what will happen to the ice of Antarctica over the next half-million years, and must regard the safety of the scheme as highly dubious. Actually, there is as yet no proper solution to the problem of radioactive wastes, and there is none in sight. To urge a huge development of nuclear fission reactors, when this problem remain unsolved, seems to me highly irresponsible.

HAZARDS OF THEFT AND SABOTAGE

Apart from the ever-present dangers of accident and carelessness, the fissionable material in these reactors, and that contained in the shipments of radioactive wastes, is vulnerable to theft and sabotage. We live in an era of violence, war, and widespread revolutionary activity; there is no indication today of the 'longevity of social institutions' that Weinberg (1972) postulates as an essential component of the 'Faustian bargain.' The recent wave of aerial hijackings was terrifying to many people, but its hazards are trivial compared with the potential dangers involved in the

reverse the order
"the reprocessing plant and the power station"

possible placing of explosives by spies within a nuclear fission-plant; a well-placed charge of explosives, in the midst of one of these huge concentrations of radioactive material, could blow into the air enough radioactivity to be carried over many thousands of square kilometres and perhaps render large areas uninhabitable for decades, if not for centuries. Moreover, the opportunities for theft of fissionable material in transit between the power station and the reprocessing plant are enormous.

The temptations to theft will be particularly strong if the breeder reactors come into operation. The concentration of plutonium, in the material of the breeder reactors, will be sufficiently high to allow its conversion into plutonium of nuclear weapons' grade by relatively simple techniques. Thus the hazard involved in the spread of nuclear weapons to the countries not now possessing them would be greatly increased. This and other related hazards have been pointed out already by several authors; they are well summarized in a recent article by Ralph E. Lapp (1973).

In short, by developing a large-scale system of nuclear fission-plants, we shall be giving hostages to terrorism. The advocates of the construction of these plants see them as being managed in an ideal world, what Alfvén (1972) has called 'a technological paradise.' Like Alfvén, I see the real world as a very different place, in which we must allow not only for human carelessness, but for the irrational violence that is always present as an element in human nature, and is displayed by some people in extreme and uninhibited form. I would consider it highly irresponsible to make plans based on the assumption that everybody will behave rationally. One need only look at the Near East today, at south-east Asia, or at the situation in Northern Ireland, to realize the intensity of irrational violence which may break out anywhere at any time.

Some people may wish to believe that the very fear of such disasters may cause mankind to become sober and careful. Weinberg (1972) illustrates this point by the example of the dikes of Holland, which must be perpetually guarded and maintained, generation after generation, to preserve the country from flooding. This very example, I believe, refutes his argument. In the closing months of the Second World War, the retreating Germans unhesitatingly destroyed much of the dike system, with consequent flooding and devastation which took years to repair. Likewise the dikes in North Vietnam, which are equally vital for the security of the country, were repeatedly bombed by United States' planes in the summer of 1972. Although the government of the United States stated that the bombing of the dikes was accidental, the dikes were not treated as being off-limits to the bombers. These examples offer little or no hope that the contending forces in a future war would refrain from attacking

nuclear fission plants in the enemy country, and thereby releasing vast quantities of radioactivity.

ALTERNATIVE SOURCES OF ENERGY, AND MODES OF ENERGY CONSERVATION

What, then, shall we do about the 'energy crisis'? In so far as a crisis exists, it has come about primarily because people chose to ignore the facts about the steady depletion of our energy resources. Experts have warned for years that the world's supply of oil was shrinking, but nearly all policy-makers chose to disregard the warnings. Coal supplies are still available, in quantities that would last a few centuries at the present rate of consumption. However, the deep mining of coal is expensive and hazardous to the miners, and surface stripmining ruins the environment—unless expensive steps are taken to restore the mined land to good condition. Moreover, the burning of coal produces pollution, unless the pollutants are removed before they escape into the atmosphere; and this, too, is an expensive process. These facts, combined with the increasing shortage of oil, have furnished the most powerful arguments for those who propose a vast programme of nuclear fission-plants. Yet the hazards of such plants, on the grounds that I have stated above, appear to me to render such a programme unacceptable. shall

There is no fully satisfactory solution to this problem. Every possible choice carries its attendant evils, and we must therefore aim at the choice that minimizes those evils, both in the near future and for generations to come. For the present we must choose, among available techniques, those that are most effective and least damaging; and we must at the same time move vigorously to increase efficiency in the use of our present energy resources. We must greatly intensify research on possible future large-scale sources of energy that are relatively non-polluting—notably nuclear fusion, solar energy, and geothermal energy. And there are other smaller but nevertheless useful ones, such as harnessing the tides, winds, and even waves of the ocean.

As to the immediate future, I believe that we must continue to rely primarily on fossil fuels—and this may mean chiefly coal—for the next twenty or thirty years. If this requires more strip-mining, there should be rigorous laws, rigorously enforced, for restoration of the land after mining, while strong anti-pollution measures should be required for factories that burn coal. Power will therefore become considerably more expensive; we should face that fact, and pay the price. The rise in the price of power will in itself compel more efficiency and economy in its use.

Numerous steps can be taken in this direction. None of the proposals suggested here is new; indeed all have been widely discussed—see, for instance, the recent paper of Hirst & Moyers (1973), and particularly the book on 'Energy and the Future' by Hammond *et al.* (1973) which gives an admirable factual survey of the present and prospective methods of energy production and conservation.

Several of the following proposals, which seemed remote to most people only a few months ago, have now become matters of urgent concern with the developing fuel crisis:

1. Consider the design and operation of all types of power-producing machinery, and redesign them in order to strive for optimum efficiency. In the days when we believed that we could spend energy freely, efficiency was often not a prime consideration. Now it is.
2. Insulate buildings better, to reduce the energy consumed in space heating, which is approximately 18 per cent of total current energy consumption in the United States (see Hammond *et al.*, 1973).
3. Increase the use of public transportation (trains, buses, etc.) to carry commuters between cities and suburbs; discourage the use of private cars, by increased taxes on fuel and by greatly increased charges for the parking of cars in the centres of cities. (A man who parks his car in a city centre is renting an extremely valuable piece of real estate.) Ban cars entirely in much of the interior of cities. This will save energy and also reduce air pollution.
4. Set a sliding scale of costs with rates charged for use of power increasing as the amount used increases. This will tend to promote both efficiency and economy. It will, as one instance, force the owners of large business buildings to turn off their lights at night, instead of letting them burn as they commonly do at present.
5. Divert to civilian purposes a large fraction of the vast amounts of energy now used to keep the arms race going. This would obviously be desirable for other reasons. This proposal may seem Utopian in the present state of the world, but it may look much more realistic within another decade or so.
6. Develop a population policy that will lead, as rapidly as possible, to zero population growth, and indeed ultimately to a slow decline of human population to a lower and more stable level than we have today. This is of course a long-term proposal. Initiation of such a policy will have no dramatic effects within the next decade or two, but in the long run it is probably the most important factor of all.*

* See the preceding paper by Professor Paul R. Ehrlich.—Ed.

PROSPECTS FOR OTHER, LESS POLLUTING, FORMS OF ENERGY

No form of energy production can be wholly non-polluting, but some are far preferable to others. If they prove feasible and adequate, nuclear fusion, solar energy, and geothermal energy, would all be much superior to the major sources of power available today.

(a) *Nuclear Fusion*: — As yet, no one can say for sure that energy from fusion will ever be commercially practicable. Nevertheless, the progress of recent years is such that expert engineers believe that the prospects are decidedly promising (Gough & Eastlund, 1971; Post, 1971; Hammond *et al.*, 1973). The funds at present going into fusion research in the United States are relatively modest. It would be a sensible gamble to increase them several-fold, at once, with further large increases to follow in the coming years. If the gamble pays off, we shall have a practically infinite source of energy, with relatively low pollution hazards; it would then render all nuclear fission-plants obsolete. If the gamble fails to pay off, we have lost nothing but some money and the time spent by some investigators. In any case, the research is likely to be a good investment; it is almost certain to yield valuable information and practical devices that will probably more than repay the cost of the investment.

(b) *Solar Energy*: — The total energy-flow from the sun is of course incomparably the largest ultimate source of energy on Earth. On a sunny day, the rate of influx of solar energy at the Earth's surface, in temperate latitudes, is of the order of one kilowatt per square metre (Glaser, 1972; Hammond *et al.*, 1973). Hitherto its employment has been limited, although it has been found useful for space-heating under suitable conditions, and this use now appears to be capable of being greatly extended. Most experts in the past have discounted the possibility of using solar energy on a large scale for the production of electrical energy, but there is now a great renewal of interest in the subject; many promising approaches are under consideration (NSF/NASA Energy Panel, 1973; Hammond *et al.*, 1973), and research on solar energy appears to deserve active support and greatly increased funding. If it can be successfully used on a large scale, it would undoubtedly be the least polluting form of energy production. We are not as yet justified in making enthusiastic claims for solar energy, but we would be grossly remiss if we did not vigorously prosecute research in this field.

(c) *Geothermal Energy*: — The heat of the interior of the Earth has been tapped in a few places, as in Iceland and in one small region of Italy, to produce

energy in a form useful for Man. It seems unlikely that it can ever provide a large fraction of our energy budget, but it can probably be tapped to a far greater extent than seemed possible until lately (Hickel *et al.*, 1972; Hammond *et al.*, 1973). It may prove to be in the end a useful auxiliary source of energy, and research in this field certainly deserves active support. The same must be ~~done~~ of some at least of the other, minor sources of energy.

True\

It seems apparent that, at least in the United States, we urgently need a National Energy Authority to study the whole field of energy production and use, to promote research in every at all promising aspect of the field, and to formulate the choices among which we must decide on the best measures to be taken for economical and efficient use of energy as well as for its large-scale production. The final decisions on those choices must of course be made by the Congress and by the people of the United States. Moreover, since the problem is world-wide and transcends all national boundaries, I believe that we shall also need an International Energy Commission, as Alfvén (1972) has suggested.

At some later period, in spite of our best efforts, it might conceivably prove that nuclear fusion, solar energy, geothermal energy, and all other techniques, will be inadequate to meet our needs. In that case we might ultimately be forced to utilize fission energy on a large scale. In view of what I have already said, I find the prospect appallingly dangerous. If mankind is to embark on such an enterprise, he should do so with full realization of the awful responsibilities it entails, for us and for hundreds or thousands of future generations. Such realization does not exist today. I believe we should hold off for at least a generation, accepting all the trouble that such a decision will involve, and make a supremely intensive effort to develop other, far less hazardous, large-scale sources of energy. The prospects for success now seem hopeful, and the survival of mankind will be far more secure if we draw our future energy supplies from these less polluting sources.

W\

SUMMARY

Nuclear fission reactors are widely regarded as the chief energy source of the future. This article holds that the hazards of such reactors, in comparison with other prospective energy sources, are unacceptably high. The biological effects of ionizing radiations, as analyzed in the recent BEIR Report (1972) of a committee of the U.S. National Academy of Sciences, are briefly reviewed; the effects include genetic mutations, induction of cancer, and developmental abnormalities. Hazards are encountered at many stages in the process

of nuclear power production: in the mining and processing of uranium, in the design and operation of the reactors, and in the handling, shipping, and storage, of the huge quantities of radioactive wastes produced by the reactors. Grave questions have been raised concerning the safety of the emergency core-cooling systems of present reactors; and the planned breeder reactors, which will contain great quantities of plutonium-239, are likely to be even more hazardous. Storage of radioactive wastes, away from all risks of environmental contamination, in order to be acceptable must be secure for about half-a-million years. No place on Earth has yet been found for which such safety can be guaranteed. Hazards of theft, sabotage, and war, are formidable threats to the future of nuclear fission power.

Use of fission power is not compulsory; present supplies of coal are adequate for two or three centuries, though its mining and use will require drastic steps to protect the environment, thereby raising costs. Alternative, and far less dangerously polluting, sources of large-scale energy production exist or can be developed: notably solar energy and probably nuclear fusion, where intensive research gives high promise of adequate systems for large-scale energy production within 20-30 years. Geothermal energy, though more limited in amount, is also promising. Great savings can also be made by reducing the extravagant use of energy, especially in such countries as the United States; and various conservation measures are indicated.

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

John T. Edsall, M.D.
Professor of Biochemistry, Emeritus
The Biological Laboratories
Harvard University
16 Divinity Avenue
Cambridge, Massachusetts 02138

Dear Dr. Edsall:

Thank you for your letter of April 21, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. AEC staff responses to your specific comments are also enclosed. More detailed information concerning your comments and concerns on Plutonium Toxicity is presented in Section 4.7 and Appendix II.G of the Final Statement.

Your letter and the attached article, "Hazards of Nuclear Fission Power and the Choice of Alternatives" express concern over the hazards of theft of materials rich in plutonium, and the hazards of sabotage of facilities or transport containing such materials. AEC safeguards have been effective in preventing such acts in the past, and, notwithstanding a possible growth in the intensity of terrorist and other illegal acts, it is believed that strengthened safeguards measures can be developed and implemented to assure the security of future commercial fuel cycles such as the LMFBR. Section 7.4 in the Final Statement has been extensively revised in response to many safeguards-related comments received. It is hoped that your careful reading of this section, as well as of the information in Section 5.4.2 on the socio-political impacts of future safeguards, will alleviate your concern.

Your interest in the LMFBR Program and comments on WASH-1535 are appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

AEC Staff Response To Comments By John T. Fdsall, M.D.

1. Comment (page 2):
Alternative Energy Sources

The significance and promise of alternative sources of energy are played down in an unjustifiable way; coal can provide our energy needs for some time.

Response:

As discussed in the "Perspectives" section of Section 6 of the enclosed Final Statement, the AEC believes that each alternative technology option has been fully evaluated and presented in an appropriate light in terms of its ability to supply significant amounts of energy in the time period under consideration. Each option is thoroughly treated in Section 6, which has been revised to reflect the comments received on the Draft Statement. Possible increased usage of coal, as suggested in the letter, is also discussed in Section 6, as are the several other technologies mentioned.

2. Comment (page 2):
Alternative Energy Sources

Other energy alternatives should be developed and a program of energy conservation should be instituted; widespread use of the breeder on a commercial basis should be considered only as a last resort.

Response:

The energy requirements of this Nation are so large and pressing that no single method currently available for meeting our needs, nor any system expected to become available by the end of this century, is completely adequate to do the job. All of the technologies often mentioned as "solutions" to the energy crisis, such as solar energy, geothermal energy, nuclear fusion, and even the breeder reactor, fall into this category. It will take the combined contributions from all these energy sources plus the more conventional systems such as fossil fueled power plants to satisfy our electricity requirements. The Atomic Energy Commission believes that the LMFBR is the most promising energy source in terms of its likelihood for providing substantial amounts of electricity in the relatively near term time period reliably, safely, economically, and in an environmentally acceptable manner. For this reason the AEC has provided substantial support to LMFBR development, but it recognizes that other energy supply systems are also required and supports their development.

The objective of the LMFBR program is to develop a broad technological and engineering base with extensive utility and industrial involvement leading to the establishment of a commercial breeder industry.

At the time this is achieved, actual deployment of the LMFBR or any other energy options then at the point of commercial usefulness will depend on the relative merits of each alternative option. The decisions on which options to use will then be made by the electrical utility industry based on the technical, economic and environmental situation prevailing at that time. As with present electrical production, it is anticipated that there will be a mix of technologies used in the future to generate power.

3. Comment (from enclosure):
LMFBR Plant Safety

The letter notes that an enclosed article deals in more detail with points in the letter. On page 33 of the article it is stated: "I believe that the confident advocates of the safety of nuclear power-plant base their confidence too narrowly on the safety that is possible to achieve under the most favorable circumstances, over a limited period of time, with a corps of highly trained and dedicated personnel. If we take a larger view of human nature and history, I believe that we can never expect such conditions to persist over centuries, much less over millenia."

Response:

The general approach towards assuring that nuclear plants are safe is summarized in Section 4.2.7.3. As is evident from this section, and other sections of the Final Statement, care is taken to assure that any possible risks related to nuclear reactors are kept as low as practicable and low relative to many other societal risks. As discussed in Section 4.2.7.5, a key aspect of design is the requirement that the plant be able to safely withstand accidents, even though extensive measures are taken to prevent accidents from occurring. Certainly these practices do not reflect a narrow view of the safety that can and is being achieved.

4. Comment (from enclosure):
LMFBR Plant Safety

On page 37 of the enclosed article it is stated: "The hazards of the present reactors will be multiplied many-fold in the breeders; an explosion in a fast breeder could make thousand of square miles uninhabitable for many years, and could endanger the lives and health of millions of people."

Response:

We are aware of no information to support this statement. A more detailed comparison of breeder reactors and LWR's is contained in Section 4.2.7.4 of the Final Statement. A discussion of explosion potential for the breeder is in Section 4.2.7.8. The recently issued draft report of the reactor safety study headed by Dr. Norman Rasmussen of MIT shows that major reactor accidents, if they occur, would not lead to the dire consequences that people have been led to believe. It also shows such accidents as highly unlikely events.

5. Comment (pages 1 and 2):
Radioactive Waste Management

It was stated that "the problem of storage of radioactive wastes is still unsolved" and that it is "irresponsible to plan a huge system of future nuclear fission power plants, when the problem of storage of wastes is still unsolved, and there is no real solution in sight." Concern over the probable results of human carelessness was expressed and the experience with the Hanford waste storage tank leaks as an example of the consequences of human carelessness was cited.

Response:

The near-term waste management program that has been adopted by the AEC for high-level waste calls for retrievable surface storage as described in Section 4.6.3.1 in the Final Statement. The AEC believes this to be a safe and reliable system for waste storage. At the same time, a comprehensive analysis of possible ultimate disposal alternatives is being carried out. There are enough promising ultimate disposals concepts presently being evaluated that the prospects for developing an acceptable ultimate disposal method within a period measured in decades is probable. The time required for development and implementation of most of these concepts has been estimated to be in the range of 20 to 30 years. Thus, safe methods for handling and storing these high-level wastes will be provided for and the implementation of concepts for ultimate disposal is in sight.

Regarding the Hanford waste tank leaks, the Hanford site was originally selected because of the soil conditions and the dry desert climate which provided for excellent retention of any liquid leaks in the soil immediately adjacent to the leak. The leaks from the Hanford waste tanks, although receiving wide publicity, have not resulted in exposure to any member of the public. Furthermore, the probability that any member of the public will be exposed to radiation in the future as a result of these incidents is essentially zero.

6. Comment (pages 1 and 2):
Transportation Accidents

The problem of ordinary human carelessness in the shipping of materials rich in plutonium is not discussed properly in the Final Environmental Statement for the LMFBR Program. Many people will be involved in transportation for the LMFBR fuel cycle in the future and some of these people are going to make mistakes.

Response:

The problem of human error is certainly of concern and action will be taken to minimize its occurrence and to mitigate the consequences of human error if it should occur. It should be noted that packages for the transportation of radioactive materials are manufactured and tested to very high standards, and must be capable of withstanding severe accidents, without releasing any radioactivity (see Section 4.5 of the Final Statement). The main opportunity for human error in the transport of these packages would appear to be in sealing before shipment. Regulatory standards and requirements as described in Appendix II.M have been promulgated to assure that human errors do not lead to significant radiation doses if such errors should occur. These regulations include quality assurance inspections of packages and radiation monitoring prior to shipment. In addition, before delivering a package to a carrier for transport, the shipper must determine that no "significant" loose radioactive contamination is on the outside of the package, that the radiation levels on the surface of the package and at a distance of 3 ft from the package meet the specified regulatory levels, and that the marking and labeling comply with the requirements. The shipper also must certify in writing on the shipping papers that the radioactive materials are properly classified, described, packaged, marked, and labeled and are in proper conditions for transport according to the applicable DOT regulations.

In conclusion, it is recognized that the problem of individual human error cannot be eliminated completely. However, it can be reduced to a major extent, and a well-designed and rigidly-enforced system of checks and certifications, as discussed in the Final Statement, can be employed to protect the health and safety of the public.

Part of the Allegheny Power System

Cabin Hill, Greensburg, Pa. 15601 (412) 837-3000

April 22, 1974

Office of the Assistant General Manager
for Biomedical and Environmental Research
and Safety Programs
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Sir:

Attached are comments concerning the WASH-1535 Draft Environmental Statement on Liquid Metal Fast Breeder Reactor Program, dated March 1974. As a participant in the review of the Gas-Cooled Fast Breeder Reactor supported by the AEC, a Utility Sponsor Group and General Atomic Company, my comments are directed toward utilizing the GCFR as a viable alternate breeder technology.

Thank you for the opportunity to comment on WASH-1535.

Very truly yours,

W. C. Guyker, Chairman
GCFR Program Review Committee

Attachment

COMMENTS ON WASH-1535
LIQUID METAL FAST BREEDER REACTOR PROGRAM
MARCH 1974, DRAFT ENVIRONMENTAL STATEMENT

Volume IV

P. A.1.4-5

In 1973, Bechtel Corporation completed its design of the Balance-of-Plant and has developed a schedule and cost for the GCFR. The Utility Group (called the Program Review Committee) has reviewed this work in depth and has concluded that GCFR is very promising; has no safety or technical problems that may preclude its being licensed; has an 11-year development time including front-end organization and engineering; has a 1973 cost level of less than \$500,000,000 for a reactor of 300 MWe; and that a size extrapolation to greater than 600 MWe be proposed for the first GCFR demonstration plant due to the importance of developing commercial-size plant components in the time frame under consideration. The reason for this is that, as sites become more difficult to obtain, larger unit sizes will take priority. In addition, the Program Review Committee questions the advisability of developing breeder reactors with large doubling times, so large in fact that the fissile inventory needed to fuel these breeders can never be recovered in the breeding process. For this reason, I feel it is imperative that an optimum breeding ratio be defined; i.e., one that realizes independence from uranium reserves or tails. The GCFR has the potential for better-than-optimum breeding ratios and should be pursued as actively as the LMFBR.

P. P-1 to P-7

In this section a discussion of breeding ratio and doubling time must be made as it affects the nation's fissile inventory.

W. C. Guyker, Chairman
GCFR Program Review Committee

4/22/74

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. W. C. Guyker, Chairman
GCFR Program Review Committee
Allegheny Power Service Corporation
Cabin Hill, Greensburg, Pennsylvania 15601

Dear Mr. Guyker:

Thank you for your letter of April 22, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. This letter provides replies to the several points you raised.

With regard to your comment questioning "the advisability of developing breeder reactors with large doubling times, so large in fact that the fissile inventory needed to fuel these breeders can never be recovered in the breeding process," the AEC believes that this opinion is unduly pessimistic and not in agreement with the actual breeding characteristics of the LMFBR as outlined in the enclosed Statement. As discussed in Section 11.2.2, advanced oxide fueled LMFBRs are expected to have a compound doubling time of 10-15 years, so that by about the year 2010 they will be able to provide the fuel to fully sustain an electrical energy demand growing at a rate as high as 6% per year, encompassing all growth projections examined in the study. Advanced fuels with their expected superior performance, such as the carbide fuels, will have compound doubling times of 8-10 years, and will therefore serve as an alternative in the event that the electric power demand doubling time exceeds that sustainable with oxide fuels. These figures fully reflect in-core fissile inventory needs and the requirements of other parts of the nuclear fuel cycle, and form the basis for the AEC's conclusion that the LMFBR will be able to supply the fuel needed for a growing electrical energy economy. For these reasons, the AEC does not believe that the Gas Cooled Fast Reactor will provide any major advantage with regard to fissile inventory despite the fact that its breeding ratio is projected to be higher than that of the LMFBR.

With regard to your suggestion that the GCFR should be pursued as actively as the LMFBR, the AEC recognizes that the GCFR has a potential for high breeding gain and favorable projections for capital cost. The ultimate

Mr. W. C. Guyker

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commercial viability of the concept is, of course, not yet determined. The AEC believes that at the present stage of development it is neither necessary nor feasible that the GCFR be pursued as actively as the LMFBR. The GCFR provides an alternative means for achieving breeder technology, and the decision has been made that the most preferable and viable breeder concept is the LMFBR (See Section 2.2.1.7 of the enclosed Final Statement). In order for GCFR development to proceed at the same pace as LMFBR development it would be necessary to either greatly increase GCFR funding, which would be economically impractical, or to decrease LMFBR funding, which would further delay the date by which LMFBRs could provide useful electricity. Some combination of these two approaches could, of course, be selected, but the results would likely be the same - a lessened assurance of the ultimate development and viability of the higher priority concept. For this reason, the AEC believes its current approach towards GCFR development, which includes a significant level of support for selected research and development tasks, is appropriate. You are referred to Section 6A.1.4.7 for an extensive discussion on the relative funding and differing research and development approaches of the LMFBR and GCFR programs.

We thank you for your comments on these important matters, and hope you will find answers to any further questions you may have in the enclosed Final Statement. Your interest in the LMFBR and GCFR Programs is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

EBASCO SERVICES
INCORPORATED

UTILITY CONSULTANTS - ENGINEERS - CONSTRUCTORS

TWO RECTOR STREET
NEW YORK, N.Y. 10006

CABLE ADDRESS "EBASCOE"

LEONARD F. C. REICHLE
VICE PRESIDENT

April 22, 1974

Office of the Assistant Manager for
Biomedical and Environmental Research
and Safety Programs
U.S. Atomic Energy Commission
Washington, D. C. 20545

Dear Sir:

Attached herewith for your consideration are the personal comments of Dr. H. C. Ott on your March 1974 Draft Environmental Statement, WASH-1535, Liquid Metal Fast Breeder Reactor Program. He points out that limitations of time have prevented as thorough a review of all aspects as he would have liked. Ebasco is in substantial agreement with his views.

Sincerely yours,

LFCR:ee

Comments on March 1974 Draft
Environmental Statement, WASH-1535
Liquid Metal Fast Breeder Reactor

Prepared by
Henry C. Ott

Ebasco Services Incorporated
New York, N. Y.
April 22, 1974

EBASCO SERVICES INCORPORATED

April 19, 1974

Office of the Assistant Manager for
Biomedical and Environmental Research
and Safety Programs
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Sir:

I am attaching for your consideration my personal comments on your March 1974 Draft Environmental Statement, WASH-1535, Liquid Metal Fast Breeder Reactor Program.

Limitations of time have prevented as thorough a review of all aspects as I should have liked.

Sincerely,

Henry C. Ott
Manager of Nuclear Technology

HCO:vb
Attachment

EBASCO SERVICES INCORPORATED

1. The statement does serve its intended purpose of showing that the development of LMFBR would have an acceptable environmental impact. I have not had time to study Volume II (Chapter 4) in detail but it appears to represent a very thorough evaluation and I have no quarrel with its conclusions.
2. I am concerned that, in my opinion, the statement goes far beyond the question of environmental impact in attempting to justify the LMFBR as the Nation's highest priority -- and almost exclusive -- energy goal. One gets the impression that LMFBR is sure of success and by itself can solve the problem of energy self-sufficiency. I do not question the need or wisdom of pursuing the LMFBR. I have no doubts about the ultimate technical success of the LMFBR -- perhaps with technical performance somewhat less than claimed, but still ample to justify its promise. I believe that there is a very good chance that someday it will be needed to extract energy from depleted uranium tails, though of course this need might be obviated by the success of fusion or some other advanced technology. However, it is by no means certain that LMFBRs can be economically competitive -- and hence commercially acceptable -- for several decades, nor that in the interim some of the alternatives, currently given lower priority, may not be able to contribute much more to alleviate energy shortages at lower cost. Admittedly there are large uncertainties for all of the alternatives -- as well as for LMFBR. No clear cut prediction can be made. The priority for the LMFBR was set by judgment -- not necessarily infallible. The draft statement does not provide any quantitative basis for the LMFBR priority. My concern is that if and when an alternate concept is shown to deserve a higher priority there will be a need to overcome prejudices established, needlessly, by the LMFBR impact statement.
3. I am well aware that the court decisions in the SIPI and Calvert Cliffs cases requires that consideration be given to the environmental impact of alternates to the proposed action and that the consideration

should include cost-benefit analyses which consider and balance the environmental effects of the facility and the alternates for reducing or avoiding environmental effects as well as environmental, economic, technical and other benefits of the facility. The required considerations are not much different from those for license applicants' environmental reports, for which the introduction to Regulatory Guide 4.2 states:

"The cost-benefit analysis shall, to the fullest extent practicable, quantify the various factors considered. To the extent that such factors cannot be quantified, they shall be discussed in qualitative terms."

Although I may disagree with some of the specific details of the cost-benefit analysis presented I don't disagree with the general conclusions regarding the environmental impact of the LMSBR program per se. However, for good reasons, no real attempt was made to quantify factors relative to the alternates, except for light water reactors.

4. I will admit that I have a special interest in the Molten Salt Reactor, which I feel has some unique advantages for solving the energy problem which have not been recognized in the statement. It is not my intent to use these comments as a sales pitch for MSR, any more than I feel it is proper to use the statement as a sales pitch for LMFBR. However, I do not want the statement to foreclose the option for MSR or for other alternatives. If I criticize misleading statements which bear on a comparison between MSR and LMFBR it is because of familiarity with the specific implications. I would not feel qualified to discuss disparities between LMFBR and non-nuclear alternates. The main thrust of my comments is that LMFBR is not the sole, certain answer to our energy problems -- and doesn't have to be to justify its development.
5. I believe it would be helpful to clarify the mission of the fast breeder in terms of present needs. I don't consider the fact that the fast

breeder can theoretically extract energy from most of the available U-238 as of overriding importance. For the same reason I am not impressed by the argument that such reactors as HTGR, LWBR and MSR, which utilize thorium, thereby exploit a new and extensive energy source. Although the draft statement advances this argument as the major advantage of the molten salt reactor I consider this point almost irrelevant compared to other attractive features of MSR.

There is no foreseeable shortage of fertile U-238 or thorium for many generations to come. However, there is a foreseeable shortage of the basic fissile material, U-235, needed for an expanding nuclear power industry. Regardless of reactor types employed, the growth of the fission nuclear industry will be limited by the availability of uranium ore. The important thing is to conserve uranium ore -- not U-238 and thorium.

Light water reactors suffer from three significant defects:

- a) They use too much uranium ore.
- b) They need too much separative work (enrichment), and
- c) Their thermal efficiency is undesirably low; not only are they deficient in converting fission energy to electricity but they add to the burden of dissipating waste heat.

On the other hand, light water reactor plants have two important advantages:

- a) They have achieved commercial status because at current prices they are economically competitive with fossil plants. There is a relatively mature light water reactor industry based on accumulated experience and the commitment of a sufficient number of large commercial units to support the economic operation of plant equipment and fuel supply facilities. Advanced reactor types must compete economically with light water reactors to become commercially acceptable. HTGR may be approaching commercial status.

- b) Light water reactors are fairly efficient in converting natural or low enrichment uranium to concentrated fissile fuel (primarily plutonium) which is essential for the introduction of virtually any of the advanced reactor types.

The mission then for LMFBR, or other advanced reactor type is to overcome the defects of LWR. Specifically one seeks the development of a reactor type which:

- a) Requires significantly less uranium ore than LWR.
 - b) Requires significantly less enrichment duty (SWU) than LWR.
 - c) Has a significantly higher thermal efficiency than LWR, thus requiring less cooling water and minimizing the amount of radioactive fission products per kwh generated.
 - d) Compete economically with LWRs and/or other energy sources. One can scarcely claim cheap power in the sense that prices would be lower than current costs from LWR, but, because one expects economic savings from realizing a, b and c, above, the new reactor type should counteract the trend toward higher costs that would result from continuing depletion of uranium reserves. The objectives of resource conservation and dollar economy are pretty much synonymous.
6. The most important attraction of LMFBR is the capability of requiring significantly less uranium ore than LWRs for the desired nuclear power industry. This capability is not measured simply in terms of breeding gain or doubling time. Also of importance is the inventory of fissile material needed to get a nuclear plant into operation. One finds at several places in the draft environmental statement the expression that "the LMFBR has no mining and milling components." The logic is most clearly expressed in Paragraph 4.1.4 (Vol. II, p. 4.1-20): "The use of natural or enriched uranium in the LMFBR fuel cycle is required only

if the plutonium available as initial fuel is insufficient for an expanding LMFBR economy. In the projected nuclear economy discussed in Chapter 11, sufficient plutonium is available during the period covered by this statement. Therefore, the LMFBR fuel cycle has no mining and milling components. "

I consider this statement misleading. To the extent that plutonium available as initial fuel comes from water reactors --- and the lion's share does in the expanding LMFBR economy discussed in Chapter 11 --- that plutonium cannot be made available without a commitment for additional mining of U_3O_8 . In the absence of LMFBRs essentially all plutonium produced would be recycled promptly in LWRs; there is nothing in the draft statement to indicate otherwise. Thus every kilogram of plutonium diverted from recycle in LWRs would have to be replaced with enriched uranium to keep the LWRs in operation. We estimate that each kilogram of fissile plutonium so diverted will require the nuclear industry to mine about 0.2 short tons of additional U_3O_8 and to expend about 110 SWU of enrichment effort. I have been told by AEC staff that their projections of ore and separative work requirements do take into account the added requirements due to interruption of plutonium recycle. I have no reason to question the projections. Nevertheless, I feel the reader is misled into believing that introduction of the LMFBR has essentially no impact on the demand for U_3O_8 or SWUs. At one time there was a common notion that, once LMFBRs were demonstrated, they would be adopted for all new plants since all other reactor types would be obsolete. There is a better recognition today that breeders are dependent on LWRs and that there will be a continuing need to install new LWRs, at least through the year 2000, just to provide initial fissile inventory for fast breeders.

7. Although the Molten Salt Reactor (MSR) cannot boast of as large a breeding gain as LMFBR it has the significant advantage that the required inventory of fissile fuel is very much less than that of LMFBR. As a consequence more MSRs than LMFBRs can be added

to the economy with a given supply of ore and separative work. This is true whether the MSRs are started with Pu from LWRs or with enriched U-235. It turns out that by using Pu from LWRs it would be possible to substitute molten salt reactors for the 400 GWe of breeder capacity of AEC's "most likely" forecast through the year 2000 ^{1/}, with essentially no difference in demands for U_3O_8 and separative work (Ebasco estimates actually show smaller requirements for MSR, based on 1000 MWe plants). Thus the advantage claimed for molten salt reactors is not the ability to burn thorium but essentially the same substantial improvement in resource utilization as LMFBRs relative to light water reactors. At least through 2000 the molten salt reactor is quite comparable to LMFBR in:

- a) Potential savings in uranium ore requirements.
- b) Potential savings in separative work requirements.
- c) Improved thermal efficiency.

In addition there are indications that early generation molten salt reactors may be better able to compete economically with light water reactors and hence reach commercial acceptance at an earlier date. The principal advantage of MSR is the elimination of fuel fabrication and the capability of on-stream refueling, whereas fuel fabrication is the largest and most uncertain component of LMFBR fuel cycle cost. Although in the long term the ability of LMFBR to utilize U-238 will probably be of importance, in the short term it is more important to reach commercial acceptance.

By extending the cost-benefit analysis to 2020 the importance of the assumed high breeding ratio for the LMFBR is accentuated and the problems of achieving commercial status are minimized. Admittedly,

^{1/} WASH-1139 (72)

there are technical problems which must be solved before MSR could fulfill its promise. These problems can be solved only if higher priority is given to developing MSR technology. The MSR can make a major contribution to the nuclear economy only if introduced before the fast breeder becomes commercial. But there is enough uncertainty as to when that might be that a parallel effort on the development of MSR, at a much higher level than heretofore seems to be warranted.

9. I consider the discussion of the benefits of LMFBR starting on page 1.5-3 to be quite weak. This seems to be a common failing of technology assessment, because of the difficulty of quantizing "external" benefits. It is difficult to do justice to the advantages of abundant and relatively cheap energy. In somewhat the same vein, there are several pages starting on 1.11-18 where the writers have put themselves on the defensive arguing against somewhat vague criticisms of the LMFBR program. It is in this discussion that I note a tendency to disparage alternates rather than to stand on the merits of the LMFBR. I personally do not consider LMFBR as a shoo-in to solve all the Nation's energy problems and I would not consider a slippage of five, ten or more years till the fast breeder becomes competitive as being tragic. Nevertheless, I do feel the breeder has enough merit to warrant a vigorous effort, but not to the exclusion of promising alternates. The draft environmental impact statement is in no way an adequate evaluation of the merits of alternates, but in some instances I feel it has needlessly gone beyond its province in that direction.
10. On page 1.8-4 the draft statement says "Further, all fission reactor systems have fundamentally the same environmental impacts as the LMFBR, and hence none of these would offer any significant improvement in that respect". (An expanded version of the same conclusion appears on page 5-4.) It might be added that, conversely, LMFBR does not necessarily offer any significant improvement over fission alternates. The final page of the Summary chapter (page 1.11-24) states: "Clearly, increased funding for alternate options is in order, but it would not be productive to allocate funds more rapidly than they can be used effectively during any given phase of development." One hopes that this criterion is applied equally to the LMFBR option and alternates.

11. With regard to the "conventional" cost-benefit analysis of Chapter 11, I do not necessarily agree with all the detailed assumptions made, but I cannot disagree with the general conclusions. To my mind the sum and substance of the analysis is best illustrated graphically by Figure 3.3.5 (page 3. -22 of Appendix III-B). By the year 2020, under the assumptions used for any of the many cases studied, there will be considerable accumulated savings in energy costs. One could hardly escape this conclusion if nothing but LMFBR and thermal reactors were available, because in that time span the cost of uranium will certainly rise to the point where LMFBR can compete very handily with LWR. The several cases studied vary numerically in the margin of cost savings, but it is substantial in any case. Obviously the sooner the LMFBR can become commercial the higher the savings. And if higher performance and/or lower cost can be achieved so much the better. The other side of the coin is the cost of reaching commercial status. Figure 3.3.5 very clearly illustrates this point by the "negative benefits" plotted for most of the rest of this century. For 1987 introduction of LMFBR the required outlay is indicated as some \$7 billion (discounted) plus another \$4.4 billion in R&D costs. There is some risk that the estimated costs and/or timetable may be optimistic or that the projected performance and cost advantages of the LMFBR may not be fully achieved in practice. Thus the price tag could be significantly higher or the benefits somewhat less than predicted. True, the ratio of long-term benefits to near term costs (both discounted to account for time lapse) would probably still be substantially greater than one. The real question is how one manages to finance \$11 billion plus in extra cost in the 1980s or 1990s for this one approach. The only obvious sources are taxpayers, and utility ratepayers and shareholders. Are they willing to dig down into their pockets now to save money on electric bills some thirty years from now? Unless the full cost barrier is crossed, no benefits will accrue. It is going to be very difficult to dictate conformance of the entire electric utility industry to the proposed pattern. The point is that the LMFBR program is worth pursuing but as a practical matter one may have to accept delays and somewhat lesser benefits. It is in this context that it seems premature to foreclose options for alternates which have potential either as backup for LMFBR or for providing benefits on a shorter time span.

12. It should be noted that the largest share of the cost of generating nuclear electricity lies in the capital investment in the plant. Furthermore, the plant investment is probably the most uncertain cost component for all plants, including light water reactors. Consequently, the economic comparisons are quite sensitive to the rather tenuous assumptions made regarding relative plant costs. It is largely for this reason that the economic comparison of alternate advanced systems is at best only semi-quantitative.
13. There is perhaps some confusion regarding the meaning of "Commercial introduction." On page 3.5-13 we find:

"The year of commercial introduction is defined as the first year during which significant numbers of commercial size LMFBRs go into operation. It is anticipated that eight commercial size LMFBRs will go into operation during the year of introduction and the following year, sixteen during the next two, thirty-two during the next two years, and economics will dictate the numbers thereafter."

It is not clear that the indicated rate of addition necessarily applies to the cost-benefit analysis. It does seem that installing as many as 56 units in the first six years of deployment is optimistic. It seems to be a faster starting rate than AEC's "most likely" case of WASH-1139 (72) and also faster than the expected introduction of large HTGRs. I believe the expected LWR population would barely be able to supply the plutonium needed to start 56 plants on that schedule starting in 1987, (assuming the LWRs operate at their forecast capacity factor) but there would soon be a shortage of plutonium if the implied acceleration of installation were continued.

I would consider an advanced reactor type to reach "commercial status" when utilities would be able to choose it freely for their next scheduled plant additions. Essentially this means it should be economically competitive with light water reactors. It seems quite clear that a sizeable number of early generation plants will require significant subsidies.

14. I have a number of miscellaneous questions and observations, not necessarily related to the above comments and not necessarily affecting the conclusions of the draft statement. On Page 1.10-3 there is a statement that a 1000 MWe LMFBFR plant would have an annual production of 0.28 metric tons of plutonium and 0.067 metric tons of fission products. Assuming 2500 MWt and 292 days operation (80% capacity factor) the annual rate of fissioning would be some 770 kg consistent with a breeding ratio of roughly 1.3. I suspect a slippage of the decimal point for the weight of fission products.
15. The discussion of "energy parks" (Page 1.5-2 and elsewhere) is of course not unique to LMFBFRs. Also, while the concept has merits it also has a host of problems, one of which is the limited number of locations with copious cooling water and proximity to loads. Certainly, the expected growth of electric power capacity will require increased consideration of such concepts, not necessarily for LMFBFRs. Related specifically to LMFBFRs is the assumption that a typical fuel fabrication plant could handle some 80 GWe of LMFBFR capacity. Parks of this size are unlikely, so the possible elimination of fuel transportation is not compatible with such large fabrication plants. Whether such large fabrication plants are needed for an economic fuel cycle is not clear. It is unlikely that such large fabrication plants could be justified for the early years of commercial LMFBFRs.
16. There is a suggestion (Pages 3-37 and 4-8 of III-B) that special reactors designed for high plutonium production might be desirable to speed the deployment of LMFBFRs in cases when insufficient LWR generated plutonium is available. It is hard to see that one could justify the added cost and headaches of designing, licensing and building special reactors for this purpose rather than slowing the deployment of LMFBFRs. A better alternative would seem to be to operate existing LWRs at shorter exposure and perhaps moderately higher conversion ratio (e.g. by lower enrichment) to gain a similar, probably smaller advantage. The LWR operator would, of course, have to raise his price for plutonium so produced. A quite similar suggestion (Pages 3-17 and 3-20 of III-B)

is that the economy might benefit after about 2010 by building LWRs specifically to burn excess plutonium produced by the breeders. When one considers that a parallel assumption is made that capital cost parity between LMFBRs and LWRs has been reached by that time, one may ask why anyone would consider paying the same price for a lower performance plant. An alternate strategy would be to modify fuel management tactics of the LMFBRs to save dollar costs commensurate with a reduced plutonium yield. There are a number of options. Free enterprise and ingenuity can be expected to guide the choice at the time, and it is pointless to try to predict detailed actions some 30 to 50 years in advance.

17. On Page 1.11-22 (also 11.4-21) we find "Regardless of the economics of the uranium resource situation, the case for the breeder can be made on purely qualitative grounds; it is a more efficient user of a finite resource." Taken literally this implies "breeders at any cost." Similar reasoning might suggest by-passing the breeder in favor of fusion. Certainly LMFBR is a promising concept worthy of development, but the emphasis and timing may be questioned. There is a popular notion that "converters" and "burners" are inferior. I believe it is fair to say that the introduction of relatively low performance light water reactors has proven to be amply justified (although the suggestion of using light water as moderator had earlier met with considerable resistance). In fact one could scarcely consider the proposed schedule for introducing the LMFBR without having first deployed many large LWRs. And the reason is as much related to utilization of uranium resources as it is to dollar economy. The light water reactor plants set the standard for commercial acceptance. Regardless of other attractive features no advanced reactor is likely to be deployed in large numbers until it can compete economically with light water reactor plants.
18. Page 2-6 of Appendix III-B indicates that "by about the year 2010 the LMFBR oxide fuel designs, for all growth projections examined in the study, can provide the fuel to fully sustain an electrical energy demand growing at the rate of about 6% a year."

This seems inconsistent with the Bethe Panel report ^{1/} which indicates an annual yield of only 3.1% (= fractional yield of 0.138 per fuel cycle ÷ 4.5 years fuel cycle time) for oxide fuel. Presumably, one would expect the LMFBR growth rate to be as great or greater than that for the total electrical energy demand.

19. With regard to fission alternates to LMFBR (Pages 1.11-15, 16 and Volume IV) I offer the following observations. As discussed previously utilization of thorium is not a compelling advantage. The attractiveness of HTGR, LWBR and MSR is determined by decreased demands for uranium ore and economic potential. I estimate that over a thirty year plant life an HTGR uses roughly half as much U_3O_8 as a light water reactor but about the same amount of separative work; LWBR uses roughly a third as much U_3O_8 and half as much separative work as a light water reactor; the molten salt reactor can virtually match a near-term fast breeder in its impact on ore and separative work requirements. Apparently HTGR is essentially competitive with LWR today and would improve with higher uranium prices; LWBR probably could not compete with LWRs until higher uranium prices prevail and it is expected to be superseded by higher performance reactors.

Since LMFBR, GCFR and MSR are expected to have lower fuel cycle costs than LWRs, their competitiveness with LWRs will undoubtedly be determined by plant investment. Although much less effort has been spent on the development of GCFR than LMFBR, and perhaps it is fair to say its technology lags that of LMFBR, there are reasons for believing the capital cost of the GCFR may be lower than that of LMFBR although their fuel cycle costs are expected to be comparable. Hence, one should not conclude that commercial introduction of GCFR would necessarily lag that of LMFBR. The molten salt reactor is estimated to have fuel cycle costs significantly lower than either LMFBR or GCFR, primarily because fuel fabrication is eliminated. This advantage is especially significant for early generation plants when fast

^{1/} Report of the Cornell Workshops on the Major Issues of a National Energy Research and Development Program (December 1973). Table G1, page G-4.

breeder fuel is both expensive and uncertain of life. For these reasons there is a good chance that the molten salt reactor could become competitive with light water reactors and hence commercially acceptable at an earlier date than either fast breeder. A particular attractive version of the molten salt reactor is one operated to emphasize conversion of plutonium to U-233, rather than maximum breeding ratio. It is attractive with respect to both low cost and minimum demand for uranium ore and separative work. It could have maximum impact on uranium resources if introduced, not after 2000, but as soon as practicable, which would be well before 2000 if its development were supported.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Leonard F. C. Reichle
Vice President
Ebasco Services, Incorporated
2 Rector Street
New York, New York 10006

Dear Mr. Reichle:

Thank you for your letter of April 22, 1974 transmitting comments by Dr. Henry C. Ott on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where necessary in response to the many comments received, and a copy of the Final Statement is enclosed for your information.

Dr. Ott's letter contained numerous statements and comments regarding the Molten Salt Breeder Reactor, the LMFBR, and other energy technologies. We were pleased to note that Dr. Ott finds that the Draft Environmental Statement "does serve its intended purpose of showing that the development of LMFBR would have an acceptable environmental impact". Please see the other enclosure to this letter for the AEC's responses to Dr. Ott's specific comments.

Thank you for your interest in the LMFBR program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

ENCLOSURE 1

AEC Staff Response To Specific Comments By Ebasco Services, Inc.1. Comment:

"....it is by no means certain that LMFBRs can be economically competitive -- and hence commercially acceptable -- for several decades, nor that in the interim some of the alternatives, currently given lower priority, may not be able to contribute much more to alleviate energy shortages at lower cost."

Response:

The AEC believes that LMFBRs can be economically competitive in a time frame significantly shorter than the "several decades" mentioned above. This is admittedly a judgment. It is recognized that new alternative energy production systems will also contribute towards meeting the Nation's energy requirements, but it is doubtful that they can contribute much during the time frame of LMFBR introduction. These matters are discussed further in Section 6 (Alternative Technologies) and Section 11 (Cost Benefit Analysis). As noted in the Perspectives section of Section 6, the energy requirements of the United States are so large and pressing that no single method of producing energy is completely adequate for the job. The AEC therefore endorses the development of several energy-producing technologies, as well as the LMFBR.

2. Comment:

"The draft statement does not provide any quantitative basis for the LMFBR priority. My concern is that if and when an alternate concept is shown to deserve a higher priority there will be a need to overcome prejudices established, needlessly, by the LMFBR impact statement."

Response:

The AEC has attempted to provide quantitative arguments for the LMFBR priority through the cost-benefit study which is documented in Section 11 of the Final Statement. We see no basis for the concern that the LMFBR Environmental Statement will establish prejudices which would have to be overcome before an alternate concept could be assigned a higher priority, if an alternate concept should at some future time be shown to deserve a higher priority. We have throughout the Statement made it clear that the AEC follows the philosophy that a number of alternative technology options should be developed for the reasons stated in the preceding response.

3. Comment:

"....I am not impressed by the argument that such reactors as HTGR, LWBR and MSR, which utilize thorium, thereby exploit a new and extensive energy source. Although the draft statement advances this argument as the major advantage of the molten salt reactor I consider this point almost irrelevant compared to other attractive features of MSR."

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"....the advantage claimed for molten salt reactors is not the ability to burn thorium but essentially the same substantial improvement in resource utilization as LMFBRs relative to light water reactors. At least through 2000 the molten salt reactor is quite comparable to LMFBR in:

- a) Potential savings in uranium ore requirements.
- b) Potential savings in separative work requirements.
- c) Improved thermal efficiency."

Response:

It was not the intent of the AEC to identify the use of thorium fuel cycle as the major advantage of the molten salt reactor exclusive of others. Please see Section 6A.1.5.7.2 of the Final Statement which lists the several benefits (advantages) the the MSBR concept, and in which it is seen that the use of thorium fuel is only one of several potential benefits.

4. Comment:

"One finds at several places in the draft environmental statement the expression that 'the LMFBR has no mining and milling components.'

I consider this statement misleading. To the extent that plutonium available as initial fuel comes from water reactors -- and the lion's share does in the expanding LMFBR economy discussed in Chapter 11 -- that plutonium cannot be made available without a commitment for additional mining of U_3O_8 . In the absence of LMFBRs essentially all plutonium produced would be recycled promptly in LWRs; there is nothing in the draft statement to indicate otherwise. Thus every kilogram of plutonium diverted from recycle in LWRs would have to be replaced with enriched uranium to keep the LWRs in operation."

Response:

In developing the position on mining and milling requirements for the LMFBR, the AEC relied on the best current estimate of growth of the U.S. nuclear power economy (WASH-1139). This analysis concluded that the LMFBR industry would require no additional mining and milling of uranium over that required for the light water reactor industry whether plutonium is recycled or not. Uranium requirements for LWRs, if plutonium is used in LMFBRs instead of being recycled, have been accounted for in the AEC's estimates of uranium requirement (see Section 6.A.1.1.2.3 and Section 11.2.4). In particular, it should be noted that the reduction of U_3O_8 and separative work requirements due to the introduction of the LMFBR provides a large portion of the benefits as defined in Section 11.2. Overall cumulative U_3O_8 and separative work requirements through 2020 are dramatically reduced by introduction of the LMFBR, as is shown in

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Section 11 of the Final Statement. Furthermore, the annual U_3O_8 and separative work requirements for the total fuel cycle with the LMFBR available are always equal to or less than the requirements when the LMFBR is not available.

5. Comment:

"Although the Molten Salt Reactor (MSR) cannot boast of as large a breeding gain as LMFBR it has the significant advantage that the required inventory of fissile fuel is very much less than that of LMFBR. As a consequence more MSRs than LMFBRs can be added to the economy with a given supply of ore and separative work. This is true whether the MSRs are started with Pu from LWRs or with enriched U-235. It turns out that by using Pu from LWRs it would be possible to substitute molten salt reactors for the 400 GWe of breeder capacity of AEC's 'most likely' forecast through the year 2000¹, with essentially no difference in demands for U_3O_8 and separative work (Ebasco estimates actually show smaller requirements for MSR, based on 1000 MWe plants)."

Response:

These assumptions regarding the potential of molten salt reactors are valid only if the molten salt breeder reactor system can be developed with the currently projected breeding characteristics and on the same time scale as the LMFBR. The AEC feels that molten salt breeder reactor technology lags that of the LMFBR by possibly as much as ten years and that, despite the MSBR's lower fissile inventory, the technical uncertainties associated with the concept preclude final judgments such as Dr. Ott has offered. In addition, only a minimum amount of study of plutonium-fueled reactors has been performed, so that system must be considered as more speculative than the U-233-fueled MSBR.

6. Comment:

"....there are indications that early generation molten salt reactors may be better able to compete economically with light water reactors and hence reach commercial acceptance at an earlier date. The principal advantage of MSR is the elimination of fuel fabrication and the capability of on-stream refueling, whereas fuel fabrication is the largest and most uncertain component of LMFBR fuel cycle cost. Although in the long term the ability of LMFBR to utilize U-238 will probably be of importance, in the short term it is more important to reach commercial acceptance."

Response:

Based on conceptual design studies performed to date, both the molten salt converter reactor and the molten salt breeder reactor are projected to have favorable economics relative to other reactor systems. As reported in ORNL-4812, the capital costs should be approximately the same as those of light water reactors while the fuel cycle costs could be significantly lower. While these studies are encouraging with respect to the molten salt breeder reactor, it is nevertheless important to recognize that the

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system is at an early stage of development at present and that the technical uncertainties associated with the concept preclude accurate projections of reactor power costs at this time. Secondly, the contention that fuel fabrication is the largest and most uncertain component of LMFBR fuel cycle cost cannot be substantiated based on examination of current LMFBR technology. This item is treated in more detail in Section 11 of the Final Statement.

7. Comment:

"By extending the cost-benefit analysis to 2020 the importance of the assumed high breeding ratio for the LMFBR is accentuated and the problems of achieving commercial status are minimized. Admittedly, there are technical problems which must be solved before MSR could fulfill its promise. These problems can be solved only if higher priority is given to developing MSR technology. The MSR can make a major contribution to the nuclear economy only if introduced before the fast breeder becomes commercial. But there is enough uncertainty as to when that might be that a parallel effort on the development of MSR, at a much higher level than heretofore seems to be warranted."

Response:

The AEC agrees that problems associated with molten salt reactor technology could be solved more expeditiously if higher priority were given to the program. However, the current AEC policy is to continue the MSBR program as a backup effort which could be expanded into a larger program if needed. Further, the AEC disagrees with the statement that "the molten salt reactor can make contribution to the nuclear economy only if introduced before the first breeder becomes commercial." It may ultimately be desirable to utilize the Nation's thorium reserves with higher utilization efficiency than can be achieved with the light water breeder and high temperature gas-cooled reactors, and the molten salt breeder reactor is currently the only thorium burning reactor concept which has potential for very high thorium utilization. In any event, the key to success for the MSBR is more likely to depend on the ultimate economics and utility of the concept rather than whether it is introduced as the first commercial breeder.

8. Comment:

"....there are several pages starting on 1.11-18 where the writers have put themselves on the defensive arguing against somewhat vague criticisms of the LMFBR program. It is in this discussion that I note a tendency to disparage alternates rather than to stand on the merits of the LMFBR. I personally do not consider LMFBR as a shoo-in to solve all the Nation's energy problems and I would not consider a slippage of five, ten or more years till the fast breeder becomes competitive as being tragic. Nevertheless, I do feel the breeder has enough merit to warrant a vigorous effort, but not to the

-5-

exclusion of promising alternates. The draft environmental impact statement is in no way an adequate evaluation of the merits of alternates, but in some instances I feel it has needlessly gone beyond its province in that direction."

Response:

In the cited pages of the Draft Statement the intent was to examine arguments that had been raised suggesting that the need for the LMFBR was less urgent than believed by the AEC. In our view those arguments are erroneous and it should not be surprising that this view was reflected in the text. These points were discussed in greater detail in Chapter 11 (Cost-Benefit Analysis), of which the cited pages provided only a summary. With regard to the suggestion that alternative energy technologies were not adequately or fairly treated, you are referred to Section 6 of the Final Statement, where both the AEC and opposing views on alternative technologies are fully discussed. It should also be noted that the Statement does not select the LMFBR and exclude other alternative technology options. The point is repeatedly made that the LMFBR is but one of a number of energy production systems which will be needed and that other feasible systems should be developed, as quickly as they can, to the point of commercial usage.

9. Comment:

"There is some risk that the estimated costs and/or timetable (of LMFBR introduction) may be optimistic or that the projected performance and cost advantages of the LMFBR may not be fully achieved in practice. Thus the price tag could be significantly higher or the benefits somewhat less than predicted. True, the ratio of long-term benefits to near term costs (both discounted to account for time lapse) would probably still be substantially greater than one (if the LMFBR is delayed). The real question is how one manages to finance \$11 billion plus in extra cost in the 1980s or 1990s for this one approach."

Response:

The Draft Statement reported a net deficit in the 1980's and 1990's in an LMFBR economy. Further analysis has shown that this deficit was an artifact introduced through calculation of end-of-life forward costs of LWRs in operation before introduction of the breeder. Recalculation has shown that in fact the LMFBR shows benefits from the year of its introduction. Section 11.2.4 describes the results of the new calculations.

10. Comment:

"The point is that the LMFBR program is worth pursuing but as a practical matter one may have to accept delays and somewhat lesser benefits. It is

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in this context that it seems premature to foreclose options for alternates which have potential either as backup for LMFBR or for providing benefits on a shorter time span."

Response:

Continued development of the LMFBR does not foreclose the development of other promising energy technologies. As noted in the response to Comment No. 8, the goal of the LMFBR program is the development of a viable energy production system option. Whether or not that option is exercised will depend upon its relative economics, environmental acceptability and other features as compared to competing systems. In the report, "The Nation's Energy Future,"* an integrated \$10 billion energy R&D program was developed for the period 1975-1979. Despite the fact that this timeframe covers the period of highest activity and expense for the LMFBR program, only about 25% of this energy R&D budget is allocated to LMFBR activities. Neither the amount of funding needed to develop the LMFBR nor any actions precluding energy option selection by the normal utility industry processes will foreclose the pursuit or selection of alternative technologies.

11. Comment:

"It should be noted that the largest share of the cost of generating nuclear electricity lies in the capital investment in the plant. Furthermore, the plant investment is probably the most uncertain cost component for all plants, including light water reactors. Consequently, the economic comparisons are quite sensitive to the rather tenuous assumptions made regarding relative plant costs. It is largely for this reason that the economic comparison of alternate advanced systems is at best only semi-quantitative."

Response:

The AEC is in agreement with these comments but emphasizes the need to conduct major program planning based on the best available economic comparisons. In this instance, we believe that the information presented in the LMFBR Program Environmental Statement meets this criterion.

12. Comment:

"There is perhaps some confusion regarding the meaning of 'Commercial introduction.' On page 3.5-13 we find:

"The year of commercial introduction is defined as the first year during which significant numbers of commercial size LMFBRs go into operation. It is anticipated that eight commercial size LMFBRs will go into operation during the year of introduction and the following year, sixteen during the next two, thirty-two during the next two years, and economics will dictate the numbers thereafter."

*"The Nation's Energy Future," a report to the President of the United States, WASH-1281, December 1973.

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"It is not clear that the indicated rate of addition necessarily applied to the cost-benefit analysis. It does seem that installing as many as 56 units in the first six years of deployment is optimistic. It seems to be a faster starting rate than AEC's 'most likely' case of WASH-1139(72) and also faster than the expected introduction of large HTGRs. I believe the expected LWR population would barely be able to supply the plutonium needed to start 56 plants on that schedule starting in 1987, (assuming the LWRs operate at their forecast capacity factor) but there would soon be a shortage of plutonium if the implied acceleration of installation were continued."

Response:

The "doubling formula" defined in the Statement simulates the ability of manufacturers to "tool up" for LMFBR production, and in proper context it is used as a limiting rate. However, the actual introduction constraint allows only one reactor in the year of introduction, eight reactors in the following biennium, sixteen in the next biennium, etc. A similar formula, assuming two reactors the first biennium, was used to limit HTGR introduction following 1982. In the absence of other constraints, such a limit must be applied to prevent the model from choosing large numbers of an economically favorable plant as soon as it is introduced.

The rates of introduction of LMFBR's and HTGR's for reference calculations were those given in WASH-1139(72). Sensitivity studies considered several alternate scenarios of introduction as well. Also, in several of the sensitivity calculations, the rates of penetration of the various reactor types were left for selection by economic preference alone, subject to fuel availability. For these cases the "doubling formulas" were applied to initial introduction as limiting rates. Under all but the most adverse conditions, LMFBR's penetrated at this limiting rate when allowed to.

13. Comment:

"I have a number of miscellaneous questions and observations, not necessarily related to the above comments and not necessarily affecting the conclusions of the draft statement. On Page 1.10-3 there is a statement that a 1000 MWe LMFBR plant would have an annual production of 0.28 metric tons of plutonium and 0.067 metric tons of fission products. Assuming 2500 MWt and 292 days operation (80% capacity factor) the annual rate of fissioning would be some 770 kg consistent with a breeding ratio of roughly 1.3. I suspect a slippage of the decimal point for the weight of fission products."

Response

A review of the mathematics and assumptions involved in this calculation indicates that the comment is correct in noting an error in the computed weight of fission products. The correct figure should have been 0.67 metric tonnes and the Final Statement has been modified accordingly.

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14. Comment:

"The discussion of 'energy parks' (page 1.5-2 and elsewhere) is of course not unique to LMFBRs. Also, while the concept has merits it also has a host of problems, one of which is the limited number of locations with copious cooling water and proximity to loads. Certainly, the expected growth of electric power capacity will require increased consideration of such concepts, not necessarily for LMFBRs. Related specifically to LMFBRs is the assumption that a typical fuel fabrication plant could handle some 80 GWe of LMFBR capacity. Parks of this size are unlikely, so the possible elimination of fuel transportation is not compatible with such large fabrication plants. Whether such large fabrication plants are needed for an economic fuel cycle is not clear. It is unlikely that such large fabrication plants could be justified for the early years of commercial LMFBRs."

Response:

Considerations of "energy parks" in the study were addressed to parks of 10 to 50 GWe capacity, based on the capacity of a given reprocessing (not fabrication) plant. Other fuel cycle industries, including fabrication plants, may be present, but will not dictate the size of the park. Siting and economics of such parks are being evaluated separately from the Environmental Statement; no parks will be built without individual environmental statements. [The point that nuclear parks would require "copious cooling water" is valid if other forms of cooling cannot be used. In addition, process water will be required and the site must be suitable to support large numbers of workers and their families, etc.]

The sizing of fuel fabrication plants will likely be dictated primarily by economic considerations. The "model" plant discussed in Section 4 of the Final Statement has a capacity of 1500 metric tonnes of fuel per year which is sufficient to supply fuel for about 80 GWe capacity. In the cost-benefit study (which, incidentally, does not consider energy parks) sizes ranging up to 2700 metric tonnes per year were considered. Plants of this size would relate to a mature LMFBR industry, when a sufficient fuel market exists. In earlier years plants would be sized in accordance with projected loads.

15. Comment:

"There is a suggestion (pages 3-37 and 4-8 of III-B) that special reactors designed for high plutonium production might be desirable to speed the deployment of LMFBRs in cases when insufficient LWR generated plutonium is available. It is hard to see that one could justify the added cost and headaches of designing, licensing and building special reactors for this purpose rather than slowing the deployment of LMFBRs. A better alternative would seem to be to operate existing LWRs at shorter exposure and perhaps moderately higher conversion ratio (e.g., by lower

enrichment) to gain a similar, probably smaller advantage. The LWR operator would, of course, have to raise his price for plutonium so produced. A quite similar suggestion (pages 3-17 and 3-20 of III-B) is that the economy might benefit after about 2010 by building LWRs specifically to burn excess plutonium produced by the breeders. When one considers that a parallel assumption is made that capital cost parity between LMFBRs and LWRs has been reached by that time, one may ask why anyone would consider paying the same price for a lower performance plant. An alternate strategy would be to modify fuel management tactics of the LMFBRs to save dollar costs commensurate with a reduced plutonium yield. There are a number of options. Free enterprise and ingenuity can be expected to guide the choice at the time, and it is pointless to try to predict detailed actions some 30 to 50 years in advance."

Response:

The cost-benefit analysis is not presented as a forecast of future electric generating systems. As you point out, the particular plants and fuel cycles utilized in the national power economy will be based on individual utility choices in the future. However, as is pointed out in Section 11.2.5 in the Final Statement, the basic systems approach utilized in the cost-benefit optimization study is similar to the utility decision-making process. Therefore, the general conclusions in the cost-benefit analysis based on evaluations of alternative energy generating systems are valid. The numerous reactor and fuel cycle alternatives available to the optimization code are provided to allow the code to make unbiased selections of plants to minimize overall power costs.

The specialized Pu-producing reactors are available but are not built in the cases considered in the Final Statement. An input error in fuel cycle calculations resulted in their inclusion in the cases considered in the Draft Statement. Also as you point out, the Pu-fueled LWRs utilized in the latter part of the study may alternatively be "de-tuned" LMFBRs. This strategy would essentially adjust plutonium production to plutonium requirements by changing LMFBR design parameters.

16. Comment:

"....light water reactor plants set the standard for commercial acceptance. Regardless of other attractive features no advanced reactor is likely to be deployed in large numbers until it can compete economically with light water reactor plants."

Response:

The comment is correct in principle but does not take into account all the factors involved. Section 11.2 illustrates the overall incentive associated with the LMFBR during the time period of the cost-benefit analysis. The LMFBR is definitely competitive on the basis of comparative economics. In the time period immediately following the introduction of the LMFBR,

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other reactors have a slight competitive advantage in the near term. However, the LMFBR provides the synergistic economic incentive of lowering the fuel cycle costs of the 400-500 GWe of LWRs operating in the early 1990's by roughly a mill/kwh. Later in the study the LMFBR is competitive in its own right, while still providing overall fuel cycle cost savings to the operating LWRs. Therefore, there is a real incentive to deploy the LMFBR in large numbers as demonstrated by the cost-benefit analysis.

17. Comment:

"Page 2-6 of Appendix III-B indicates that 'by about the year 2010 the LMFBR oxide fuel designs, for all growth projections examined in the study, can provide the fuel to fully sustain an electrical energy demand growing at the rate of about 6% a year.

"This seems inconsistent with the Bethe Panel report which indicates an annual yield of only 3.1% (+ fractional yield of 0.138 per fuel cycle + 4.5 years fuel cycle time) for oxide fuel. Presumably, one would expect the LMFBR growth rate to be as great or greater than that for the total electrical energy demand."

Response:

The performance of the oxide fueled LMFBR described in Appendix III-B results from reduction in design conservatism based on the current R&D program. Specific details of reduction in design conservatism are contained in Section 11 of the Final Statement. Based on this information, the AEC believes that the capability of the LMFBR to sustain an annual electrical growth rate of 6% as stated in the Final Statement is valid.

18. Comment:

"Since LMFBR, GCFR and MSR are expected to have lower fuel cycle costs than LWRs, their competitiveness with LWRs will undoubtedly be determined by plant investment. Although much less effort has been spent on the development of GCFR than LMFBR, and perhaps it is fair to say its technology lags that of LMFBR, there are reasons for believing the capital cost of the GCFR may be lower than that of LMFBR although their fuel cycle costs are expected to be comparable. Hence, one should not conclude that commercial introduction of GCFR would necessarily lag that of LMFBR. The molten salt reactor is estimated to have fuel cycle costs significantly lower than either LMFBR or GCFR, primarily because fuel fabrication is eliminated. This advantage is especially significant for early generation plants when fast breeder fuel is both expensive and uncertain of life. For these reasons there is a good chance that the molten salt reactor could become competitive with light water reactors and hence commercially acceptable at an earlier date than either fast breeder. A particular attractive version of the molten salt reactor is one operated to emphasize conversion of plutonium to U-233, rather than maximum breeding ratio. It is attractive with respect to both low cost and minimum demand for uranium ore and

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separative work. It could have maximum impact on uranium resources if introduced, not after 2000, but as soon as practicable, which would be well before 2000 if its development were supported.

Response:

The technology of GCFR's and molten salt reactors lags that of the LMFBR by several years at best. Thus, the contention that the MSR could virtually match a near-term fast breeder in its impact on ore separative work requirements or could become commercially acceptable at an earlier date than either fast breeder is difficult to support. The earliest date for commercial introduction of the molten salt breeder reactor is likely to be in the early 1990's, assuming that the necessary R&D could be performed successfully. With regard to molten salt converters, it is difficult to justify development of a second thorium converter in addition to the HTGR since a breeder will be required to offset dwindling uranium reserves.

P. O. Box 11267
Knoxville, TN 37919
April 22, 1974

Office of the Assistant General Manager for
Biomedical and Environmental Research and
Safety Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Re: WASH - 1535

Sir:

We appreciate the opportunity to review and reply to the Draft Environmental Statement of the Liquid Metal Fast Breeder Reactor Program (WASH - 1535), dated March, 1974. The scope of the DES is commendable; however, the following points should be given further attention:

Much of the impetus for rapid development of the Liquid Metal Fast Breeder Reactor Program is derived from the fact that the current generation of Light Water Reactors is consuming uranium fuel at a rate which can not be economically maintained for longer than a few more decades:

There has been a progressive increase in breeder benefits over the period in which the AEC cost-benefit studies have been conducted largely due to increases in projected costs for uranium and separative work, which have relatively little effect on breeder costs.

- Section 1.11-1

The process of enriching the percentage of U-235 in fuel from 0.7% to 3-4% (the level used in LWR fuels), conducted in gaseous diffusion plants, is indeed extravagant, not fully utilizing the small amounts of U-235 present in ore, and even then requiring vast amounts of electrical energy. Consequently, to follow the argument propounded in the DES, within the next few decades the cost of obtaining and enriching scarce uranium fuel will result in correspondingly higher costs associated with electrical production in LWR's. However, recent developments and possibilities complicate the issue. Intensive research and development in the use of centrifuge enrichment, both domestically and abroad (Science, 183: 1270-1272 (1974)), offers the possibility of uranium separation at a considerable savings over present gaseous diffusion processes. Additionally, it has now been

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reported (Science, 183: 1172-1174 (1974)) that laser separation techniques may be in the developmental stage - techniques which might not only render both the gaseous diffusion and centrifuge processes obsolete but which might, at the same time, enable us to more fully utilize the small percentage of U-235 found in ore, allowing known reserves to last for decades more. To the extent that the AEC's justification of a massive commitment to the LMFBR Program is based on the issues of minimizing costs due to procurement and enrichment of uranium fuel, and of not relying on a fuel source (U-235) which will become exhausted in the near future, to the extent that justification of the LMFBR Program is based on matters of time and money, then developments affecting such time-and-money considerations should be fully explored. It would be useful if the Final Environmental Statement included a discussion of the implications of centrifuge and laser enrichment technology for the cost-benefit analysis of the LMFBR Program.

Although the DES does mention the fact that an adequate cost-comparison analysis should take into account factors other than capital and operating costs, fuel costs, and other such traditional measures, and that factors heretofore considered "external" to energy-production costs, such as environmental and societal costs, should be "internalized" to obtain a truer picture of total costs and benefits, in fact there is little evidence that such "external" factors were seriously considered in many sections of the DES. Particularly in Section 8 (Alternative Technology Options), wherein the feasibility of these options is measured in dollars-and-cents, and in many cases rejected on this criterion, it appears that traditional "internal" costs were given primary and often total consideration, to the exclusion of "external" costs. For example, the discussion on "Hydrogen and Other Synthetic Fuels" contains the argument:

At an electric power cost of 5 mills/kWh, the power cost in terms of hydrogen produced is about 10¢/lb H₂ resulting in a total cost, excluding labor, maintenance, and overhead costs, of 14.3¢/lb H₂, or about \$ 2.80/ 10⁶ Btu. This is considerably higher than the cost of other fuels (e.g., low Btu gas can be produced from coal at a cost of about 60¢ to 85¢/ 10⁶ Btu).

- Section A.6.4

Although further discussion on the following page admits that environmental effects would have to be considered, such effects are not in any manner accorded a monetary or

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otherwise quantitative status. Such avoidance of "internalizing" costs is symptomatic of the entire Alternative Technology Options discussion, and this weakness should be remedied in the FES. In this period in history, the public is increasingly aware that there are "costs" in energy production besides those read on the meter outside one's home and printed on the monthly electricity bill; it is reasonable that this same public would appreciate the sophisticated and comprehensive analysis of Alternative Technology Options which should result from the attempt to "internalize" all recognizable costs. Section 8 of the LMFBR Program DES is not fully complete without such a comprehensive cost-comparison analysis.

The discussion on "Conservation of Energy" (Section 8 C) as an Alternative Technology Option is wide-ranging and outlines how various modifications to and developments in the modes in which we generate, distribute, and utilize energy may result in savings of energy resources. The discussion is nevertheless limited in that changes necessitating serious adaptations in our national life-style are not included. Certainly, it would be difficult if not impossible to quantify such changes in the manner that other conservation measures in the section were quantified as to possible savings, and some changes might at this time be so repugnant to sectors of the public that the possibilities of implementation in the near future are slight. However, the same changes in life-style which we may now reject might someday be considered desirable or needed, and a section on conservation as an Alternative Technology Option in the DES provides an excellent opportunity to begin to enumerate changes in our life-style which might now seem radical.

We have become somewhat accustomed to one-way commuting distances of 50 and 100 miles between home and work, although perhaps not as accustomed to the vast energy resources which are expended to maintain this life-style. A scenario of future life might include residing in much closer proximity to one's place of employment. Replacement of the largely home-isolated entertainment centers (audio and visual) by more efficient public or semi-public systems can be envisioned. The proliferation of inefficient (based on the criteria of heating and cooling requirements and materials utilization) single-family dwellings might be reversed in the future.

While we may now recoil from the major changes in our life-style which would be indicated by such situations as exemplified above, it is nonetheless reasonable that we con-

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sider, as a significant conservation measure, the alteration of the life-style to which we have become accustomed. The LMFBR Program DES does not probe conservation measures having such a major impact on our lives - a discussion of this sort might prove useful.

The basis for early introduction of LMFBR'S is changed in the face of a slower increase in demand for electricity. The "recognized" electricity demand forecasts used in the LMFBR DES do not include those demand forecasts which include the price of electricity as a causal factor affecting the demand for electricity. (Section 2.1.2.4) This is inexcusable in light of recent events. These "recognized" studies which were used in projection estimates for the LMFBR DES generally conclude that the price of electricity does not influence demand. "Unrecognized" studies (1-5), at least by the AEC, conclude that the price of electricity is a determinant of demand and that predictions of future needs can be greatly affected by this causal factor. (1. D. Chapman, T. Tyrrell, T. Mount. "Electricity demand growth and the energy crisis". Science. 178, 703, 1972. 2. R. Halvorsen. "Residential electricity: demand and supply". presented at the Sierra Club Conf. on Power and Public Policy, Vermont, Jan. 1972. 3. P. W. MacAvoy. "Economic strategy for developing nuclear breeder reactors", MIT Press, Cambridge, Ma. 1969. 4. T. D. Mount, L. D. Chapman, T. J. Tyrrell. "Electricity demand in the U.S.: an econometrics analysis". ORNL-NSF-EP-49, Oak Ridge, Tn. 1973. 5. J. W. Wilson. "Residential and industrial demand for electricity". unpublished Ph.D. thesis, Cornell Univ. 1969) A comparison of the expected demand for electricity by the "recognized" forecasters for the year 2000 as extrapolated from FPC data up to 1990 is 9.01 trillion KWH, while "unrecognized" forecasters predict a range of 1.91-3.45 trillion KWH, depending mainly on price assumptions. (electricity price doubling by 2000 using 1970 prices, a 3.3% increase per year or a price increase of 19% for the period 1970-2000) In the same study that these estimates are taken from (1), a prediction of 9.89 trillion KWH for 2000 was obtained only if the assumption of an electricity price decline of 24% from 1970-1980 and 12% each 10 years thereafter until 2000 was used, which is a very unlikely occurrence.

Historically the price of electricity declined until 1970 when the first real (deflated) price increase occurred. The price of electricity has been stable or increasing ever since then and is expected to increase further due to environmental protection costs. Aubrey J. Wagner, chairman of the Tennessee Valley Authority has stated that "TVA would be faced with an approximate doubling of its revenue requirements," to meet the many environmental protection costs. (Public Util. Fortn. 89 No. 13, 27, 1972) Using data from the EEI Statistical yearbook Edison Electric Institute, (New York 1969-1972 years), the

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percent growth in demand for electricity for the years 1969-1972 was 7.6%, 6.8%, 4.2% and 2.9% respectively. The decrease in the rate of increase over these years is 59%. "Recognized" forecasters did not predict this occurrence. The claim that price is a determinant of demand growth is supported by the simultaneous occurrence of a decrease in the rate of increase of demand and the increase in the price of electricity which has occurred over this period.

Before embarking on an undertaking which has never in the history of mankind involved so many resources and commitments of long term guardianship an agency is required by law to examine alternatives of which the basic assumption of need is one. It is incredible that demand predictions for the future could be examined sufficiently in less than two pages of an DES. The magnitude of the differences between the "recognized" and "unrecognized" estimates should be sufficient propellant for an agency to examine the studies further as to the assumptions made and whether these assumptions are in fact still applicable. A thorough discussion of the reasons for these great differences in demand predictions and the supporting evidence for these predictions is the minimum requirement for satisfying NEPA.

"More energy will be needed to raise the standard of living of low income people to a more equitable level." (Section 2.1.2.2) This statement is an unsupported emotional appeal and should be removed from the DES. The facts show that the gap between the two groups, poor and nonpoor, has been widening since the advent of inexpensive power. "Helping the poor" can not be used to justify the implementation of an LMFBR program. In the perspective on alternative technology options (Vol. IV P-3) there is a statement which maintains that "systems on which little or no work has been done will look most attractive since the natural enthusiasm of their proponents will highlight the advantages of the system while the difficulties and limitations are minimized or, most likely, have not been discovered." This statement is a collection of unsupported emotional inferences. The inference that natural enthusiasm prevents limitations and difficulties of new technologies from being discovered, while not necessarily true, could be used to characterize certain aspects of the LMFBR program, as well as other new technologies. The statement that the limitations have most likely not been discovered is a misuse of subjective probability.

Upon the implementation of the LMFBR Program, a number of nuclear power parks have been postulated. This park could consist of a reprocessing plant, several nuclear power reactors, and other types of nuclear fuel facilities. It is stated in the DES that centers from 10,000 MWe to 50,000 MWe have been postulated. Specific plans have already been made for six to eight reactors in the 1000 MWe power range. This tendency towards clustering of power plants at an acceptable site is expected to grow. The feasibility of clustering nuclear facilities in parks is questioned on several grounds.

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One of the basic points to consider is the site selection procedure. In Section 7.2.6.5 it is stated:

Before nuclear power parks can be constructed, present nuclear power plant site criteria will have to be modified somewhat and new ones developed for application to such parks.

Site selection is quite important, and judging from past experience with the LWR, site selection has been justified after the fact; the FES must list working criteria for the site selection of nuclear parks. Special consideration should be directed towards meteorological factors in relation to convection currents resulting from large numbers of cooling towers that would be concentrated in nuclear parks.

An appraisal (using a systems approach or some other meaningful and applicable tool) of the environmental impact of industry that would be attracted to these power clusters should be made in the FES. In Section 5.3.3 it is stated that a nuclear park would attract several large industries that consume significant quantities of electricity or process heat, and in Section 5.4.1 it is implied that nuclear parks would cause extensive industrial development. In addition to the above considerations, the FES should evaluate the social and economic impacts of these large energy- and resource-consuming industries upon the region. The FES should predict the effect of added heat to the environment from industries associated with the nuclear park. Thus, the FES will have to address itself to nuclear facilities and the associated industrial plants that they attract.

A major problem with a nuclear facility is waste heat. In Section 9.1.2.1, it is stated that the discharge of heated effluents to the environment is "not really an environmental impact but is instead an index of such impact, actual impacts are better described by enumerating the effects of heated discharge." The point is well taken, but heated effluents can have an environmental impact that must be dealt with in a meaningful way, and the index-versus-impact argument should not be used to justify inadequate consideration of thermal impacts. In appropriate site selection criteria were formulated and adhered to then the effects of thermal discharge on the biota could be lessened.

In Section 7.4.3.5 the DES discusses the prospects of theft or sabotage at a nuclear facility. The probability of theft and/or sabotage could be increased at a nuclear park. The FES should address itself more fully to these two problem areas and provide suggestions to minimize or prevent theft and sabotage. Consideration of nuclear parks as strategic targets for foreign powers to attack or for radical and fanatic groups to use for attainment of their goals should be included in the FES.

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Throughout the DES the local and regional effects of parameters such as radioactive doses, land use, transmission lines, water use for heat dissipation, etc., were based upon a single 1000 MWe nuclear plant. If the nuclear park concept is adopted, and these centers range from 10,000 MWe to 50,000 MWe in capacity, then the FES should address itself to computing local effects and regional effects upon the basis of the total capacity of the facility and not a single plant.

Section 1.11.2 states "one of the principal advantages of the LMFBR is that it helps conserve natural resources." Table 1.11-3 demonstrates that nuclear power production could save considerable amounts of uranium fuel, and nuclear-produced electricity is cited as a means of conserving limited supplies of fossil fuels. These are presumably valid considerations, but the resource consumption resulting directly from construction and operation may be more significant in impact than the DES would reveal. Table 10.2 lists the materials and estimated quantities to be used in the construction of a 1000 MWe LMFBR plant, while Table 10.3 compares production, uses, and resources of these materials. The production and consumption figures are based on 1969 data which are of questionable use in estimating production and consumption of these materials in the future of an economy expanding consumption in all sectors (not only in nuclear energy production). The assumption is made in the DES that the United States can produce or obtain the resources it needs for the development of a breeder economy. Important social, political, and environmental impacts from the acquisition of these materials have been neglected. For example, a considerable amount of copper is to be used in each LMFBR plant (not to mention that which would be required for transmission lines and industrial centers near the nuclear parks). Based on the 1969 figures in the DES, the annual consumption of copper in the U.S. is more than half of the known reserves in the U.S. ; thus, we are faced with the alternatives of searching for more reserves or extracting low-grade ore from known but previously unprofitable holdings. Either alternative involves great expense and potential environmental damage. Political ramifications are inevitable, since many of these materials are obtained from other countries (copper from Chile, oil from U.A.R., aluminum from Jamaica, etc.). The recent oil embargoes and the nationalization of Chile's copper reserves are prominent examples.

Social costs to people living near or working in copper and other mineral mines could be increased; public health and occupational safety would have to be considered. Land and water as resources are presumed in the DES to be little different from conventional power production uses, on the basis of 1000 MWe plants; but for larger plants and nuclear parks, the DES has not fully considered the effect. Recognizing that nuclear parks would attract industry the use of these resources is complicated beyond their use by the plants alone.

Concerning financial resources, is it reasonable to assume that private utilities could raise the estimated capital

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of \$ 512 billion (through 1990) ? 15% of the GNP seems a large sum to be raised through public financing in an expanding inflationary economy.

Respectfully submitted by

Michael T. Carter

Michael T. Carter

Robert M. Cushman

Robert M. Cushman

J. Carter Davis

J. Carter Davis

Patricia D. Tyrrell

Patricia D. Tyrrell

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Micheal T. Carter
Mr. Robert M. Cushman
Mr. J. Carter Davis
Ms. Patricia D. Tyrrell
P. O. Box 11267
Knoxville, Tennessee 37919

Dear Messrs. Carter, Cushman, Davis
and Ms. Tyrrell:

Thank you for your letter of April 22, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the other enclosure to this letter for responses to your specific comments.

It is hoped that the revisions to the Draft Statement and the responses in Enclosure 1 will help alleviate your concerns. Your interest in the LMFBR Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

Enclosure 1

AEC Staff Response to Comments
by Messrs. Carter, Cushman, Davis and Ms. Tyrrell

1. Comment (pp 1-2):

"It would be useful if the Final Environmental Statement included a discussion of the implications of centrifuge and laser enrichment technology for the cost-benefit analysis of the LMFBR Program."

Response:

As you suggested, discussions of the implications of centrifuge and laser enrichment technology have been included in the Final Statement. The potential effects of advanced enrichment technology are discussed in Sections 6A.1.1 and 11.2. Discussions in Section 11 contain the results of estimates of the maximum potential economic impact of advanced enrichment technology. In terms of base case conditions, the development of an enrichment technology by 1990 which provides separative work at \$5/kg, with no 235-U in the tails, does not remove the incentive for the LMFBR.

2. Comment (pp. 2-3):

"Although the DES does mention the fact that an adequate cost-comparison analysis should take into account factors other than capital and operating costs, fuel costs, and other such traditional measures, and that factors heretofore considered "external" to energy-production costs, such as environmental and societal costs, should be "internalized" to obtain a truer picture of total costs and benefits, in fact there is little evidence that such "external" factors were seriously considered in many sections of the DES. Particularly in Section 8 (Alternative Technology Options), wherein the feasibility of these options is measured in dollars-and-cents, and in many cases rejected on this criterion, it appears that traditional "internal" costs were given primary and often total consideration, to the exclusion of "external" costs. For example, the discussion on "Hydrogen and Other Synthetic Fuels" contains the argument:

At an electric power cost of 5 mills/kWh, the power cost in terms of hydrogen produced is about 10¢/lb H₂ resulting in a total cost, excluding labor, maintenance, and overhead costs, of 14.3¢/lb H₂ or about \$2.80/10⁶ Btu. This is considered higher than the cost of other fuels (e.g., low Btu gas can be produced from coal at a cost of about 60¢ to 85¢/10⁶ Btu)."

- Section A.6.4 -

"Although further discussion on the following page admits that environmental effects would have to be considered, such effects are not in any manner recorded a monetary or otherwise quantitative status. Such avoidance of "internalizing" costs is symptomatic of the entire Alternative Technology Options discussion, and this weakness should be remedied in the FES."

Response:

External costs have been considered in preparing the Section on Alternative Technology Options and were an important part of the cost-benefit discussions in most parts of that Section. For example, in the discussion of the first alternative considered, light water reactors, a table was included on page A.1.1-74 of the Draft Statement comparing the costs and impacts of light water reactors and coal fueled power plants. This table included consideration of the conventional internal costs such as plant capital costs, operating and maintenance costs, and fuel costs, and also covered occupational health and safety "costs" (fatalities and injuries), transportation considerations, environmental degradation, and other external costs of the type indicated in the letter. Similarly, the HTGR section included a table of this type (Table A.1.2-4 in the Draft Statement), and the coal section carried a discussion of "Indirect or External costs" (page A.2-61 in the Draft Statement).

The environmental effects of effluents which are controllable by modifications in mining and processing practices and by equipment added to the power plant would be transferred to direct costs recoverable from utility revenue. Adoption of full-cost pricing at all stages of the energy system - i.e., internalizing the environmental costs of energy production and use - would significantly reduce but not eliminate the external costs. Indirect costs were also examined in the discussions of solar energy and geothermal energy, which noted for example, that certain costs of geothermal energy will not appear in the market price of the products. These may include: (1) ground subsidence, (2) environmental effects of gaseous and liquid effluents, (3) withdrawal of land from other potential uses, and (4) increased seismic activity. Of course, not all of these will be present in every geothermal development, and some, such as environmental effects of effluents, may be controlled by added power-plant equipment and would thus be transferred to direct costs recoverable from power revenue.

It should be kept in mind that external costs are somewhat difficult to foresee in the early stages of technology development and only become apparent as the technology is placed into large scale commercial use.

The degree to which these external costs are recognized is also a function of the extent of awareness of the public as to what constitutes an external cost. Thus, for many decades the environmental consequences of coal mining and automotive transportation were accepted as tolerable until the accumulated environmental burden could no longer be ignored. In this respect, nuclear power, being the most closely supervised of energy technologies, has gone further in identifying external costs and internalizing them at an early stage of commercial utilization than any energy technology to date. New technologies which have not reached the stage of significant commercialization have substantial uncertainties associated with evaluating their full external costs. In any event, some of the most profound though subtle external costs of a technology can never adequately be expressed in dollar terms. For example, it is not possible to apply a dollar value to the effects of the automobile in promoting urban decay and suburban sprawl or the effects of coal mining practices in promoting Appalachian poverty. With these limitations in mind, it is felt that the extent to which the costs and benefits of each alternative have been examined, which includes general consideration of external costs, is an adequate basis on which to make comparisons of the overall advantages and disadvantages of alternative technology options.

3. Comment (p. 3):

"The discussion of Conservation of Energy in section 8C is 'limited in that changes necessitating serious adaptations in our national life-style are not included...the same changes in life-style which we may now reject might someday be considered desirable or needed..'"

Response:

Conservation measures which would require changes in life style were alluded to as, for example, on page C.6-20 of Chapter 8 in the Draft Statement. More specific information on this subject has now been added under Section 6C.6 in the Final Statement, and your attention is directed thereto. It is shown there that although some changes in lifestyle may involve little inconvenience or hardships, some major concepts for energy conservation could involve substantial restructuring of our economy and perhaps even our landscapes. For example, redesign of cities and transportation systems requiring several decades and billions of dollars would be among the many measures required to meet the Zero Energy Growth concept suggested by some conservationists. Obviously, the decisions that will have to be made regarding potential changes in lifestyle must include consideration of economic, technical, political and environmental factors, as well as social and energy conservation matters.

4. Comment (pp. 4-5)

"Before embarking on an undertaking which has never in the history of mankind involved so many resources and commitments of long term guardianship an agency is required by law to examine alternatives of which the basic assumption of need is one." "A thorough discussion of the reasons for these great differences in demand predictions and the supporting evidence for these predictions is the minimum requirement for satisfying NEPA."

Response:

The Final Environmental Statement has been modified to include discussions of energy demand predictions from a number of sources and an expanded discussion of the techniques utilized in the energy demand projections for the cost-benefit analysis. An additional cost-benefit calculation was made to determine the effects of a 50% reduction in the year 2020 electrical energy demand. This reduced electrical energy demand is indicative of the anticipated demand assuming successful energy conservation measures.

5. Comment (p. 5):

"'More energy will be needed to raise the standard of living of low income people to a more equitable level.' (Section 2.1.2.2) This statement is an unsupported emotional appeal and should be removed from the DES. The facts show that the gap between the two groups, poor and nonpoor, has been widening since the advent of inexpensive power. 'Helping the poor' cannot be used to justify the implementation of an LMFBR program'."

Response:

The sentence in question has been deleted. On balance, we agree that more energy does not necessarily assure societal equities.

6. Comment (p. 5)

"In the perspective on alternative technology opinions (Vol. IV P-3) there is a statement which maintains that systems on which little or no work has been done will look most attractive since the natural enthusiasm of their proponents will highlight the advantages of the system while the difficulties and limitations are minimized or, most likely, have not been discovered. This statement is a collection of unsupported emotional inferences. The inference that natural enthusiasm prevents limitations and difficulties of new technologies

from being discovered, while not necessarily true, could be used to characterize certain aspects of the LMFBR program, as well as other new technologies. The statement that the limitations have most likely not been discovered is a misuse of subjective probability."

Response:

The quoted statement on page P-3 of Chapter 8 in the Draft Statement is part of a paragraph explaining the need for a basis for comparison of alternatives. Experience has shown that conceptual technology often is evaluated by its maximum theoretical potential, while proven technology is compared on the basis of performance. Between these two levels of maturity a number of milestones in the development of a new technology can be delineated. A set of three milestones is defined on page P-4 of the Draft Statement as a basis for comparing alternatives. Thus, the Statement attempts to provide an objective framework for the necessarily subjective comparisons which must be made among conceptual technologies.

7. Comment (pp. 5-6):

"The feasibility of clustering nuclear facilities in parks is questioned on several grounds." "One of the basic points to consider is the site selection procedure." "...the FES will have to address itself to nuclear facilities and the associated industrial plants that they attract.

In Section 7.4.3.5 the DES discusses the prospects of theft or sabotage at a nuclear facility. The probability of theft and/or sabotage could be increased at a nuclear park. The FES should address itself more fully to these two problem areas and provide suggestions to minimize or prevent theft and sabotage. Consideration of nuclear parks as strategic targets for foreign powers to attack or for radical and fanatic groups to use for attainment of their goals should be included in the FES."

Response:

Nuclear energy centers potentially provide a means of reducing certain costs and environmental impacts, in particular those related to shipment of spent fuel, as discussed in Section 4.5.6.3. However, the utilization of a specific site and the total environmental impact of a nuclear energy center and any associated industry will be subject to individual review as stipulated by NEPA. As noted in Section 7.2.6.4, an analysis of nuclear parks is planned.

The AEC does not believe that the probability of theft or sabotage would be increased at a nuclear park. As indicated in Section 7.4.9.4.2 of the Final Statement, increased safeguards effectiveness could be expected to result from the consolidation of perimeter protection and response forces made possible by the adoption of the nuclear energy center (nuclear park) concept. Regarding wartime attack on nuclear parks, the conclusion reached in Section 7.4.4.1, that the additional effect of targeting nuclear facilities would be masked by the overall consequences of a massive strategic attack, is believed valid whether or not the nuclear park concept is adopted.

8. Comment (p. 6):

"A major problem with a nuclear facility is waste heat. In Section 9.1.2.1, it is stated that the discharge of heated effluents to the environment is "not really an environmental impact but is instead an index of such impact, actual impacts are better described by enumerating the effects of heated discharge." The point is well taken, but heated effluents can have an environmental impact that must be dealt with in a meaningful way, and the index-versus-impact argument should not be used to justify inadequate consideration of thermal impacts. If appropriate site selection criteria were formulated and adhered to then the effects of thermal discharge on the biota could be lessened."

Response:

The concept of "index-versus-impact" was introduced only to point out that the discharge of heated effluents is only an index to site-specific impacts on water usage, land usage and related effects of biota and man. Land and water usage are discussed in Section 9.1.4 of the Draft Statement. As stated in Section 9.1.2.1, biological impacts have not been included for two reasons. First of all, the potential impacts are varied and complex and strongly dependent upon the specific plant site. Secondly, it is presumed that discharges conform to applicable state and federal regulations designed to protect the environment.

9. Comment (p. 7):

"Table 10.2 lists the materials and estimated quantities to be used in the construction of a 1000 MWe LMFBR plant, while Table 10.3 compares production, uses, and resources of these materials. The production and consumption figures are based on 1969 data which are of questionable use in estimating production and consumption of these materials in the future of an economy expanding consumption

in all sectors (not only in nuclear energy production). The assumption is made in the DES that the United States can produce or obtain the resources it needs for the development of a breeder economy. Important social, political, and environmental impacts from the acquisition of these materials have been neglected."... "Political ramifications are inevitable, since many of these materials are obtained from other countries (copper from Chile, oil from U.A.R., aluminum from Jamaica, etc.). The recent oil embargoes and the nationalization of Chile's copper reserves are prominent examples."

Response:

As was stated on p. 13 in Chapter 10 of the Draft Statement, "...the commitment of resources to the projected LMFBR industry does not appear to be appreciable or critical..." Uranium resources, which are unique to fission power, will be conserved with the introduction of the LMFBR. Dependence on foreign supplies for metals is not unique to the LMFBR. On the other hand, the LMFBR can reduce the commitment to imported fossil fuels.

10. Comment (pp. 7-8):

"Concerning financial resources, is it reasonable to assume that private utilities could raise the estimated capital of \$512 billion (through 1990)? 15% of the GNP seems a large sum to be raised through public financing in an expanding inflationary economy."

Response:

The estimated annual capital requirements for fossil-fueled plants and nuclear power reactors were compared to GNP projections in Table 5.3-1 in the Draft Statement. The total annual capital requirements for the years 1985 through 2020 are always less than 3% of the GNP, or a factor of 5 lower than your estimate. In 1970 private utilities accounted for 7% of the total funds raised in all credit markets. The total credit funds in 1970 were about 12% of the GNP. The estimated financial requirements do not seem unreasonable.

Dean E. Abrahamson
1092-25th Ave. S.E.
Minneapolis, Mn. 55414

April 24, 1974

Dr. James L. Liverman
Assistant General Manager for Biomedical
and Environmental Research and
Safety Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. Liverman:

Enclosed please find three (3) copies of the Natural Resources Defense Council, Inc.'s comments on the safeguards and diversion portions of the draft environmental statement on the LMFBR Program (WASH 1535).

Should you have questions on these comments, or if there is any way that we can be of assistance to you, please contact Mr. J. G. Speth at NRDC in Washington, or me.

When it is ready, I would appreciate receiving a copy of the final environmental statement for the LMFBR Program.

Sincerely yours,

Dean E. Abrahamson, M.D., Ph.D.

enclosure:

cc: J. G. Speth, Esq.

Natural Resources Defense Council, Inc.

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Executive Director

NRDC Comments on WASH 1535

Draft Environmental Statement

Liquid Metal Fast Breeder Reactor Program

Re: Volume I, Section 1.7.3
Volume III, Sections 5.4.2 and 5.4.3
Volume III, Section 7.4
Volume III, Appendix III-A

Safeguards and Diversion of Special Nuclear Materials

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Introduction

On August 14, 1973, NRDC submitted for consideration in the preparation of this Draft Environmental Statement on the LMFBR Program our comments on the general scope of the statement, including the safeguard and diversion problems.¹ In addition, over the past several years and particularly during the past months, increasing attention has been drawn to these problems through various means, including: testimony before the Joint Committee on Atomic Energy;² publications in the general press;³ and the publication of major studies on nuclear theft and

1/ J.G. Speth and Thomas B. Cochran, "Comments Submitted to the Atomic Energy Commission Regarding the Preparation of the Draft Environmental Impact Statement for the LMFBR Program," Natural Resources Defense Council, August 14, 1973.

2/ Theodore B. Taylor, Remarks before the U.S. Congress, Joint Committee on Atomic Energy, January 28, 1974. Because of the general applicability of this testimony to these general remarks on the adequacy of the safeguards section of the Draft Environmental Statement, WASH 1535, the entire testimony is included in these comments as Appendix A.

3/ John McPhee, "The Curve of Binding Energy," The New Yorker, December 3, 10, and 17, 1974.

safeguards.⁴ All of these activities and many more relating to the same topics, must be known to the AEC. These publications, and others, discuss in some detail the availability of special nuclear materials (SNM) in the fission fuel cycles, the means through which SNM might be diverted by national governments or sub-national groups or individuals, the motivations for such diversions, the details of construction of explosive or radiological weapons from SNM, and the effects which might result from the use of these radiological or explosive weapons. Hence, we assumed that the AEC would take the opportunity afforded by the Draft Environmental Statement on the LMFBR to state the findings of these studies, to respond in detail to them, to critically comment on the conclusions stated by their authors, and to outline in detail the measures being taken or anticipated to cope with the risks of diversion from the LMFBR fuel cycle.

Upon receipt of copies of the Draft Environmental Impact Statement we were appalled at the treatment of this problem in: Section 1.7.3, Safeguards, Volume I; Section 5.4.2, Socio-Political Impacts: The National Dimension, Volume III; Section 5.4.3, Socio-Political Impacts: The International Dimension, Volume III; Section 7.4, Safeguards, Volume III, and; Appendix III-A, Consideration of Selected Safeguards-Related Topics, Volume III. In addition, we were profoundly shocked to find safeguards-related matters totally ignored in the balance of the Draft Environmental Statement, particularly in: Chapter 3, LMFBR Program, Volume I, a chapter which purports to set forth the objectives of the entire LMFBR Program Plan, and which includes, "A summary of the scope

4/ See e.g. Mason Willrich and Theodore B. Taylor, Nuclear Theft: Risks and Safeguards (a report to the Ford Foundation Energy Policy Study), Ballinger Publishing Co., Cambridge, Mass., 1974.

and, Mason Willrich, (editor), International Safeguards and Nuclear Industry, Johns Hopkins University Press, Baltimore and London, 1973.

and status of each of the studies and program plans;" Chapter 8, Volume III and all of Volume IV, both titled, Alternative Technology Options, and; Chapter 11, Cost-Benefit Analysis of Implementing the LMFBR Program, Volume III.

While the Draft Environmental Statement does mention the problems of preventing diversions of SNM, the problems are not discussed in sufficient detail to characterize their dimensions. The manner in which these diversions will be attempted to be prevented or the effects should diversions take place are totally ignored. Further, the Draft Statement does not describe studies underway which address the various aspects of the safeguards and diversion problem. Nowhere does the Draft Statement include even the most rudimentary description of the LMFBR fuel cycle including such things as the quantities and chemical or physical form of the special nuclear materials at each point in the fuel cycle. No mention is made of the relative advantages or disadvantages, from the standpoint of prevention diversions of SNM, of alternatives to the LMFBR Program. No mention is made in the economic analyses of the costs of safeguards programs or the costs which could accrue to society should there be a failure of the safeguards.

In short, other than to define the general nature of the safeguards problems--both national and international--the Draft Environmental Statement ignores the issue. Safeguards has not been taken into account. The issue has been excluded from consideration. The situation is reminiscent of that of a few years ago when the AEC attempted, unsuccessfully, to ignore the thermal effects of fission power reactors.

The Nature of the Safeguards Problems

The general nature of the problems associated with safeguarding SNM is defined in the Draft Environmental Statement as:

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"Certain materials present in nuclear reactor fuel cycles must be considered as possible targets for illegal diversion and subsequent use in the fabrication of nuclear explosive devices or in dispersal to create radiological incidents. The possibility of sabotage of facilities resulting in radiological incidents must also be considered."⁵

In another section of the Draft Statement it is acknowledged that this hazard is not present in non-nuclear options to the LMFBR Program, and further, the nature of the hazard is again emphasized:

"A major difference between an electrical energy system based on nuclear fission and alternative non-nuclear systems derives, in the former case, from the wide distribution of fissile materials (i.e., plutonium or uranium) in the economy. A significant concern regarding the use of plutonium is the potential for diversion of this material for the production of weapons or sabotage, resulting in potential radiological danger to the public. The need to protect hazardous materials has, of course, existed in the past. Nuclear power reactors are a potential hazard to the public in that they create the means, in theory at least, of a new form of anti-social behavior."⁶

The Draft Statement also acknowledges that in addition to these hazards, there is an international component, namely to prevent SNM from being diverted from reactors into national atomic weapons programs:

"A nuclear energy economy has a number of international implications with difficult institutional aspects. Generally, as reactor technology extends beyond the technologically sophisticated, politically stable countries of the world, the international implications of nuclear power will require international agreements and institutions to assure that the common good is, indeed, protected."⁷

After briefly describing the system of international safeguards which it is hoped will "prevent the diversion of material suitable for weapons production from peaceful applications,"⁸ the Draft Statement goes on to recognize that the present systems are inadequate for a reactor economy including LMFBR's:

^{5/} WASH 1535, page 7-64.

^{6/} WASH 1535, page 5-31 and 5-32.

^{7/} WASH 1535, page 5-33.

^{8/} WASH 1535, page 5-33.

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"One may, therefore, conclude that the institutional framework for an effective international safeguards program does exist although significant expansion and modification is anticipated as an LMFBFR economy develops."⁹

It is noteworthy that the Draft Statement does not claim that the present international safeguards system is adequate even for today's reactor economy, but simply states that "the institutional framework for an effective international safeguards program does exist." Further nowhere in the Draft Statement is there comment on the degree to which other nations have found the present international safeguards program acceptable, or the degree to which there is acceptance that this program must undergo "significant expansion and modification."

That SNM is present in significant quantities in the LMFBFR fuel cycle is also recognized by the authors of the Draft Environmental Statement:

"In the year 2020, about 550 LMFBFR electrical generating stations [each of 4000 Mw(e)], about 28 fuel fabrication plants and about 28 reprocessing plants could be in operation. In the same year, there might be about 5000 metric tons of fissile plutonium present in the U.S. LMFBFR fuel cycle, about half of which would be in reactors. The extent of plutonium product transportation between facilities would be strongly influenced by facility location and siting practices; about 100,000 shipments (including highway and rail) might take place in the year 2020."¹⁰

The above excerpt is the total description of the quantities and form of SNM which would be present in the LMFBFR fuel cycle. Although the information in the Draft Statement does suffice to indicate that these materials are present in large quantities, it is totally inadequate to permit the reader to appreciate the distribution, and the chemical and physical form, of the SNM at various points of the fuel cycle. For this material, we refer the AEC to the recent analysis of nuclear theft possibilities. The heavy lines in the schematic diagram of the LMFBFR fuel cycle depicted below indicate the parts of the LMFBFR

⁹/ WASH 1535, page 5-34.

¹⁰/ WASH 1535, pages 7-64 and 7-65.

fuel cycle in which there will be materials that can be used directly in fission

LIQUID METAL-COOLED FAST BREEDER FUEL CYCLE¹¹

bombs. The weight of materials required to provide one critical mass of fission explosive material without either chemical processing or isotope enrichment has also been reported. The quantities, in the LMFBR fuel cycle are:¹²

LMFBR fuel fabrication input or reprocessing output	PuO_2	about 9 Kg
LMFBR fabricated fuel or fuel pellets	$\text{PuO}_2 + \text{U(D)}\text{O}_2$ or $\text{U(N)}\text{O}_2$	about 30-60 Kg

Although these are impressively small numbers compared with the total quantities that would be present at various places in the LMFBR fuel cycle, and imply extraordinarily high standards of materials accountability, the quantities of plutonium required to make a bomb are very large compared with the quantities that would be required to make a radiation weapon. Again from

^{11/} Mason Willrich and Theodore Taylor, op cit, Figure 3-3, page 48.

^{12/} Willrich and Taylor, op cit, page 55.

Willrich and Taylor:

"Sufficient quantities of plutonium to cause considerable damage if widely dispersed exist at all stages in the LWR [light water reactor] or LMFBF fuel cycles that contain plutonium. Even a few pellets of plutonium-bearing LWR fuel or LMFBF fuel, if ground into an extremely fine powder, would contain enough plutonium (a few grams or so) to be usable in a plutonium dispersal device that could seriously contaminate a large area. But theft of small amounts of plutonium from parts of the fuel cycle where it is mixed with intensely radioactive fission products does not appear credible to us. This leaves the output of reprocessing plants, plutonium storage facilities, fuel fabrication plants, fresh fuel storage facilities, and the transportation links between these facilities as the likely places for theft of plutonium for use in radiological weapons. Among these, the places that would be most vulnerable to attempted thefts would be the plutonium load-out rooms at reprocessing plants, where an employee might pour very small quantities of plutonium nitrate into a container for surreptitious removal; or at fuel fabrication plants, where an employee might steal a few fuel pellets or a plutonium-bearing fuel rod or fuel pin."¹³

Given then that SNM exists in large quantities in the LMFBF fuel cycle, that were it diverted it could form the basis for the fabrication of either an atomic bomb or a radiation weapon, what does the Draft Environmental Statement have to say about those who might wish to utilize the potential for this "new form of anti-social behavior?"⁶ On the questions associated with the international safeguards issue the Draft report is completely silent. There is not a single word addressing this topic although the unclassified literature is replete with such discussions.^{14, 15, 16, 17, 18} As to the threat of domestic diversion we

13/ Mason Willrich and Theodore Taylor, op cit, pages 55-56.

14/ B. Feld (editor), Impact of New Technologies on the Arms Race, MIT Press, Cambridge, Mass., 1971.

15/ United Nations Association of the U.S.A., Safeguarding the Atom: A Soviet-American Exchange, U.N. Association of the USA, New York, July 1972.

16/ Sheldon L. Williams, The U.S., India, and the Bomb, Johns Hopkins Press, Baltimore, 1969.

17/ Mason Willrich, Global Politics of Nuclear Energy, Praeger Publishers, New York, 1971.

18/ C.F. Barnaby, Preventing the Spread of Nuclear Weapons, The Humanities Press, New York, 1969.

NOTE: References 14/ through 18/ are cited as examples only, there is a very large number of publications which discuss these issues.

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find only:

"The above information relates to one major aspect of the future safeguards problem: the extensiveness of the 'target' for sabotage or diversionary activities. The other major aspect--the inclination of individuals or groups to attempt diversionary acts--is not readily subject to quantitative description. Considering the present social/political climate in the U.S. and abroad, it is assumed that the prevalence of criminal activity will not diminish in future years. Also, the number of individuals with technical/scientific training can be expected to increase. These general factors, coupled with the broadened 'target' for diversion offered by the increased use of plutonium, indicate the need for continuous upgrading and strengthening of the AEC's safeguards program."¹⁹

What then are the objectives of the "AEC's safeguards program?" They too are set forth in the Draft Environmental Statement:

"The primary safeguards objective of the AEC is to prevent theft of special nuclear materials (SNM) [plutonium and the fissionable isotopes of uranium] and other materials whose illegal use could create a radiological hazard, and to prevent sabotage of facilities containing such materials. A second important objective is to respond or initiate response to such acts, if they are carried out, in a way that neutralizes or minimizes the consequences."²⁰

And the goal is absolute prevention of any theft:

"The AEC seeks to prevent any diversion of nuclear material and does not recognize any quantitative limit on this objective."²¹

How this goal of perfect containment, of absolute prevention of theft or recovery of SNM should there be a theft, is to be achieved is left to the reader's imagination. To what example can he turn, for history indicates that any valuable commodity has been stolen and is being stolen. Again, as in the case of consideration of serious reactor accidents, the AEC seems to be falling back on faith--it is fully recognized that diversion of SNM simply cannot be permitted to happen, hence it will not happen. How? Have faith young man, have faith.

^{19/} WASH 1535, page 7-65.

^{20/} WASH 1535, pages 7-65 and 7-66.

^{21/} WASH 1535, page III-A-1.

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Whatever be in the collective mind of the AEC for this hypothetical, perfect system which will prevent any and all theft, the present system is recognized as being inadequate. In the case of the international safeguards program, "significant expansion and modification is anticipated as an LMFBFR economy develops,"⁹ and in the case of the domestic program, "These general factors, coupled with the broadened 'target' [the LMFBFR fuel cycle] for diversion offered by the increased use of plutonium, indicate the need for continuous upgrading and strengthening of the AEC's safeguards program."¹⁹

At this point in the Draft Environmental Statement the reader would expect to find a full, candid, and explicit discussion of the features in the present safeguards program which would be inadequate were the LMFBFR to be developed, of the nature of the anticipated measures to "expand and modify" and to "upgrade and strengthen" the existing safeguards program. What instead is found is a flatulent exposition of the "safeguards measures presently in place," and nary a word on what would come, other than:

"The expected growth of commercial nuclear power in the U.S., including the LMFBFR with its large quantities of plutonium, indicates the need for continuous upgrading and strengthening of the AEC's safeguards program. The currently defined AEC safeguards objectives and program elements are believed to provide the broad scope and flexibility necessary for timely development, placement and enforcement of such modified or new safeguards requirements as may be found necessary. The program elements themselves are not fixed, but may be strengthened or expanded as the result of continuing in-house review. Similarly, while the safeguards program in its present implementation provides a strong base, it must be viewed as an evolving program. As indicated earlier in this section, a number of areas are currently under investigation which may result in new or modified requirements. Additional investigations, analyses, social studies and hardware developments are anticipated."²²

What are the characteristics of the various means available to eliminate or to reduce the hazards posed by a diversion of SNM? The Draft Statement

^{22/} WASH 1535, pages 7-84 and 7-85.

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gives few clues, one must look elsewhere for any indication of the various means available. It is obvious that one way to eliminate the hazard is to eliminate the "target"--that is to not initiate the LMFBR Program and as quickly as possible to cease the current production and utilization of special nuclear materials. It is not surprising that the AEC wishes not to discuss this option. There are, however, means available short of abandonment of commercial nuclear fission which could, if not eliminate, at least minimize the hazards. These include: denaturing the plutonium and other SNM such that even if diverted it is incapable of being used in weapons, with means that would be available to the group or individual bent on "anti-social behavior;" confinement of those elements of the LMFBR fuel cycle from which diversion is credible to a single location, the basis for the nuclear park concept, and; a system of physical, social, and behavioral controls. As the first of these methods is totally ignored in the Draft Statement, and the second mentioned only obliquely, a few comments are in order.

These various alternatives have been most recently outlined in a short paper by Professor Bernard T. Feld, part of which follows:

"...if this is the case [the utilization of uranium/plutonium fuel cycles] then, within the coming decade or two, the major security problem that the world will face is how to prevent the widespread dissemination of nuclear weapons, not only to governments or semi-governmental bodies, but to groups of unauthorized, even antisocial, elements as well.

"Accepting these premises as fact, we may ask whether there are any means available for frustrating this prediction of widespread proliferation of nuclear weapons, arising from the inevitable diffusion of plutonium and the knowledge of its chemical and nuclear properties.

"A number of possibilities are outlined here for coping with this problem....

- "1. The most straightforward means of coping with the problem of the proliferation of nuclear weapons would be for the technologically-advanced nations to agree at this time to forego the plutonium breeder reactor

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route to the solution of the power crisis: to agree individually and in concert, that fission energy is to be regarded as an interim solution. Moreover, sufficient stores of ordinary and slightly enriched uranium are available to carry us, via conventional reactor sources, through the energy crisis of the next decade....

- "2. Assuming the inevitability of a growing plutonium-based power economy, the next-best approach would be to devise an iron-clad system of control over the plutonium stores--preferably an effective international agency--to insure that under no reasonably conceivable circumstances could they fall into irresponsible hands (the Fort Knox approach)....even this relatively milder form of international action (as compared to banning plutonium) does not appear to have any appreciable prospect for adoption.
- "3. Barring such 'political' solutions, it is incumbent upon us to explore the possibilities of a technical solution to the problem--to seek to devise a means whereby the vast stores of plutonium in circulation might be rendered unsuitable for conversion into nuclear weapons. This brings us to a question of 'denaturing' plutonium, a possibility that was frequently mentioned in earlier discussions of nuclear weapons control, but has recently been cast into serious doubt as a result of improvements in nuclear weapons technology in the most developed countries. (See Carson Mark in Impact of New Technologies on the Arms Race, Cambridge, Mass., MIT Press, 1971.)

"The concept of plutonium denaturing arises from the peculiar properties of a heavier isotope of plutonium (plutonium-240). This isotope is, on the one hand, similar to the heavy uranium-238 isotope in that it does not readily undergo fission and, therefore is not suitable for making atomic bombs. But it has the additional property of being a prolific and spontaneous neutron emitter. This latter property renders the normal plutonium-239, with which plutonium-240 may be mixed, very much more difficult to detonate in an explosive fashion.

"...it should be possible to design the plutonium breeder reactors so as to maximize the concentration of plutonium-240 in the breeding process.

"It is doubtful whether it would be feasible to increase the plutonium-240 concentration to a degree that would render the plutonium non-explodable. But such highly denatured plutonium might increase the technical difficulty sufficiently so as to require a technology beyond the means of any but the most technologically-advanced laboratories. This would be one way of handling the 'Mafia problem.'

"It would also be well worthwhile to investigate other means, both physical and chemical, of denaturing plutonium....

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"The objective would be to raise the barriers against the clandestine diversion of reactor-intended plutonium into weapons production. The importance of the nuclear proliferation problem is so immense as to require the greatest urgency in further investigations of the denaturing of plutonium as well as other technical and political solutions."²³

We do not represent the denaturing proposal forth as being a solution to the safeguards and diversion problem, for at best it would minimize the hazard posed by illegal atomic explosives as it is difficult to imagine a credible denaturing process that would diminish the hazard of a dispersal weapon. Further, we have serious doubts as to whether the denaturing scheme is even credible means to reduce the illegal explosives problem. It is a scheme, however, which is proposed from time to time and the AEC should take the opportunity afforded by the Final LMFBR Program Impact Statement to present a full discussion of the technical and economic merits and penalties of denaturing.

Another scheme for reducing the hazards of diversion of SNM is to locate the most vulnerable elements of the LMFBR fuel cycle at a single site. This concept, that of the "nuclear park," would involve the common siting of: fuel fabrication facilities, several reactors, the chemical reprocessing plant, and perhaps also the high-level radioactive waste management installations. The safeguards advantages of such nuclear parks are mentioned almost in passing in the Draft Environmental Statement, but consistent with any other aspect of the safeguards and diversion problems, are treated in a wholly inadequate manner:

"Nuclear energy centers [nuclear parks] would have the advantages of significantly reducing the requirements for transportation of fuel and radioactive waste and of simplifying nuclear safeguard problems."²⁴

23/ Bernard T. Feld, "The Menace of a Fission Power Economy," Science and Public Affairs, April 1974, pp. 32-34.

24/ WASH 1535, page 1.5-2 (a nearly identical statement, again without any elaboration or further discussion, is found at page 5-28).

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This option deserves more discussion than is contained in the Draft Environmental Statement. Not only does siting of LMFBR's in nuclear parks appear to have major advantage in reducing the hazards of diversion of SNM, but also there are several other advantages. As with all things, however, nuclear parks have disadvantageous implications. The Draft Environmental Statement sheds no light whatsoever on these issues, and does not even contain a superficial discussion of the advantages and disadvantages of nuclear parks, say nothing of the detailed analysis--including analyses of the economic and institutional factors--which an adequate Environmental Impact Statement demands. An excellent framework from which the AEC might begin these analyses can be found in several articles by Alvin Weinberg.^{25, 26}

The Draft Statement is seriously deficient in its treatment of the one approach to the diversion problem which it does purport to consider. A major deficiency in the Draft Statement is the failure to include any discussion at all of the attitude and response of the nuclear industry to the significant "upgrading," "modification," "expansion," and "strengthening" of the safeguards program which the AEC asserts in the Draft Statement as an essential feature of the LMFBR Program. The only hint that the AEC is aware of industry's interests in these matters is found in:

"In carrying out its program, the Commission seeks to be responsive to the views of the public and the industry, consistent with its charter to assure protection of public health and safety and of the common defense and security."²⁷

^{25/} Alvin Weinberg, "The moral imperatives of nuclear energy," Nuclear News, December 1971, pp. 33-37.

^{26/} Alvin Weinberg, "How can man live with fission?" unpublished paper circulated for discussion at a conference at the Woodrow Wilson International Center for Scholars, Washington, D.C., June 18, 1973.

^{27/} WASH 1535, page 7-67.

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Some indication of the degree to which the atomic industry is sensitive to the diversion hazards, and the degree with which the industry is likely to be an effective partner in the enforcement and implementation of safeguards programs can be gleaned from published accounts of the industry's response to the modest strengthening of the AEC safeguards rules which were first published in the February 1, 1973, Federal Register.²⁸

Some of the comments received on these proposed regulations were:

"...it is clear that the severity of the proposed [physical security] procedures greatly exceeds any reasonable relationship to the public need intended to be served. We are unaware, and we believe the industry as a whole is unaware, of occurrences of industrial sabotage which would tend to justify the imposition of requirements as strict as those proposed. The Commission has not demonstrated the need...or offered any justification or explanation.... Certainly the public interest will not be served by adoption of burdensome requirements disproportionate to the end sought."

---from comment of Kerr-McGee:

and

"...a move backward to the types of security practices in the Manhattan District era."

---from comment of Westinghouse;

and,

"One principal objection is to the emphasis placed on the use of armed personnel...and the seeming reliance on such personnel to protect against threats to the common defense and security.... To the extent that the proposed regulations...require an armed confrontation between a licensee's security force and potential divertors, the proposed regulations should be amended. The surest and most proper method of protection...is prompt detection and reporting...."

---from comment of United Nuclear.²⁹

28/ anon, "Industry Inundated by Proposed New Safeguards Rules," Nuclear Industry, February 1973, pp. 45-47.

29/ The segments of the comments by Kerr-McGee, Westinghouse, and United Nuclear, are as quoted in: anon, "Sharp Industry Criticisms of Proposed New Safeguard Rules," Nuclear Industry, May 1973, pp. 31-34.

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The final Environmental Statement must include a full and candid discussion of either how the AEC proposes to enact and enforce the safeguards program which it contends will be necessary with the LMFBFR without the support and cooperation of the nuclear industry, or the means that are anticipated to proceed with the LMFBFR without depending on industry participation in matters involving potential diversions of special nuclear materials.

There is in the Draft statement a hint that the AEC is not anxious to discuss the possibility of coercive measures, imposed against either individuals or the industry, but also that the necessity for these measures is being evaluated:

"Some secondary impacts of the safeguards program are mentioned here. The Federal Government has established regulations which must be complied with not only by the electric utilities, but also by the industrial sector engaged in the storage, processing or transportation of nuclear materials. These regulations will be followed by companies which, in some cases, may have no other connection with or requirements imposed upon them by the government aside from those inherent in normal industrial or commercial activities. For example, only authorized individuals, perhaps eventually only those with AEC security clearances, will be permitted entry to nuclear materials storage areas. This imposition of security controls will represent an increase in the role of the Federal Government in the private industrial sector. The significance of this tendency will, in all probability, be small because of the very small fraction of the labor force involved. Nevertheless, as the LMFBFR program progresses and as it affects a larger segment of the industry, the public should be conscious of possible restrictions in employment opportunities, for example, for some individuals because of their past or current political activity. The extent to which the Federal Government may becoming (sic) concurrently involved in sectors of the economy now considered 'private' is beyond the scope of this Statement."³⁰

We must take strong exception to this final assertion for the extent to which the existence of the LMFBFR program, which cannot of course be divorced from other civilian fission programs, will impose the necessity for behavioral,

^{30/} WASH 1535, page 5-32.

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social, and other controls is among the most profound and grave of all of the many questions surrounding the development of the LMFBR Program. What are the changes, not in technology, but in our very social institutions that may be dictated by a decision to proceed with the LMFBR Program? The many reports, and other publications of the AEC are of little value in addressing this aspect of atomic energy, one must look to the writings of individuals who although committed to the development of atomic energy yet have concern for the dignity of the individual and for the stability of our social institutions, for example:

"...the discovery of the bomb has imposed an additional demand on our social institutions. It has called forth this military priesthood upon which in a way we all depend for our survival.

"It seems to me (and in this I repeat some views expressed very well by Atomic Energy Commissioner Wilfrid Johnson) that peaceful nuclear energy probably will make demands of the same sort on our society, and possibly of even longer duration."³¹

Before leaving this general point, we are obligated to make one additional comment. In an Appendix to the Draft Statement, passing mention is made to a recent evaluation of then existing practices involving the safeguarding of strategic quantities of SNM:

"Improvements Needed In The Program for the Protection of Special Nuclear Material" [Report No. B-164105, dated November 7, 1973, U.S. General Accounting Office], a report by the Comptroller General of the United States to the Congress, discusses observations made by General Accounting Office personnel in the summer of 1972 during their inspection of three facilities handling SNM. These observations related to guard systems, physical barriers, automatic detection devices and action/response plants. A number of deficiencies or apparent deficiencies were identified, and recommendations were made regarding corrective action. The AEC agreed with the recommendations of the report and has taken action to implement them."³²

³¹/ Alvin Weinberg, "Social Institutions and Nuclear Energy," Science, 7 July 1972, pp. 27-34.

³²/ WASH 1535, page III-A-4.

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In fact, the deficiencies identified by the GAO were extremely serious and were sufficient to question whether or not SNM was receiving even the degree of protection afforded ordinary articles of commerce. The GAO study bears testimony, in stark and chilling detail, to the opinion expressed by Ralph Lumb in 1972:

"A critical review of experience during this latter period [1966 to 1972] will result in only one conclusion: normal industrial practice for the protection of corporate assets has not always been employed in the safeguarding of special nuclear material."³³

It seems to us that an adequate Final Impact Statement must also include a candid and complete discussion of the circumstances which prevailed within the Atomic Energy Commission through at least the summer of 1972 and which permitted this lax, and given the degree of the hazard, irresponsible abrogation of responsibility in the protection of special nuclear materials.

And what might be the result of a successful diversion? Again we find the Draft Statement grossly deficient. Nowhere in the Draft Statement is it claimed that were there a successful diversion, that it would be technically difficult, nor a threat to the individuals involved, to fabricate and deliver a device intended to disperse plutonium. We agree. However, the Statement contains a comment on the ease in constructing a nuclear explosive:

"The construction of a workable nuclear explosive device is a complex and difficult task requiring specialized skills and considerable resources. Without testing, there is a substantial possibility that there would be no nuclear yield at all."³⁴

This statement is unsupported either by material included in the Draft Environmental Statement or included by reference. The statement is also in

33/ Remarks of Ralph F. Lumb, as quoted in: anon, "AEC Policy, Safeguards, Discharge Limits, Plutonium," Nuclear Industry, February 1972, pp. 19-20.

34/ WASH 1535, pages III-A-2 and III-A-3.

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direct contradiction to conclusions reached and supported by exhaustively detailed reports by persons acknowledged to be expert in the design of fission bombs. Two of the many such statements follow:

"First, nuclear weapons are relatively easy to make, assuming the requisite nuclear materials are available. All of the information, non-nuclear materials, and equipment that would be required to design and build a variety of types of fission explosives are readily available throughout the world. The technical skills and resources required would depend on the desired efficiency, predictability, total weight, and yield of the explosives. Under conceivable circumstances, for example, a few persons, perhaps even one person working alone, who possessed about ten kilograms of plutonium or uranium-233 oxide or two dozen kilograms of highly enriched uranium oxide and a substantial amount of high explosive could, within several weeks, safely design and build a crude, transportable fission bomb. By a 'crude, transportable fission bomb' I mean one that would be very likely to explode with a yield equivalent to at least 100 tons of high explosive, and that could be carried in an automobile. This could be done using materials and equipment that could be purchased at a hardware store and from commercial suppliers of scientific equipment and materials for student laboratories. All types of plutonium, highly enriched uranium, or uranium-233 now used or contemplated for use by the nuclear industry could be used for this purpose, as long as they are not diluted with large amounts of non-fissionable materials or mixed with dangerous quantities of gamma-ray emitting radioisotopes, such as fission products. The explosion of such a device could, under many circumstances, kill at least tens of thousands of people.

"Smaller quantities of plutonium or uranium-233 than are required for fission explosives could also be incorporated into dispersal devices that could contaminate very large volumes of air with lethal concentrations of suspended, small particles of these substances that are exceedingly toxic if they are breathed. Air dispersal of a few grams of the type of plutonium now being produced in power reactors could kill most of the occupants of a large office building or enclosed industrial facility."²

and

"As a summary, I have tried to be more convincing in the statement that almost all forms of fully enriched uranium--greater than 90 percent--constitutes a real and not an imagined hazard as an explosive device. This statement includes oxides of uranium, in contrast to earlier remarks. The same statement can be made for plutonium, including commercial grades, with the added concern that its enrichment is obtained by chemical separative techniques

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fully described by the Atomic Energy Commission in its handbooks."³⁵

The enormity of the AEC's failure to address the facts which have been presented to the general public by such work as that of Drs. Willrich, Taylor, Hall, and others is difficult to comprehend. There are several possible explanations: (1) it is possible that the authors are simply unaware of the work of Drs. Taylor, et al; (2) it is possible that the statement in WASH 1535 that "The construction of a workable nuclear explosive is a complex and difficult task requiring specialized skills and considerable resources" is correct and the studies and conclusions of Drs. Taylor, et al are badly in error, or; (3) it is possible that the conclusions of Drs. Taylor, et al are correct, but that the AEC has made the political decision to remain silent. It is our opinion that explanation (3) is the more likely situation for it requires fewer assumptions and is completely compatible with the past behavior of the AEC. The traditional practices of the Commission have been to ignore in its own publications any information not favorable to the promotion of atomic power, to suppress such discussion by others whenever it has been possible to do so, and to refuse to include deleterious environmental impacts when preparing the statements required under the National Environmental Policy Act (NEPA). Once again, it appears that "the Commission's crabbed interpretation of NEPA makes a mockery of the Act."

The Final Statement on the LMFBR Program cannot be considered to be adequate unless it directly joins the issues raised by Drs. Taylor, et al, offers convincing evidence that Taylor's conclusions and analyses are in error if they are, and offers a credible and socially acceptable remedy if they are

35/ D.B. Hall, "The Adaptability of Fissile Materials to Nuclear Explosives," Chapter 19 in, Robert B. Leachman and Phillip Althoff (editors), Preventing Nuclear Theft: Guidelines for Industry and Government, Praeger Publishers, New York, 1972, p. 281.

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not.

The treatment of the environmental, social, and political consequences were there a disruptive use of SNM is equally unsatisfactory. The totality of the discussions of these matters, in addition to what is above, is:

"The AEC recognizes the potential for illegal nuclear weapons to produce severe consequences in terms of property damage and loss of life. The destructiveness of any nuclear explosion depends on its yield and on the circumstances at the time and place of its detonation. For an illegal nuclear weapon, neither the yield nor the circumstances can be predicted;

and

"Similarly, an estimate of the effects of a radiological weapon utilizing plutonium would require knowledge of the method and circumstances of its use."³⁶

While the above statements are obviously true, they are also completely inadequate. Are we to believe that the AEC is incapable of imagining the "circumstances at the time and place" of the detonation of an illegal nuclear weapon in the hands of an individual or group bent on "anti-social behavior?" Are we to believe that the AEC is incapable of specifying the effects--in terms of property loss, deaths and injuries, and of political and social responses--for an array of "circumstances at the time and place" which would bracket the possibilities in sufficient detail for policy considerations. We would remind the Commission that while the discussions of matters such as these need not, and should not, be a blueprint for terrorists, neither are they a work order for the crews that would be called in to decontaminate, recover the bodies, and otherwise respond to the use of an illegal explosive or radiological weapon at a precise time and location.

We can turn again to the work of Drs. Willrich and Taylor for some insights into the potential physical effects of these weapons:

^{36/} WASH 1535, pages III-A-2 and III-A-3.

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"A 'crude fission bomb' is defined as one which has an excellent chance of exploding, with a probable yield equal of at least 100 tons of chemical high explosive, and a possible yield of as much as a few kilotons. Even a 'small' nuclear explosion could cause enormous havoc. A nuclear explosion produces not only a blastwave and heat, but also lethal radiation. The effects of a nuclear weapon depend on the characteristics of the target as well as of the weapon itself. In a typical suburban residential area, a 'crude fission bomb' might kill 2000 people, mostly by exposure to radioactive fallout. The same explosion in a parking lot beneath a skyscraper could kill as many as 50,000 people and destroy the entire building.

"In criminal hands, plutonium could be a danger not only as raw material for a bomb, but also in a relatively simple dispersal device. Plutonium is among the most toxic substances known. Airborne particles small enough to be barely visible can cause fibrosis or cancer of the lung. The amounts that could pose a threat to society are accordingly very small. One hundred grams (three and one half ounces) of the stuff could be a deadly risk to everyone working in a large office building or factory, if it were effectively dispersed. In open air, the effects would be more diluted by wind and weather, but they would still be serious and long-lasting."³⁷

There are likewise many discussions in the open literature as to plausible international scenarios dealing with illegal diversion of SNM by nation states. Only one such discussion is included here as being illustrative of the analyses that must be addressed by the AEC in the Final Impact Statement:

"What is new in the problem of war is, of course, the advent of nuclear weapons with their potential for 'irreparable' damage, as contrasted with the much more restricted and more easily repaired damage of most conventional wars. As with the population problem, however, we are in danger of being rendered insensitive to the political ramifications of this element of danger in the human prospect by our tendency to picture it mainly in humanitarian terms.

"The humanitarian aspect of nuclear war has focused our attention mainly on the stupendous killing power of the new weaponry. As Hans Bethe has described it:

^{37/} From pages 4 and 5 of "A Summary of: Nuclear Theft: Risks and Safeguards, by Mason Willrich and Theodore B. Taylor, *op. cit.* at ref: 4. The entire summary of this report, which was distributed at the time that the report was issued, is incorporated into these comments as Appendix B.

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" Let us assume an H-bomb releasing 1,000 times as much energy as the Hiroshima bomb. The radius of destruction by blast from a bomb increases as the cube root of the increase in the bomb's power. At Hiroshima the radius of severe destruction was one mile. So an H-bomb would cause almost complete destruction of building up to a radius of 10 miles. By the blast effect alone a single bomb could obliterate almost all of Greater New York or Moscow or London or any of the largest cities of the world. But this is not all; we must consider the heat effects. About 30 percent of the casualties in Hiroshima were caused by flash burns due to the intense burst of heat radiation from the bomb. Fatal burns were frequent up to distances of 4,000 to 5,000 feet. The radius of heat radiation increases with power at a higher rate than that of blast, namely by the square root of the power instead of the cube root. Thus the H-bomb would widen the range of fatal heat by a factor of 30; it would burn people to death over a radius of up to 20 miles or more. It is too easy to put down or read numbers without understanding them; one must visualize what it would mean if, for instance, Chicago with all its suburbs and most of their inhabitants were wiped out in a single flash.' [Hans A. Bethe, "The Hydrogen Bomb II", in Scientific American Reader, Simon and Schuster, 1953, pp. 194-95.]"

"Our horrified fascination with these and similar statistics has led us to contemplate the consequences of nuclear warfare in terms of the oblitative results of using these weapons en masse, unleashing the 11,000 warheads now possessed by the United States or the 1,200 or so warheads possessed by the Soviets. Indeed, there are estimates of such an exchange, with fatalities ranging from 50 to 135 million for the United States alone, depending on the defense 'posture' of the various estimates.

"It is understandable that we should be hypnotized by the vision of such ghastly possibilities. The risk, however, is that our concentration on this aspect of the consequences of nuclear warfare will lead us to overlook another result of the new technique of war. Essentially it resides in the fact that many small or relatively poor nations, even though they possess no fully developed industrial base or highly skilled labor force, can gain possession of nuclear weapons. As the example of China has shown, a nation with only a limited amount of industrial capacity can manufacture nuclear warheads by itself, although probably not missile delivery systems. The warheads can nonetheless be launched by bombers, smuggled into enemy harbors by ship, and so on. In addition, poor nations can obtain nuclear weapons as a by-product of the atomic power plants that many of them are now building or contemplating (or that will be built for them in the coming years by the developed countries). [See Mason Willrich, "International Control of Civil Nuclear Power," Bulletin of the Atomic Scientists, May 1967.]

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"Thus there seems little doubt that some nuclear capability will be in the hands of the major underdeveloped nations, certainly within the next few decades and perhaps much sooner. The difficult question must then be faced as to how these nations might be tempted to use this weaponry. I will suggest that it may be used as an instrument of blackmail to force the developed world to undertake a massive transfer of wealth to the poverty-stricken world....

"I do not raise the specter of international blackmail merely to indulge in the dubious sport of shocking the reader. It must be evident that competition for resources may also lead to aggression in the other 'normal' direction--that is, aggression by the rich nations against the poor. Yet two considerations give a new credibility to nuclear terrorism: nuclear weaponry for the first time makes such action possible; and 'wars of redistribution' may be the only way by which the poor nations can hope to remedy their condition."³⁸

Regarding the international implications of a failure of the systems designed to "prevent the diversion of material suitable for weapons production from peaceful applications,"⁸ we fully appreciate that there are developments in addition to the proliferation of LMFBR's that could lead to nuclear weapons capability being extended to virtually any nation-state. If, however, the AEC is arguing that it need not discuss the weapons proliferation implications of the LMFBR on the grounds that other developments, for example, in new uranium enrichment technology, assure that this capability will be developed quite independently of the decision to proceed with the LMFBR, then the AEC has the obligation to fully discuss these other developments in the Final Impact Statement.

In Conclusion

The necessity to prevent the diversion of special nuclear materials both by nation-states and by sub-national groups is one of the most vexing of the environmental and social problems associated with the Liquid Metal Fast Breeder Reactor. In considering these problems, David Rose recently

^{38/} Robert L. Heilbroner, An Inquiry Into The Human Prospect, Norton, New York, 1974, pp. 40-43.

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wrote:

"It seems to me that the greatest diversionary hazard is related not to civilian nuclear power, but to weapons and their components. At increasing cost, more protection can be bought, and no one--public or private--would imagine settling for less than enough. But in dealing with irrationality, how much is enough? No one knows. It would be bitter irony if civilization had to renounce its claim to that name through inability to control these aspects of nuclear power; meanwhile, illegal use is to me the most worrisome and least resolved hazard, and a prime motivation for exploring the possibilities of controlled nuclear fusion."³⁹

Alvin Weinberg, in a paper which considers the safeguards problem in addition to the other unresolved hazards associated with the LMFBR and other fission options states:

"It may turn out, after seriously studying the question, that one will conclude that [Hannes] Alfvén is right--man cannot in the very long run live with fission."²⁶

Lawrence Scheinman, another acknowledged expert in safeguards wrote last month:

"The United States has always conducted its nuclear business in the framework of fairly elaborate precautionary and accountability rules. However, the experience of the United States with lost or misplaced shipments of nuclear material during transportation, as well as the not insignificant quantities of material unaccounted for (MUF) at particular nuclear facilities, indicates the reality of the problem. The MUF and temporarily lost shipments may be purely accidental and, at least from a national security point of view, harmless (compare risks to public health and safety); but they also might be the consequences of intentional acts. We are unaware of the experience of other nation-states, but it is not unreasonable to assume that similar situations have arisen elsewhere as well.

"The EURATOM community, which prides itself on one of the most advanced and sophisticated safeguard systems in the world, has no special precautions in the area of transportation, largely because hijacking is not common to the European political landscape!

"The United States, in a spate of recent legislation, has sought to fill some of the lacunae in its physical security system. The inconsistency of some of the new provisions, and the resistance of industry to what it regards as futile or overbearing provisions, attest to the complexity of the problems at hand. Other nation-states have yet to make even these first approximations to a solution of the physical

^{39/} David J. Rose, "Nuclear Eclectic Power," Science, 19 April 1974, pp. 351-59.

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security issue.

"The inescapable conclusion is that any effort to seriously move toward closure of the risk of nuclear diversion or theft requires all nation-states with a significant nuclear fuel cycle to give considerable thought and effort to the problem of developing as effective physical security systems as possible, consonant with the continued economic viability of peaceful nuclear power. If these objectives should prove irreconcilable, the even more difficult issue--whether nuclear power development ought to be pursued--might have to be faced. In an era of an alleged 'energy crunch' of worldwide proportions, this would create a truly awesome issue."⁴⁰

Hence, knowledgeable observers, friend and foe of nuclear power alike, recognize the ability to prevent diversion of special nuclear materials as central to the basic question of the acceptability of nuclear power.

It is little wonder that the AEC in the Draft Statement on the LMFB Program has treated this topic in a schizoid manner. The topic is included in the Draft Statement to the extent of defining the problems, in a general and non-specific way. However, the questions and issues which are raised by the problem are not addressed. In some instances the problems and hazards are completely ignored; in other instances the Commission has responded with self-serving, assertions which often are at complete variance with the results of published, credible work.

In essence the AEC has, by definition, excluded a consideration of safeguards from the analysis of the impact of the LMFB. Although acknowledging that the LMFB Program, if approved, would exacerbate both the national and international aspects of the safeguards problems, they go on to define it as being outside of the scope of the analysis:

"A further development which has become an important factor in the U.S. nuclear power program over the past several years is the increased concern of the American public about the safety

40/ Lawrence Scheinman, "Safeguarding Nuclear Materials," Science and Public Affairs, April 1974, pp. 34-36.

and environmental impact of modern technologies. The aspects of nuclear power plants which are of prime concern include: the thermal effects resulting from the discharge of power plant cooling water into lakes, rivers, or estuaries; the control of radioactive effluents; the transportation of radioactive materials; and the storage of high level radioactive wastes. These matters - particularly as these apply to the fast breeder - will be discussed in detail in other sections of this statement."⁴¹

The treatment of safeguards in the Draft Environmental Statement is consistent with the above declaration that it is not one of the "matters" which "will be discussed." The Draft Statement contains no attempt to fully explore the diversion implications of the LMFBR Program, makes absolutely no attempt to spell out the various measures which the AEC deems necessary to prevent diversion other than to indicate that it would be necessary to "expand and modify" and to "upgrade and strengthen" the existing programs. The AEC also acknowledges that social and behavioral controls would have to be a part of the expanded and modified and upgraded and strengthened safeguards programs. Yet it then goes on to refuse to discuss them further, stating blandly that this, probably the aspect of the safeguards problem of most concern to those concerned with individual and societal values, is outside of the scope of an Impact Statement:

"The extent to which the Federal Government may becoming (sic) concurrently involved in sectors of the economy now considered 'private' is beyond the scope of this Statement."³⁰

The Draft Statement does not include a comparison of the safeguards and diversion implications of alternative fission programs, although the various fission systems are known to differ in that regard. There is no consideration given to the economic costs of the expanded and modified and strengthened and upgraded safeguards system which is acknowledged to be required by the LMFBR Program. In addition, there is no analysis of the effects--economic, social,

^{41/} WASH 1535, page 2.1-33.

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political, or environmental--which could result were the safeguards and diversion program to fail. This latter failing is particularly puzzling in view of the statement in the Draft Report that one of the primary goals or objectives of the safeguards program is to "respond or initiate response to such acts [attempted or successful diversion of SNM], if they are carried out, in a way that neutralizes or minimizes the consequences."²⁰

Perhaps the AEC is motivated in its failure to include a complete and candid discussion of safeguards in its Draft Statement by the same considerations that lead Allen V. Kneese, developer and long-time practitioner of economic benefit/cost analysis, to write:

"It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. This is because these questions are of a deep ethical character. Benefit-cost analyses certainly cannot solve such questions and may well obscure them."⁴²

We sympathize with the Commission in its desire not to be required to acknowledge the existence of a safeguards and diversion problem and its apparent hope that it will not be required to discuss the problem in the evaluation of the LMFBR. We too wish that these problems did not exist and that society did not have to consider their implications in such mundane activities as consideration of alternative means of producing steam or electricity. That these considerations are new and that society has yet to evolve means to cope with them has been noted by the British economist E.J. Mishan, who wrote:

"...only since the last war have men succeeded finally in prying open Pandora's box, and among other exciting things which flew out was the secret of instant annihilation of

42/ Allen V. Kneese, "The Faustian Bargain," Resources, Sept. 1973, pp. 1-5. This reference is incorporated in full into these comments as Appendix C.

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all living things. Time, measured only in short years, will disseminate this sort of knowledge among smaller, poorer and less stable nations, some of which are ruled by adventurers or fanatics.... In sum, doomsday fears of yesterday had no rational basis. Those of today have plenty."⁴³

These hazards do exist. Much as we would like to ignore them, doing so will not make them any less real.

We close by reminding the authors of the Final Environmental Impact Statement for the LMFBR Program of comments by one of the most staunch supporters of nuclear energy:

"Are there moral responsibilities that we as nuclear technologists ought to face today, when the enterprise is small and the cost of error is small, rather than defer these responsibilities to a later generation when the enterprise is huge and the cost of error incalculably large? Are we doing all we can to assure that future generations will not be faced with foreclosed options wherever we do not see precisely clear and satisfactory answers to the techno-moral questions posed by the release of our intrinsically dangerous nuclear fire?...

"...we are indeed immoral if we do not exert every humanly possible effort to uncover, assess, and remedy whatever deficiencies we can find in nuclear energy, not only when it is small and unimportant and the deficiencies can be minimized, but also when it is overwhelmingly important and the deficiencies, if unremediable, could mean catastrophe for the human race. And the burden of proof is upon us: it is we who have created the phoenix of nuclear energy upon which the world will probably depend; it is we who must bend every effort to visualize the problems in their full magnitude, so that if any appear insuperable we can seek out appropriate alternatives."²⁵

43/ E. J. Mishan, "On Making the Future Safe for Mankind," The Public Interest, Summer 1971, p. 36.

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APPENDICES ATTACHED AS PART OF THESE COMMENTS:

A/ Statement by Theodore B. Taylor, Chairman of the Board, International Research and Technology Corporation, before the Joint Committee on Atomic Energy, Hearings on Nuclear Reactor Safety, January 28, 1974 [This Appendix is 11 pages in length.]

B/ A summary, Nuclear Theft: Risks and Safeguards, by Mason Willrich and Theodore B. Taylor. This summary was circulated with the announcements of publication of the book. [This Appendix is 11 pages in length.]

C/ Allen V. Kneese, "The Faustian Bargain," Resources, September 1974, pp. 1-5. [This Appendix is 5 pages in length.]

APPENDIX A

Statement by Theodore B. Taylor
Chairman of the Board, International Research and Technology Corporation
before the
Joint Committee on Atomic Energy
Hearings on Nuclear Reactor Safety

January 28, 1974

Mr. Chairman and Members of the Joint Committee: I appreciate the opportunity to testify at these hearings on nuclear reactor safety. The subject I shall focus on concerns what I believe is one of the most urgent and critical tasks now facing the United States and the rest of the world. This task is to establish control systems that will reduce to an acceptable level the threat of destructive use of nuclear materials diverted or stolen outright from components of nuclear power systems. Without much more stringent worldwide controls of nuclear materials than now exist or are definitely planned, I find it credible that nuclear violence may, within the next decade or two, reach levels that most of us would consider intolerable.

These concerns have been explored in considerable detail in a series of articles by John McPhee in the *New Yorker* last December. These will be published in book form under the title *The Curve of Binding Energy* this spring. Mason Willrich, professor of law at the University of Virginia, and I have also made a study of this subject for the Energy Policy Project under the auspices of the Ford Foundation. It will be published in book form early this year, under the title *Nuclear Theft: Risks and Safeguards*. We have come to the following six conclusions:

First, nuclear weapons are relatively easy to make, assuming the requisite nuclear materials are available. All of the information, non-nuclear materials, and equipment that would be required to design and build a variety of types of fission explosives are readily available throughout the world. The technical skills and resources required would depend on the desired efficiency, predicability, total weight, and yield of the explosives. Under conceivable circumstances, for example, a few persons, perhaps even one person working alone, who possessed about ten kilograms of plutonium or uranium-233 oxide or two dozen kilograms of highly enriched uranium oxide and a substantial amount of high explosive could, within several weeks, safely design and build a crude, transportable fission bomb. By a "crude, transportable fission bomb" I mean one that would be very likely to explode with a yield equivalent to at least 100 tons of high explosive, and that could be carried in an automobile. This could be done using materials and equipment that could be purchased at a hardware store and from commercial suppliers of scientific equipment and materials for student laboratories. All types of plutonium, highly enriched uranium, or uranium-233 now used or contemplated for use by the nuclear industry could be used for this purpose, as long as they are not diluted with large amounts of non-fissionable materials or mixed with dangerous quantities of gamma-ray emitting radioisotopes, such as fission products. The explosion of such a device could, under many circumstances, kill at least tens of thousands of people.

Smaller quantities of plutonium or uranium-233 than are required for fission explosives could also be incorporated into dispersal devices that could contaminate very large volumes of air with lethal concentrations of suspended, small particles of these substances that are exceedingly toxic if they are breathed. Air dispersal of a few grams of the type of plutonium now being produced in power reactors could kill most of the occupants of a large office building or enclosed industrial facility.

Second, the use of nuclear energy to generate electric power at rates now projected by the AEC would result in very large domestic and foreign flows of materials that can be used to make nuclear weapons. The annual rate of extraction of plutonium from reprocessed nuclear fuels from light water reactors in the United States would be about 30,000 kilograms in 1980. By the year 2000, light water reactors and fast breeder reactors in the U.S. would produce more than 300,000 kilograms annually. Worldwide, annual plutonium production would be more than 60,000 kilograms in 1980, rising to roughly a million kilograms in the year 2000. In addition, worldwide flows of highly enriched uranium and uranium-233 associated with high temperature gas cooled reactors or other types of reactors that use the U^{233} -thorium cycle may reach several hundred thousand kilograms or more by the end of the century.

Third, there are important differences between different reactor systems, and between different parts of the fuel cycle supporting a particular type of reactor, in the extent to which the nuclear fuel materials they contain are inherently vulnerable to theft or would require chemical or physical conversion to be suitable for direct use in a nuclear explosive. In general, irradiated fuels elements are largely self protecting before they are reprocessed, since gamma-rays from the fission products they contain would deliver lethal doses of radiation in minutes or less to anyone trying to handle them without massive shielding. This type of self protecting feature disappears when plutonium or uranium-233 have been separated from fission products at a reprocessing plant. Highly enriched uranium hexafluoride or oxide, used as feed material for making fuel for high temperature gas cooled reactors and most types of research reactors, are also safe to handle without shielding. Once these materials enter the process streams at fuel fabrication plants, they are generally diluted, to varying degrees, as they are incorporated into fresh fuel. As this happens, the total weight of objects that would have to be stolen to acquire sufficient fissionable material, when separated from the dilu-

tants, to make a fission explosive generally increases, but by different amounts for different types of reactor fuel. For example, the total weights of several types of fuel assembly materials that would have to be picked up to provide thieves with enough contained fissionable material for a crude fission bomb are roughly as follows: high temperature gas cooled reactor (HTGR) fuel, 10,000 lb.; light water reactor fuel, 2000 lb.; fast breeder reactors (LMFBR or GCFR), 50-75 lb. I offer these examples to illustrate that, in designing and assessing nuclear material security measures at different points in fuel cycles, more should be considered than simply the types of fissionable materials involved.

Important changes affecting opportunities for nuclear theft can occur as the nuclear industry develops. It happens, for example, that flows of fission product-free plutonium and highly enriched uranium for civilian power plants are now practically at a standstill, and are not expected to reach large inter-facility flow rates for at least several years. Since mid-1972, when the Nuclear Fuel Services fuel reprocessing plant shut down for expansion and renovation, no plutonium has been extracted at commercial reprocessing plants in the United States. The General Electric reprocessing plant at Morris, Illinois has not yet reprocessed any irradiated fuel, but is expected to start doing so within the next few months. The amount of previously separated commercial plutonium now at the New York State Atomic and Space Development Authority's (ASDA) plutonium storage facility is, I understand, less than ten percent of its storage capacity of 2,000 kilograms of plutonium. This situation will change rapidly, however, if the G.E. plant soon starts reprocessing the large and growing backlog of irradiated fuel from light water reactors. Until plutonium recycle starts on a more or less routine basis, which may not happen until about 1980, most separated plutonium is likely to go into long term storage or be used primarily for R&D programs. After plutonium recycle starts, however, tens of thousands of kilograms of plutonium per year can be expected to flow from storage to fuel fabrication plants and

on to something like a hundred power plants. I also understand that all of the highly enriched uranium required to refuel the Fort St. Vrain HTGR reactor for the next few years is already mixed with thorium at the General Atomic Company's HTGR fuel fabrication facility. Startup fuel for the new HTGR's now on order will not be fabricated until the late 1970's. In short, there appears to be a relative hiatus in the flow of concentrated commercial plutonium and highly enriched uranium in the United States that will probably last for several years, to be followed by a rather sudden increase in the flows. This situation, roughly speaking, appears to hold for nuclear fuel cycles in other countries. I should point out, however, that flows of fission product-free plutonium for R&D purposes are, and will continue to be significant. In fiscal year 1973, for example, there were about forty shipments of more than two kilograms of plutonium by licensees in the United States. The total amount shipped was more than 600 kilograms.

Our fourth conclusion is that, without effective safeguards to prevent nuclear theft, the development of nuclear power on the scale now in prospect will create substantial risks to the American people and people generally. Individuals or groups may attempt to steal nuclear weapon materials for money or to engage in political blackmail. It would be relatively easy for a small group possessing nuclear weapon materials to use them in any number of ways to threaten other groups within society, governments, or entire communities. The frequency and character of nuclear theft attempts in the future is likely to be influenced greatly not only by the nature of physical safeguards against theft, but also by the general political climate and by prevailing attitudes toward violent behavior within societies where opportunities exist for such theft.

Fifth, the U.S. system of nuclear material safeguards is incomplete at this time. Although recent regulatory actions have strengthened requirements substantially, some basic issues pertaining to physical protection and materials accountability measures have not been resolved.

The preamble to the new regulations concerning nuclear material in transit, for example, states that the measures are intended to protect the materials from any attempted theft "short of a significant armed attack." Are transportation safeguards expected to deal only with *insignificant* armed attacks, or significant *unarmed* attacks? Does this same guiding principle apply, by implication, to fixed sites? If so, then, I submit, licensees are not being asked to protect these materials even as well as financial institutions protect their money. If the AEC's real intention is to have licensees go significantly further than this in protecting their materials, then its objectives must be clearly spelled out. Otherwise, the adversary nature of negotiations between the AEC regulatory staff and licensees is likely to continue to drag out the negotiations and cause further delays in the licensing procedure. I am now not optimistic about representatives of the nuclear industry offering to go substantially beyond satisfying the letter of the AEC regulations and guides in cases where the direct or indirect costs of doing so are likely to be substantial.

This leads me to another important unresolved issue concerning safeguards. Who should pay the added costs of new safeguards measures, and by what mechanism? Present contributions to the overall cost of nuclear electric power are much higher at some points in the fuel cycle than at others. The costs of transportation of concentrated plutonium or highly enriched uranium, for example, are much lower than the costs of capital depreciation and operations at nuclear power plants. But the costs of effective safeguards to prevent theft of materials in transit may be much higher than their costs at nuclear power plants. Thus a plutonium shipper may see his costs rising sharply, perhaps even by more than 100%, as a result of new safeguard regulations, while a utility company may see a practically insignificant rise in cost per kilowatt hour of delivered electricity as a result of the same action. If the plutonium shipper absorbs the costs of a really good physical

protection system, he may have to price himself above his competitors and go out of business. So we have this question: How can the added costs of highly effective safeguards be equitably distributed across the entire fuel cycle, so that they are finally borne by the consumers of nuclear electric power? I shall return to this briefly later in my statement.

Finally, we have concluded that a system of safeguards can be developed that will keep the risks of theft of nuclear weapon materials from the nuclear power industry at very low levels, without interfering significantly with the continued rapid development of nuclear power. We have suggested a guiding principle, called the "Principle of Containment" for use in designing such a system. According to this principle, the overall objective of a safeguards system would be to detect attempts at theft of nuclear materials from authorized channels as early as possible, and to place sufficient impediments in the way of people attempting a theft to assure that whatever reserve forces are required can be brought to the scene in time to control any credible theft operation. Measures that could be used for applying this principle fall into five broad categories:

1. Containment of nuclear materials at fixed sites within physical barriers designed to prevent unauthorized penetration long enough to allow on-site or reserve guard forces capable of dealing with *any credible type* of attempted theft to arrive at the scene before the theft is completed.

2. Shipment of nuclear materials in massive containers and vehicles designed to resist penetration, transfer of the shipment to another vehicle, or commandeering of the vehicle itself long enough for accompanying or reserve guard forces to be able to deal effectively with *any credible theft attempt*.

3. Provision of automatic alarms that will immediately detect attempts to remove materials from authorized channels and sound alarms at several specified control points.

4. Provision of on-site and in-transit guard forces for the purpose of denying access of unauthorized people to places where nuclear materials exist.

5. Provision of on-call law enforcement forces that can be brought to the scene of an attempted theft before a theft can be completed, along with secure communications between the control points where the alarms are sounded and the off-site forces.

In addition, materials accounting procedures should be used as a backup to the above types of physical security measures, to help assure detection of any covert diversion of materials not detected by the alarm systems.

The present AEC approach to safeguards is, in fact, along these general lines but simply does not go anywhere near far enough to prevent thefts by groups of people with at least the skills and resources that have been used for major thefts of other valuables in the past. I am convinced that a safeguards system that would accomplish this objective could be designed and implemented in the United States *before* the relative hiatus in the flow of commercial fissionable materials comes to an end in the late 1970's or early 1980's. But this will not happen, in my view, unless both the AEC and the nuclear industry considerably increase the intensity of present efforts to bring this problem under control.

The nuclear industry has many options for designing highly effective nuclear safeguards into its systems, and both the AEC and the industry should devise and implement practicable ways to respond to these opportunities.

I would like to mention a few possible examples. These, along with other alternatives, should obviously be thoroughly assessed before they are implemented.

Some particularly vulnerable transportation links could be removed if nuclear fuel cycle facilities were located at the same sites. Ship-

ments of concentrated plutonium oxide or plutonium nitrate could be avoided if fuel reprocessing facilities and fuel fabrication plants that use their output were next to each other. Facilities for intermediate conversion of plutonium or highly enriched uranium, which are often now located by themselves, could be integral parts of fuel reprocessing or fabrication facilities. As an extreme, but possibly generally attractive option, all fuel cycle components that handle fissionable materials, including very high capacity power reactors, could be located at the same site. This would not only remove the need for transportation of fissionable materials over large distances, but would also reduce, through economies of scale, the overall costs of safeguards for a complete fuel cycle.

As another example, it now appears likely that rather massive gamma-ray and, in some cases, neutron shielding will be required to insure insignificant radiation exposure to workers at all points in the fuel cycle for systems that use recycled plutonium or uranium-233. This would mean that, for reasons not connected with safeguards, heavy containers and barriers will have to be used in the storage, transport, and fabrication of nuclear fuels from the time they are separated at a reprocessing plant to the time they are placed in reactors for refuelling. These barriers and containers will make theft much more difficult.

Finally, I want to mention a possibility for providing expert protective security services to the nuclear industry in a way that would assure the greatest practicable security along with an equitable way to pay the added costs. If this service--including the required professional personnel, equipment, communications systems, and so on--were provided, where and as needed, by the federal government, the industry would not have to deal with the problems of arming its own employees or depending on private protective services whose effectiveness may vary considerably from place to place. If, further, the costs of such a service were paid for out of a federal fund raised by taxes on the utilities that

were proportional to their annual production of nuclear power, and these taxes were included in the utilities' pricing structure, the costs of the required protective services would be equitably passed on to the consumers of nuclear electric power. I should emphasize that this is only one of a number of possibilities that I believe should be thoroughly assessed.

This leads me to the primary recommendation I would like to place before this Committee. The AEC should take the leadership in assembling a task force of experts that represent the interests and expertise of government, the nuclear industry, universities, and the general public to work full time on the conception and assessment of alternative ways to establish and maintain an effective nuclear material safeguard system in the United States. By a system I mean to include everything from its legislative framework, technical standards, and technological and procedural components through the detailed mechanism by which it is implemented and, as necessary, revised. System concepts covering a range of likely effectiveness and costs should be assessed. The results of this task should be made publicly available and, together with comments following public review, should be used as a basis for the AEC to formulate and implement modifications of the nuclear safeguards regulations and regulatory guides that exist at that time. I also suggest that the initial task force be scheduled to complete its work in about one year.

I frequently hear objections to the general kinds of safeguards measures I am proposing, on the grounds that they will cost too much. I generally respond with three points. First, I know of no detailed studies of alternative national safeguards systems that are attempts to determine what level of effectiveness can be achieved at different costs. That is one of the reasons for the recommendation I have just made. Second, an increase of only one percent in the projected cost of nuclear electric power in the United States in 1980, if attributed to added costs of safeguards, would amount to approximately \$100 million per year, which very preliminary studies have suggested to me would be

sufficient to cover the costs of the kinds of safeguards I propose. Third, the cost to society of an *inadequately* safeguarded national nuclear power system is likely to be far greater than the dollar costs of any conceivable safeguard system.

.. . Implementation of a highly effective safeguards system in the United States is a necessary, but not sufficient response to the worldwide threat of nuclear violence following nuclear theft. At least thirty nations now have or are planning to build nuclear power reactors. Achieving a worldwide level of control of nuclear materials that will keep these risks at acceptable levels is among the greatest challenges humanity has ever faced. But respond aggressively to this challenge we must, or face the prospects of living in a world in which nuclear violence may become commonplace. We have little time, and much to do. The first task for those of us that live in this country is to get our own house in order. As we do this, we must use all the creative energies we can muster to work with people in other countries to bring this problem under global control. The fundamental reason why I now believe this goal can be achieved is that it is so evidently in the best self interests of every nation in the world.

A SUMMARY

NUCLEAR THEFT: RISKS AND SAFEGUARDS
by Mason Willrich and Theodore B. Taylor

This book analyzes the possibility that nuclear materials may be stolen from the fast-growing U.S. nuclear power industry and used to make weapons. It finds the risk will be "substantial" unless effective steps are taken to assure the public's safety and the nation's security.

Nuclear energy is rapidly becoming a major source of electric power in the U.S. and many other countries. The same materials, plutonium and highly-enriched uranium, that form the explosive cores of atomic bombs, are also produced and used as fuel in nuclear power reactors. Within a few years, tens of thousands of kilograms of these fissionable materials will be flowing through the U.S. nuclear power industry. A few kilograms of these same materials are enough for an atomic bomb; and a few grams of plutonium are enough for a device that could cause widespread radioactive contamination.

The design and manufacture of a crude fission bomb is no longer a difficult task technically, once nuclear materials are at hand; making a plutonium dispersal device is even simpler.

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Effective safeguard measures are therefore necessary, so that materials intended for use as nuclear fuels are not stolen and misused by criminals or terrorists. Based on their study, Willrich and Taylor find that the U. S. program to guard against the risk of nuclear theft is improving but incomplete; comparable measures in other nations with nuclear power programs also need improvement. But there are safeguards which, if implemented, will reduce the risk of nuclear theft to a very low level -- an acceptable level, in the authors' judgment. They are convinced that the costs of these safeguards will be small compared to the overall costs of nuclear power. The most difficult problems in developing an effective safeguards system are institutional and political, not technical, in character.

Many policymakers in the energy field are only vaguely aware of the nuclear theft problem, and most of the general public does not know that it exists. This study is intended to contribute to public understanding of the technical facts and policy issues involved. It contains no classified information. Drawing from extensive unclassified data, it describes in general terms what materials and skills are required to make crude atomic weapons; how much destruction they could cause; where in the nuclear power industry the key materials for such weapons are present; and why and how criminals or terrorists might try to steal them.

How much does the public need to know about the risks of nuclear theft? The most compelling argument against informing the public is that such an effort might inspire warped or evil minds. But the fact

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is that a large amount of information, in more technical detail than this study presents, is already in the public domain.

More basically, the security risks which are intrinsic in nuclear power are not temporary; they are an inescapable characteristic of the use of nuclear energy to meet more and more of the world's demand for electricity. The public needs to know that the years just ahead provide the last chance to develop long-term safeguards. Once nuclear materials are flowing through the power industry at the levels expected in a few years, it will be too late to begin to develop effective safeguards against theft.

On the basis of an extensive review of published material open to the public, unclassified conversations with experts, and considerable thought, the authors conclude:

"Under conceivable circumstances, a few persons, possibly even one person working alone, who possessed about ten kilograms of plutonium oxide and a substantial amount of chemical high explosive could, within several weeks, design and build a crude fission bomb."

Fission explosives can also be made with a few kilograms of high-enriched uranium, or with uranium-233. All these materials are found in the civilian nuclear power industry. Besides nuclear material and chemical explosives, the other materials necessary for making a crude fission bomb can be bought in hardware stores or from commercial suppliers of scientific equipment for students.

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People involved in this kind of criminal enterprise would need some laboratory and machine shop skills. They would have to be reasonably inventive, and able to find and understand the unclassified literature that deals with nuclear explosives, nuclear reactor safety, and ordinary explosives. They would have to be willing to take moderate risks of serious injury or death.

"Whatever opinions anyone may have about the likelihood that an individual or very small group of people would actually steal nuclear materials and use them to make fission bombs, those opinions should not be based on a presumption that all types of fission bombs are very difficult to make," the authors say.

A "crude fission bomb" is defined as one which has an excellent chance of exploding, with a probable yield equal of at least 100 tons of chemical high explosive, and a possible yield of as much as a few kilotons. Even a "small" nuclear explosion could cause enormous havoc. A nuclear explosion produces not only a blast wave and heat, but also lethal radiation. The effects of a nuclear weapon depend on the characteristics of the target as well as of the weapon itself. In a typical suburban residential area, a "crude fission bomb" might kill 2000 people, mostly by exposure to radioactive fallout. The same explosion in a parking lot beneath a skyscraper could kill as many as 50,000 people and destroy the entire building.

In criminal hands, plutonium could be a danger not only as raw material for a bomb, but also in a relatively simply dispersal device. Plutonium is among the most toxic substances known. Airborne particles small enough to be barely visible can cause fibrosis or cancer of the lung. The amounts that could pose a threat to society are accordingly

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very small. One hundred grams (three and one half ounces) of the stuff could be a deadly risk to everyone working in a large office building or factory, if it were effectively dispersed. In open air, the effects would be more diluted by wind and weather, but they would still be serious and long-lasting.

In the very near future, nuclear materials will be circulating in huge quantities through the fuel cycles of nuclear power plants. By 1980, tens of thousands of kilograms will be present in the U. S. industry, and several thousand kilograms will be flowing through civilian fuel cycles in other countries. Thereafter, it is expected that the total amounts of these materials in nuclear power industries throughout the world will rapidly increase.

Some parts of the nuclear fuel cycles are inherently more vulnerable to theft than others. Each kind of nuclear reactor, with its own distinctive fuel cycle, presents different problems.

The most common reactor in use today is the light-water reactor (LWR). The possibilities for theft in the LWR fuel cycle, as it now operates, are minimal. The low-enriched uranium the LWR uses for fuel is not at present a usable nuclear weapon material. However, the light-water reactor does produce plutonium (which now goes into storage but will by the late 1970's be recycled as LWR fuel). The plutonium is well protected against theft from the time it is made in the reactor until after it is separated from intensely radioactive spent fuel at a reprocessing plant; the radioactivity itself is a built-in safeguard against theft. The only points in the present LWR cycle where theft of plutonium might occur are after separation at a fuel reprocessing plant, during shipment to a storage plant, or

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at the storage plant itself. Transportation, as in all the fuel cycles, is probably the weakest security link.

When LWR's begin to use recycled plutonium as fuel, the chances for theft will multiply. The most vulnerable parts of the fuel cycle will be at the reprocessing plant, at the fuel fabrication plant, and during shipment between these sites. Completed fuel assemblies containing plutonium could also be stolen, but the heavy weight of such assemblies would make it a difficult undertaking.

One high-temperature gas-cooled reactor (HTGR) is ready to start up in 1974, as a demonstration model; several commercial-scale HTGR plants are on order. In the more distant future this kind of reactor may play a larger role. To begin with, the HTGR will use high-enriched uranium (which is 90 to 95 percent U-235) as fuel, and create uranium 233; later uranium 233 will be recycled and used as fuel.

The possibilities that uranium 233 might be stolen from the HTGR fuel cycle parallel in general those for plutonium in the light-water reactor cycle. However, fabricated HTGR fuel is much more dilute and difficult to convert to forms that would be usable in nuclear explosives. High-enriched uranium, the other HTGR fuel, is especially vulnerable at these points: as it leaves the fuel enrichment plant, in the form of a highly enriched uranium gas; while it is in transit to a chemical conversion plant (to be converted into solid form); at the conversion plant; and during shipment to the fuel fabrication plant.

The liquid metal fast breeder reactor (LMFBR) is still at an early stage today. But intensive development is underway, and the LMFBR may become the mainstay of nuclear power production toward the end of the century because it is able to "breed" from common uranium more nuclear

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fuel than it burns. The LMFBR dramatically extends the lifetime of uranium reserves.

The weak points in the LMFBR fuel cycle are the same as in the LWR cycle which includes a plutonium recycle. There is a difference however. The fast breeder's fuel assemblies contain a much higher concentration of plutonium than the LWR's; and it is easier to extract.

The probability of nuclear theft is very low, yet if it did happen the consequences could be catastrophic. In this way, the risk of nuclear theft is similar to the risk of a major accident in a nuclear power plant. But it is more difficult to assess the likelihood of theft, because the risks arise primarily, not from malfunctioning machines, but from malfunctioning people. The possible damage from nuclear theft is even greater than from the maximum credible reactor accident.

Terrorists or criminals or even a single fanatic might try to steal nuclear weapon materials, for money or for purposes of political coercion. If they succeeded, they could use the materials in a number of ways to threaten groups, governments, or whole communities. It is likely that nuclear theft attempts will be very much influenced by the general social and political climate. Factors over which the nuclear power industry has no control will, in other words, largely determine the range of threats. Without effective safeguards to prevent theft, the development of nuclear power will create substantial risks to the security and safety of Americans and people everywhere.

"The U. S. system of safeguards is incomplete at this time," the authors conclude. Although the AEC has substantially strengthened

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safeguard requirements in recent years, some basic issues pertaining to physical protection have not yet been resolved.

In many areas present security regulations are vaguely defined. The AEC is now at work developing better guides for some, such as design standards for a safe secure vehicle to transport nuclear weapon materials. For others, serious ambiguities still remain. In still other areas, requirements are precisely defined, but inadequate. For example, there are no specific requirements for the physical protection of less than two kilograms of plutonium, even though a small fraction of that amount is enough to make a radiological weapon. For another example, the requirements for keeping contact with vehicles while they carry nuclear shipments are ineffective.

There are no AEC or internationally-administered requirements for the physical protection of nuclear materials which the U. S. exports for other countries to use in their nuclear power programs. Theft of such materials could pose a serious risk to the security of the U. S. as well as other countries. This will be a difficult need to fulfill, though the International Atomic Energy Agency in Vienna does administer an international system of nuclear materials accountancy.

Taken together, present U. S. safeguards do not constitute a system. An effective system of safeguards may evolve, if present trends continue. Today, there is no basis for evaluating such a system as it develops, because the AEC has not determined the maximum credible threat which safeguards are intended to meet, and the

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essentials of the safeguard system are hidden from public view, in the physical security plans which nuclear licensees file with the AEC on a confidential basis.

It is clearly necessary to keep detailed plans a secret. But the need for secrecy makes it doubly important for the AEC to develop specific safeguard standards that can be justified in public hearings, and to develop an inspection process that will make sure the standards are met.

"A system of safeguards can be developed that will keep the risks of theft of nuclear weapon materials from the nuclear power industry at very low levels," Willrich and Taylor conclude. The system should emphasize the prevention of theft and the detection of any theft in time to prevent its completion.

The principle of containment should be the basis for safeguard measures. The physical barriers and security forces that are designed to protect nuclear weapon materials should be capable of defeating the maximum credible threat that can be reasonably expected anywhere in any nuclear fuel cycle. That threat might involve an attack by a group of perhaps five to ten persons using sophisticated firearms and equipment.

Insofar as practical, techniques should be developed to provide a timely, accurate picture of the material flows in the various nuclear fuel cycles, so that any movement of nuclear weapon materials outside authorized channels can be immediately detected.

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The study recommends:

The AEC should design a detailed system of safeguards for each of the nuclear fuel cycles based on use of the best available technology and institutional mechanisms. (The safeguard designs could then be evaluated for cost-effectiveness, to help determine what requirements should be adopted for the nuclear power industry, what safeguard R & D priorities should be established, and what risks of nuclear theft should be accepted.)

The AEC should consider the establishment of a federal nuclear materials security service with the sole responsibility of protecting nuclear materials subject to safeguards.

The AEC should develop and publish a set of procedures for the review of physical security plans submitted by industry licensees. (These procedures should provide the nuclear industry and the public with strong assurance that the security plans proposed by licensees will be assessed thoroughly; that standards will be uniform and equitable; that all plans will result in effective measures to prevent theft.)

The U.S. Government should initiate discussions with the governments of other nations with substantial nuclear power programs with a view to developing a common policy in favor of effective safeguards against nuclear theft anywhere in the world.

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"None of man's previous discoveries compare with nuclear energy in terms of the demands placed on him to use it wisely," the authors conclude. "Indeed the widespread use of nuclear energy requires the rapid development of near perfect social and political institutions. This is the unprecedented challenge before us."

RESOURCES

Some findings and conjectures from recent research
into environmental quality and resource development and use

The cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run.

H. D. Thoreau: *Walden*

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The Faustian Bargain

In its original form, this statement bore the somewhat abstract title, "Benefit-Cost Analysis and Unscheduled Events in the Nuclear Fuel Cycle." The Atomic Energy Commission had asked for comments on one of its documents, noting that environmental statements for a power reactor should contain a cost-benefit analysis which, among other things, "considers and balances the adverse environmental effects and the environmental, economic, technical and other benefits of the facility." In response to the invitation, Allen V. Kneese, director of RFF's program of studies in the quality of the environment, submitted the following remarks.

I AM SUBMITTING this statement as a long-time student and practitioner of benefit-cost analysis, not as a specialist in nuclear energy. It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. This is so because these questions are of a deep *ethical* character. Benefit-cost analyses certainly cannot solve such questions and may well obscure them.

These questions have to do with whether society should strike the Faustian bargain with atomic scientists and engineers, described by Alvin M. Weinberg in *Science*. If so unforgiving a technology as large-scale nuclear fission energy production is adopted, it will impose a burden of continuous monitoring and sophisticated management of a dangerous material, essentially forever. The penalty of not bearing this burden may be unparalleled disaster. This irreversible burden would

be imposed even if nuclear fission were to be used only for a few decades, a mere instant in the pertinent time scales.

Clearly, there are some major advantages in using nuclear fission technology, else it would not have so many well-intentioned and intelligent advocates. Residual heat is produced to a greater extent by current nuclear generating plants than by fossil fuel-fired ones. But, otherwise, the environmental impact of routine operation of the nuclear fuel cycle, including burning the fuel in the reactor, can very likely be brought to a lower level than will be possible with fossil fuel-fired plants. This superiority may not, however, extend to some forms of other alternatives, such as solar and geothermal energy, which have received

comparatively little research and development effort. Insofar as the usual market costs are concerned, there are few published estimates of the costs of various alternatives, and those which are available are afflicted with much uncertainty. In general, however, the costs of nuclear and fossil fuel energy (when residuals generation in the latter is controlled to a high degree) do not seem to be so greatly different. Early evidence suggests that other as yet undeveloped alternatives (such as hot rock geothermal energy) might be economically attractive.

Unfortunately, the advantages of fission are much more readily quantified in the format of a benefit-cost analysis than are the associated hazards. Therefore, there exists the danger that the benefits may seem more real. Furthermore, the conceptual basis of benefit-cost analysis requires that the redistributive effects of the action be, for one or another reason, inconsequential. Here we are speaking of hazards that may affect humanity many generations hence and equity questions that can neither be neglected as inconsequential nor evaluated on any known theoretical or empirical basis. This means that technical people, be they physicists or economists, cannot legitimately make the decision to generate such hazards. Our society confronts a moral problem of a great profundity; in my opinion, it is one of the most consequential that has ever faced mankind. In a democratic society the only legitimate means for making such a choice is through the mechanisms of representative government.

For this reason, during the short interval ahead while dependence on fission energy could still be kept within some bounds, I believe the Congress should make an open and explicit decision about this Faustian bargain. This would best be done after full national discussion at a level of seriousness and detail that the nature of the issue demands. An appropriate starting point could be hearings before a committee of Congress with a broad national policy responsibility. Technically oriented or specialized committees would not be suitable to this task. The Joint Economic Committee might be appropriate. Another possibility would be for the Congress

to appoint a select committee to consider this and other large ethical questions associated with developing technology. The newly established Office of Technology Assessment could be very useful to such a committee.

MUCH HAS been written about hazards associated with the production of fission energy. Until recently, most statements emanating from the scientific community were very reassuring on this matter. But several events in the past year or two have reopened the issue of hazards and revealed it as a real one. I think the pertinent hazards can usefully be divided into two categories—those associated with the actual operation of the fuel cycle for power production and those associated with the long-term storage of radioactive waste. I will discuss both briefly.

The recent failure of a small physical test of emergency core cooling equipment for the present generation of light-water reactors was an alarming event. This is in part because the failure casts doubt upon whether the system would function in the unlikely, but not impossible, event it would be called upon in an actual energy reactor. But it also illustrates the great difficulty of forecasting behavior of components in this complex technology where pertinent experimentation is always difficult and may sometimes be impossible. Other recent unscheduled events were the partial collapse of fuel rods in some reactors.

There have long been deep but suppressed doubts within the scientific community about the adequacy of reactor safety research vis-à-vis the strong emphasis on developing the technology and getting plants on the line. In recent months the

Union of Concerned Scientists has called public attention to the hazards of nuclear fission and asked for a moratorium on the construction of new plants and stringent operating controls on existing ones. The division of opinion in the scientific community about a matter of such moment is deeply disturbing to an outsider.

No doubt there are some additional surprises ahead when other parts of the fuel cycle become more active, particularly in transportation of spent fuel elements and in fuel reprocessing facilities. As yet, there has been essentially no commercial experience in recycling the plutonium produced in nuclear reactors. Furthermore, it is my understanding that the inventory of plutonium in the breeder reactor fuel cycle will be several times greater than the inventory in the light-water reactor fuel cycle with plutonium recycle. Plutonium is one of the deadliest substances known to man. The inhalation of a millionth of a gram—the size of a grain of pollen—appears to be sufficient to cause lung cancer.

Although it is well known in the nuclear community, perhaps the general public is unaware of the magnitude of the disaster which would occur in the event of a severe accident at a nuclear facility. I am told that if an accident occurred at one of today's nuclear plants, resulting in the release of only five percent of only the more volatile fission products, the number of casualties could total between 1,000 and 10,000. The estimated range apparently could shift up or down by a factor of ten or so, depending on assumptions of population density and meteorological conditions.

With breeder reactors, the accidental release of plutonium may be of greater consequence than the release of the more volatile fission products. Plutonium is one of the most potent respiratory carcinogens in existence. In addition to a great variety of other radioactive substances, breeders will contain one, or more, tons of plutonium. While the fraction that could be released following a credible accident is extremely uncertain, it is clear that the release of only a small percentage of this inventory would be equivalent to the release of *all* the volatile fission products in one of today's nuclear plants. Once lost to

the environment, the plutonium not ingested by people in the first few hours following an accident would be around to take its toll for generations to come—for tens of thousands of years. When one factors in the possibility of sabotage and warfare, where power plants are prime targets not just in the United States but also in less developed countries now striving to establish a nuclear industry, then there is almost no limit to the size of the catastrophe one can envisage.

It is argued that the probabilities of such disastrous events are so low that these events fall into the negligible risk category. Perhaps so, but do we really know this? Recent unexpected events raise doubts. How, for example, does one calculate the actions of a fanatical terrorist?

The use of plutonium as an article of commerce and the presence of large quantities of plutonium in the nuclear fuel cycles also worries a number of informed persons in another connection. Plutonium is readily used in the production of nuclear weapons, and governments, possibly even private parties, not now having access to such weapons might value it highly for this purpose. Although an illicit market has not yet been established, its value

has been estimated to be comparable to that of heroin (around \$5,000 per pound). A certain number of people may be tempted to take great risks to obtain it. AEC Commissioner Larsen, among others, has called attention to this possibility. Thus, a large-scale fission energy economy could inadvertently contribute to the proliferation of nuclear weapons. These

might fall into the hands of countries with little to lose, or of madmen, of whom we have seen several in high places within recent memory.

In his excellent article referred to above, Weinberg emphasized that part of the Faustian bargain is that to use fission technology safely, society must exercise great vigilance and the highest levels of quality control, continuously and *indefinitely*. As the fission energy economy grows, many plants will be built and operated in countries with comparatively low levels of technological competence and a greater propensity to take risks. A much larger amount of transportation of hazardous materials will probably occur, and safety will become the province of the sea captain as well as the scientist. Moreover, even in countries with higher levels of technological competence, continued success can lead to reduced vigilance. We should recall that we managed to incinerate three astronauts in a very straightforward accident in an extremely high technology operation where the utmost precautions were allegedly being taken.

DEEPER MORAL questions also surround the storage of high-level radioactive wastes. Estimates of how long these waste materials must be isolated from the biosphere apparently contain major elements of uncertainty, but current ones seem to agree on "at least two hundred thousand years."

Favorable consideration has been given to the storage of these wastes in salt formations, and a site for experimental storage was selected at Lyons, Kansas. This particular site proved to be defective. Oil companies had drilled the area full of holes, and there had also been solution mining in the area which left behind an unknown residue of water. But comments of the Kansas Geological Survey raised far deeper and more general questions about the behavior of the pertinent formations under stress and the operations of geological forces on them. The ability of solid earth geophysics to predict for the time scales required proves very limited. Only now are geologists beginning to unravel the plate tectonic theory. Furthermore, there is the political factor. An increasingly informed and environmentally aware public

is likely to resist the location of a permanent storage facility anywhere.

Because the site selected proved defective, and possibly in anticipation of political problems, primary emphasis is now being placed upon the design of surface storage facilities intended to last a hundred years or so, while the search for a permanent site continues. These surface storage sites would require continuous monitoring and management of a most sophisticated kind. A complete cooling system breakdown would soon prove disastrous and even greater tragedies can be imagined.

Just to get an idea of the scale of disaster that could take place, consider the following scenario. Political factors force the federal government to rely on a single above-ground storage site for all high-level radioactive waste accumulated through the year 2000. Some of the more obvious possibilities would be existing storage sites like Hanford or Savannah, which would seem to be likely military targets. A tactical nuclear weapon hits the site and vaporizes a large fraction of the contents of this storage area. The weapon could come from one of the principal nuclear powers, a lesser developed country with one or more nuclear power plants, or it might be crudely fabricated by a terrorist organization from black-market plutonium. I am told that the radiation fallout from such an event could exceed that from all past nuclear testing by a factor of 500 or so, with radiation doses exceeding the annual dose from natural background radiation by an order of magnitude. This would bring about a drastically unfavorable, and long-lasting change in the environment of the majority of mankind. The exact magnitude of the disaster is uncertain. That massive numbers of deaths might result seems clear. Furthermore, by the year 2000, high-level wastes would have just begun to accumulate. Estimates for 2020 put them at about three times the 2000 figure.

SOMETIMES, analogies are used to suggest that the burden placed upon future generations by

the "immortal" wastes is really nothing so very unusual. The Pyramids are cited as an instance where a very long-term commitment was made to the future and the dikes of Holland as one where continuous monitoring and maintenance are required indefinitely. These examples do not seem at all apt. They do not have the same quality of irreversibility as the problem at hand and no major portions of humanity are dependent on them for their very

existence. With sufficient effort the Pyramids could have been dismantled and the Pharaohs cremated if a changed doctrine so demanded. It is also worth recalling that most of the tombs were looted already in ancient times. In the 1950s the Dutch dikes were in fact breached by the North Sea. Tragic property losses, but no destruction of human life, ensued. Perhaps a more apt example of the scale of the Faustian bargain would be the irrigation system of ancient Persia. When Tamerlane destroyed it in the 14th century, a civilization ended.

None of these historical examples tell us much about the time scales pertinent here. One speaks of two hundred thousand years. Only a little more than one-hundredth of that time span has passed since the Parthenon was built. We know of no government whose life was more than an instant by comparison with the half-life of plutonium.

It seems clear that there are many factors here which a benefit-cost analysis can never capture in quantitative, commensurable terms. It also seems unrealistic to claim that the nuclear fuel cycle will not sometime, somewhere experience major unscheduled events. These could range in magnitude from

local events, like the fire at the Rocky Mountain Arsenal, to an extreme disaster affecting most of mankind. Whether these hazards are worth incurring in view of the benefits achieved is what Alvin Weinberg has referred to as a trans-scientific question. As professional specialists we can try to provide pertinent information, but we cannot legitimately make the decision, and it should not be left in our hands.

One question I have not yet addressed is whether it is in fact not already too late. Have we already accumulated such a store of high-level waste that further additions would only increase the risks marginally? While the present waste (primarily from the military program plus the plutonium and highly enriched uranium contained in bombs and military stockpiles) is by no means insignificant, the answer to the question appears to be no. I am informed that the projected high-level waste to be accumulated from the civilian nuclear power program will contain more radioactivity than the military waste by 1980 or shortly thereafter. By 2020 the radioactivity in the military waste would represent only a small percentage of the total. Nevertheless, we are already faced with a substantial long-term waste storage problem. Development of a full-scale fission energy economy would add overwhelmingly to it. In any case, it is never too late to make a decision, only later.

WHAT ARE THE benefits?

The main benefit from near-term development of fission power is the avoidance of certain environmental impacts that would result from alternative energy sources. In addition, fission energy may have a slight cost edge, although this is somewhat controversial, especially in view of the low plant factors of the reactors actually in use. Far-reaching clean-up of the fuel cycle in the coal energy industry, including land reclamation, would require about a 20 percent cost increase over uncontrolled conditions for the large, new coal-fired plants. If this is done, fission plants would appear to have a clear cost edge, although by no means a spectacular one. The cost characteristics of the breeder that would follow the light-water

reactors are very uncertain at this point. They appear, among other things, to still be quite contingent on design decisions having to do with safety. The dream of "power too cheap to meter" was exactly that.

Another near-term benefit is that fission plants will contribute to our supply during the energy "crisis" that lies ahead for the next decade or so. One should take note that this crisis was in part caused by delays in getting fission plants on the line. Also, there seems to be a severe limitation in using nuclear plants to deal with short-term phenomena. Their lead time is half again as long as fossil fuel plants—on the order of a decade.

The long-term advantage of fission is that once the breeder is developed we will have a nearly limitless, although not necessarily cheap, supply of energy. This is very important but it does not necessarily argue for a near-term introduction of a full-scale fission economy. Coal supplies are vast, at least adequate for a few hundred years, and we are beginning to learn more about how to cope with the "known devils" of coal. Oil shales and tar sands also are potentially very large sources of energy, although their exploitation will present problems. Geothermal and solar sources have hardly been considered but look promising. Scientists at the AEC's Los Alamos laboratory are optimistic that large geothermal sources can be developed at low cost from deep hot rocks—which are almost limitless in supply. This of course is very uncertain since the necessary technology has been only visualized. One of the potential benefits of solar energy is that its use does not heat the planet. In the long term this may be very important.

Fusion, of course, is the greatest long-term hope. Recently, leaders of the U.S. fusion research effort announced that a fusion demonstration reactor by the mid-1990s is now considered possible. Although there is a risk that the fusion option may never be achieved, its promise is so great that it merits a truly national research and development commitment.

A strategy that I feel merits sober, if not prayerful, consideration is to phase out the present set of fission reactors, put large amounts of resources into dealing

With the environmental problems of fossil fuels, and price energy at its full social cost, which will help to limit demand growth. Possibly it would also turn out to be desirable to use a limited number of fission reactors to burn the present stocks of plutonium and thereby transform them into less hazardous substances. At the same time, the vast scientific resources that have developed around our fission program could be turned to work on fusion, deep geothermal, solar, and other large energy supply sources while continuing research on various types of breeders. It seems quite possible that this program would result in the displacement of fission as the preferred technology for electricity production within a few decades. Despite the extra costs we might have incurred, we would then have reduced the possibility of large-scale energy-associated nuclear disaster in our time and would be leaving a much smaller legacy of "permanent" hazard. On the other

hand, we would probably have to suffer the presence of more short-lived undesirable substances in the environment in the near term.

This strategy might fail to turn up an abundant clean source of energy in the long term. In that event, we would still have fission at hand as a developed technological standby, and the ethical validity of using it would then perhaps appear in quite a different light.

We are concerned with issues of great moment. Benefit-cost analysis can supply useful inputs to the political process for making policy decisions, but it cannot begin to provide a complete answer, especially to questions with such far-reaching implications for society. The issues should be aired fully and completely before a committee of Congress having broad policy responsibilities. An explicit decision should then be made by the entire Congress as to whether the risks are worth the benefits.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Dr. Dean E. Abrahamson
1092-25th Avenue, S.E.
Minneapolis, Minnesota 55414

Dear Dr. Abrahamson:

Thank you for your letter of April 24, 1974 transmitting comments by the Natural Resources Defense Council (NRDC) on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received. In particular, the Safeguards section has been significantly expanded in the Final Statement and we believe that it addresses the major concerns expressed by the NRDC. The enclosed staff response identifies the issues raised in your letter and offers specific responses.

The NRDC comments were very helpful to the AEC in the preparation of the Final Statement, a copy of which is enclosed for your information. Your interest in the LMFBR Program and assistance in this matter are appreciated.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical & Environmental
Research & Safety Programs

Enclosures:

1. AEC Staff Response to
Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

cc: J. G. Speth, NRDC, with enclosure 1.

Enclosure 1

AEC Staff Response To Comments By The Natural Resources Defense Council

1. Nature of the Threat

Comment

Page 7 - "Given then that SNM exists in large quantities in the LMFBR fuel cycle, that were it diverted it could form the basis for the fabrication of either an atomic bomb or a radiation weapon, what does the Draft Environmental Statement have to say about those who might wish to utilize the potential for this 'new form of anti-social behavior'?"

Response

Section 7.4.3 of the Final Statement addresses this question. It is, of course, not possible to define the characteristics of the adversary with confidence and it becomes necessary to reflect this fact in the nature of the safeguards employed. The basis for future safeguards is described in Section 7.4.8.

2. Future AEC Safeguards

Comment

Page 2 - "...we assumed that the AEC would take the opportunity afforded by the Draft Environmental Statement of the LMFBR...to outline in detail the measures being taken or anticipated to cope with the risks of diversion from the LMFBR fuel cycle..."

Page 3 - "The manner in which these diversions will be attempted to be prevented or the effects should diversions take place are totally ignored. Further, the Draft Statement does not describe studies underway which address the various aspects of the safeguards and diversion problem."

Page 8 - "And the goal is absolute prevention of any theft: 'The AEC seeks to prevent any diversion of nuclear material and does not recognize any quantitative limit on this objective.' How this goal of perfect containment, of absolute prevention of theft or recovery of SNM should there be a theft, is to be achieved is left to the reader's imagination..."

Page 9 - "At this point in the Draft Environmental Statement the reader would expect to find a full, candid, and explicit discussion...of the nature of the anticipated measures to 'expand and modify' and to 'upgrade and strengthen' the existing safeguards program. What instead is found is a flatulent exposition of the 'safeguards measures presently in place,'..."

Response

Section 7.4.8 describes the basis for development of safeguards for future fuel cycles. It recognizes the need to provide protection commensurate with the potential consequences. The basic principle is to provide multiple opportunities to interrupt the sequences of actions that would be necessary to carry out the adversary's purpose. In selecting the set of countermeasures, one aim would be to make the effectiveness of the system as independent as possible of the nature of the adversary.

Where the potential consequences of a particular adversary action sequence are extreme, the probability or likelihood of success must be reduced to near zero levels. It is not expected that a perfect system can be devised; however, it is not considered useful to establish a quantitative limit on such an objective.

The development of safeguards measures is a continuing, dynamic procedure of review and evaluation. The research and development activities, described in general terms in Section 7.4.8, include both efforts to define the problem and efforts to resolve it.

3. Cost of Future SafeguardsComments

Page 3 - "No mention is made in the economic analysis of the cost of safeguards programs or the costs which could accrue to society should there be a failure of the safeguards."

Page 12 - "...the AEC should take the opportunity afforded by the Final LMFBR Program Impact Statement to present a full discussion of the technical and economic merits and penalties of denaturing."

Page 13 - "The Draft Environmental Statement...does not even contain superficial discussion of the advantages and disadvantages of nuclear parks, say nothing of the detailed analysis--including analyses of the economic and institutional factors--which an adequate Environmental Impact Statement demands."

Response

Section 7.4.9 of the Final Statement provides preliminary estimates of the economic impact of safeguards on the LMFBR fuel cycle. The estimates are necessarily preliminary since commercial LMFBR fuel cycles are not likely to become operational until the late 1980's and the detailed

characteristics have not yet been determined. The conclusions of the cost estimates are:

- . The operating cost of safeguards with a high level of effectiveness will be less than two percent of the total operating costs of a large (80,000 MWe) fuel cycle module.
- . The capital costs of safeguards equipment will be less than one percent of the LMFBR fuel cycle capital costs.
- . Safeguards costs for LWR without plutonium recycle would be about half of LMFBR safeguards costs.
- . The costs of safeguarding components of LMFBR fuel cycles will be somewhat greater than the costs of safeguarding components of NTGR, LWR with plutonium recycle, or MSBR, and comparable to the costs of safeguarding GCFR fuel cycles.

The merits of "denaturing" and nuclear parks and other possible changes in the LMFBR fuel cycle to improve the effectiveness or reduce the costs of Safeguards are discussed in Section 7.4.9.4.

4. Safeguards Aspects of LMFBR and Other Fuel Cycles

Comments

Page 3 - "Nowhere does the Draft Statement include even the most rudimentary description of the LMFBR fuel cycle including such things as the quantities and chemical or physical form of special nuclear materials at each point in the fuel cycle. No mention is made of the relative advantages or disadvantages, from the standpoint of prevention [sic] diversions of SNM, of alternatives to the LMFBR Program."

Page 4 - "... (the Draft Statement) is totally inadequate to permit the reader to appreciate the distribution, and the chemical and physical form, of the SNM at various points of the fuel cycle."

Page 26 - "The Draft Statement does not include a comparison of the safeguards and diversion implications of alternative fission programs, although the various fission systems are known to differ in that regard."

Response

Section 7.4.6 of the Final Statement discusses the LMFBR and other fuel cycles from a safeguards viewpoint. In addition, Section 7.4.9 examines

the economic aspects of safeguarding different fuel cycles and different nuclear power generation "mixes".

It is postulated that the materials in the various parts of the different fuel cycles represent an attractive target in inverse proportion to the amount of processing necessary to obtain fissile material in pure, concentrated form. Various possibilities exist for reducing the availability of attractive materials in the fuel cycles (e.g. co-precipitation of fissile and fertile product at the reprocessing plant or co-location of fabrication and reprocessing plants). The selection of these depends on the nature and design of the particular facilities and does not lend itself to generalized discussion.

All fission systems either use or produce materials that would be useable in a nuclear explosive after chemical processing. The range of difficulty of safeguarding the various fuel cycles, as expressed by the range of costs, does not appear to be a significant variable in comparison to the other variables involved in the selection of a future technology.

5. Consequences of Successful Theft or Sabotage

Comments

Page 17 - "...the Statement contains a comment on the ease in constructing a nuclear explosive: 'The construction of a workable nuclear explosive device is a complex and difficult task requiring specialized skills and considerable resources. Without testing, there is a substantial possibility that there would be no nuclear yield at all.' This statement is unsupported either by material included in the Draft Environmental Statement or included by reference. The statement is also in direct contradiction to conclusions reached and supported by exhaustively detailed reports by persons acknowledged to be expert in the design of fission bombs."

Page 20 - "Are we to believe that the AEC is incapable of imagining the circumstances at the time and place of the detonation of an illegal nuclear weapon in the hands of an individual or group bent on 'anti-social behavior?' Are we to believe that the AEC is incapable of specifying the effects--in terms of property loss, deaths and injuries, and of political and social responses--for an array of 'circumstances at the time and place' which would bracket the possibilities in sufficient detail for policy considerations."

Response

The debate on whether it is easy to construct a nuclear explosion device revolves around matters of degree. There appears to be general agreement that, given the availability of the requisite nuclear material, the construction of an illicit explosion device requires a certain level and range of skills and resources. Disagreement arises with respect to the way the level or required skills and resources are characterized. This is important because if the task is made to appear too difficult, the safeguards problem might not be seen in its true dimension; if it is made to appear too easy, that could stimulate overconfidence among those who might be encouraged to attempt such acts. Clearly, what would be easy for one man or group might be difficult for another. The design and implementation of the AEC's safeguards system is based on the premise that making an illicit nuclear explosive is within the range of skills and resources available to persons or groups operating outside the law.

The destructiveness of any illicit nuclear explosion depends on the circumstances at the time and place of its detonation and on its yield. The circumstances are a matter of choice for the adversary, as affected by such constraints as logistics and target accessibility, and will depend on the characteristics of the nuclear material and the skills and resources of the adversary. The possible effects of the use of illicit weapons is discussed in a speculative way in Section 7.4.5.1.1 of the Final Statement.

6. Socio-Political ImplicationsComment

Page 15 - "The Final Environmental Statement must include a full and candid discussion of either how the AEC proposes to enact and enforce the safeguards program which it contends will be necessary with the LMFBR without the support and cooperation of the nuclear industry, or the means that are anticipated to proceed with the LMFBR without depending on industry participation in matters involving potential diversions of special nuclear materials."

Pages 15-16 - "...the extent to which the existence of the LMFBR program, which cannot, of course, be divorced from other civilian fission programs, will impose the necessity for behavioral, social, and other controls is among the most profound and grave of all of the many questions surrounding the development of the LMFBR Program. What are the changes, not in technology, but in our very social institutions that may be dictated by a decision to proceed with the LMFBR Program?..."

Response

The Atomic Energy Act provides the statutory authority for the U.S. government to establish and enforce safeguards requirements on facilities such as those in the LMFBR program. Whereas this provides a mechanism for unilateral imposition of these requirements we are confident that the tradition of cooperation by the nuclear industry, which has been exemplary in matters of safety and national interest, will result in full industry participation in the development and implementation of the safeguards program.

There is ample evidence to indicate that the nuclear industry fully appreciates the need for appropriate safeguards and that the costs of safeguards are part of the costs of doing business. Section 7.4.9.7 of the Final Statement discusses possible ways of distributing these costs.

Sections 5.4.2 and 5.4.3 deal with the broader aspects of socio-political implications. In particular, three types of effects are discussed: (a) effects on employees and potential employees of nuclear industries; (b) effects on the general population during normal periods arising from implementation of safeguards, and (c) effects on the public during recovery operations following a theft of nuclear materials.

Many of the most serious issues entail value judgments as well as large uncertainties and complex technical factors that cannot be dealt with in the absolute dollars and cents terms of cost-benefit. Unsatisfactory as this may be to those who want to prove acceptability or non-acceptability of a technology, no such proof is possible with regard to many of these issues. Many of them, such as the question of safeguards, have such direct social implications that they will be the subject of continuing public discussion. By that discussion, society can contribute to, and assure that its values are reflected in, the evaluation of the program. In its most general aspect, the intent of the Statement is to provide opportunity for that process of public discourse.

7. International Implications

Comment

Page 5 - "It is noteworthy that the Draft Statement does not claim that the present international safeguards system is adequate even for today's reactor economy, but simply states that 'the institutional framework for an effective international safeguards program does exist.' Further,

nowhere in the Draft Statement is there comment on the degree to which other nations have found the present international safeguards program acceptable, or the degree to which there is acceptance that this program must undergo 'significant expansion and modification'."

Page 7 - "On the questions associated with the international safeguards issue the Draft Report is completely silent. There is not a single word addressing this topic although the unclassified literature is replete with such discussions."

Page 23 - "Regarding the international implications of a failure of the systems designed to 'prevent the diversion of material suitable for weapons production from peaceful applications', we fully appreciate that there are developments in addition to the proliferation of LMFBR's that could lead to nuclear weapons capability being extended to virtually any nation-state. If, however, the AEC is arguing that it need not discuss the weapons proliferation implications of the LMFBR on the grounds that other developments, for example, in new uranium enrichment technology, assure that this capability will be developed quite independently of the decision to proceed with the LMFBR, then the AEC has the obligation to fully discuss these other developments in the Final Impact Statement."

Response

There are two international aspects to safeguards. One relates to the question of sub-national attempts at diversion in other countries. That subject is discussed in Section 7.4.4.2. The second aspect is the proliferation issue addressed by your comments. That subject is covered in Section 5.4.3.

8. The Current Safeguards System

Comment

Page 17 - "It seems to us that an adequate Final Impact Statement must also include a candid and complete discussion of the circumstances which prevailed within the Atomic Energy Commission through at least the summer of 1972 and which permitted this lax, and given the degree of the hazard, irresponsible abrogation of responsibility in the protection of special nuclear materials."

Response

The Final Statement discusses the adequacy of the current AEC safeguards system in Section 7.4.7.6. The GAO report to which your comment refers*

*Improvement Needed in the Program for the Protection of Special Nuclear Material, Report No. B-164105, U.S. General Accounting Office, Nov. 7, 1973.

identified deficiencies, or apparent deficiencies, many of which were due to conditions that would be resolved by the regulatory amendments then under review. These amendments became effective March 6, 1974, and represent a significant strengthening of the previous regulations. The amendments resulted from internal AEC review and staff study carried out over a period of several years.

9. Appendices

Comment

Three appendices were attached as part of the comments.

Response

It is believed that the safeguards-related points raised in these appendices have been treated in the response to individual comments above, or in the Final Statement.

WASHINGTON STATE UNIVERSITY
PULLMAN, WASHINGTON 99163

COLLEGE OF ENGINEERING
RESEARCH DIVISION

April 23, 1974

Office of the Assistant General Manager
for Biomedical and Environmental Research
and Safety Programs
U. S. Atomic Energy Commission
Washington, D. C. 20545

Gentlemen:

The AEC should be complimented for its attempt to prepare a NEPA environmental impact statement on a very complex and far-reaching program, the Liquid Metal Fast Breeder Program. I hope that the following comments on WASH-1535 will be helpful to the AEC.

1. Annual Dose from Nuclear Facilities (Vol. III, 9.1.3.1, P 9.1-30)

It appears that the AEC has conservatively estimated the environmental radiation impacts but it is impossible to check the validity of the data as summarized in the TVR and UMRB (WASH-1209) studies. Studies of the "Year 2000" type can be very misleading. Basically, the "Year 2000" studies, which use the HERMES code (HEDL-TME-71-168), are analogous to Forrester type modeling -- "Limits of Growth, Urban Dynamics, etc.".

If one examines the modelling literature, it appears that models are used to justify a position or opinion about how things ought, should, or might be. The pessimistic interpretations of Meadows, et al. and the optimistic ones of Starr, et al., both dealing with the same topic, are two such examples.

No model, whether it is the "Year 2000" study or "World Dynamics", are unique representations of real or natural systems. Models are rough approximations or abstractions of a system which, if carefully and thoughtfully constructed, may give some insight on the behavior of natural systems. Bernard C. Patten has discussed this point at length in his recent books.

Models have an uncertainty principle, which is very loosely analogous to the Heisenberg uncertainty principle. (See recent IEEE Trans., Systems, Man, Cybernetics). It is probably more related to Henri Poincaré's (Science and Hypothesis, p 217) observation that there are no unique mechanisms. Since models have some of the attributes of mechanisms, and since the "Year 2000" studies are models, there are other models of the TVR and UMRB that may be significantly different. These possibilities should be recognized.

Office of the Assistant General Manager for
Biomedical and Environmental Research and
Safety Programs

Page 2

April 23, 1974

Stochastic perturbations, such as weather, should be considered in the "Year 2000" analysis, or at least there should be some qualification that stochastic effects make predictions very uncertain. It is interesting to note that Eberhardt and Hanson (Health Phys. 17, 793 (1969)), who were studying the simple lichen-caribou-eskimo system, could not adequately analyze the system because of a stochastic effect. The situation is obviously worse for the TVR and UMRB systems.

When one considers the low success rate of demographic predictions, which have more substance than those of the "Year 2000" studies, it seems to me that the AEC should express some reservations or qualifications about the "Year 2000" studies. Studies of this type are unprovable at one end, difficult to disprove for those without access to large computers, misleading to the un-informed, and most likely incorrect at the other end.

I make these comments as one who has used a computer for a number of years and who thinks that computers are very useful machines. But I think that presentation of computer data should be done with care, not to "hoodwink" others, accidentally or otherwise.

2. Reactor Heat Generation System (Vol. II, part 1 of 2, 4.1.2.1.1, P 4.2-27 and Vol. III appendix III-B)

There appears to be no satisfactory discussion of potential environmental impacts of alternative fuels such as plutonium nitrides and carbides. The use of these fuels obviously will result in varying environmental impacts. Nitride fuels probably will generate large amounts of ^{14}C which, if not trapped, will be released to the environment. Similar impacts can be expected for carbide fuels, though much smaller. My calculations, which are admittedly very rough, also indicate that oxide fuels may generate substantial ^{14}C through the $^{17}\text{O}(\text{n},\alpha)^{14}\text{C}$ reaction in the core and blanket. The ^{14}C carbon production rate may be one to ten percent of the tritium production rate. This calculation probably should be done with computer codes, such as ORIGEN or ISOGEN, to get a better fix on the ^{14}C generation rate.

3. Siting Considerations (Vol. II, part 1, 4.2.21, P 4.2-4)

It is my opinion that the AEC underestimates the problems associated with the siting of any type of reactor, especially ten to thirty years from now. The acceptable sites may not be available at that time.

4. Transmission Requirements (Vol. II, part 1, 4.1.1.2, P 4.2-17)

The discussion of the routing of transmission lines is inadequate because it does not consider the lost timber and agricultural production caused by a proliferation of transmission lines and corridors. Here in the Pacific Northwest,

Office of the Assistant General Manager for
Biomedical and Environmental Research and
Safety Programs

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timber production lost to transmission corridors is a serious economic loss. Did the AEC consider such factors in the B/C analysis? Aesthetics and recreation were hardly considered at all.

5. The Role of Energy in Economic Growth (Vol. III, 5.2.1, P 5-4)

It appears that Federal Agencies believe in the relationship shown in Figure 5.2-3 more than professional economists. My conversation with an economist, who worked on the Ford Foundation Energy study, indicated that plots similar to Figure 5.2-3 have questionable validity. The use of D. C. White's article as a reference seems unfortunate since a more rigorous analysis is needed. I'm hoping that a Ford Foundation economist will discuss this aspect in greater detail.

Sincerely,

John C. Sheppard
Associate Nuclear Engineer and Head,
Radioisotopes and Radiations Laboratory

JCS/ag

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. John C. Sheppard
Associate Nuclear Engineer and Head,
Radioisotopes and Radiations Laboratory
Washington State University
Pullman, Washington 99163

Dear Mr. Sheppard:

Thank you for your letter of April 23, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the other enclosure to this letter for responses to your specific comments.

We appreciated receiving your comments and found them helpful in preparing the Final Statement. Thank you for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Responses to Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

AEC Staff Response to Comments
by John C. Sheppard

1. Comment: (pp. 1-2)

"Basically, the 'Year 2000' studies, which use the HERMES code (HEDL-TME-71-168), are analogous to Forrester type modeling-- "Limits of Growth, Urban Dynamics, etc."

"Studies of this type are unprovable at one end, difficult to disprove for those without access to large computers, misleading to the un-informed and most likely incorrect at the other end."

Response:

An explanation of the purpose and scope of the "Year 2000" Studies is contained in Section 3.6.4. The HERMES model is not analogous to "Forrester type modeling." The model is a computerized accounting system for individual radiological pathway evaluations. The "Year 2000" Studies examine perturbations in the various input parameters, while the base case consists of the best known estimates of the parameters. The results reflect the potential radiological implications of operating a large number of nuclear facilities. The size of the projected nuclear industry is consistent with the economics discussed in Section 11 of the enclosed Final Statement. Thus, the study results are important as an indication of potential environmental impacts. The results should not be considered an absolute forecast of future conditions.

2. Comment: (p. 2)

"Nitride fuels probably will generate large amounts of ^{14}C which, if not trapped, will be released to the environment. Similar impacts can be expected for carbide fuels, though much smaller." "The ^{14}C carbon production rate [in oxide fuels] may be one to ten percent of the tritium production rate. This calculation probably should be done with computer codes, such as ORIGEN or ISOGEN, to get a better fix on the ^{14}C generation rate."

Response:

Effluent characteristics were calculated using the ORIGEN code and codes which simulate the radionuclide release pathways in reactor systems. Carbon-14 releases from advanced fuels will certainly have to be examined as part of the future development of the fuels.

3. Comment: (p. 2)

"It is my opinion that the AEC underestimates the problems associated with the siting of any type of reactor, especially ten to thirty years from now. The acceptable sites may not be available at that time."

Response:

The AEC has, for a number of years, supported research studies pertinent to the siting of nuclear power plants. Many of these studies have been directed toward obtaining a better understanding of specific siting problems, such as the ability of available bodies of water as receptors for nuclear plant waste heat and the implications of seismic activity on nuclear power plant siting. In conducting these studies, emphasis has been placed upon attempting to understand the implications of the projected increased demands for nuclear power plant sites in the future. It is anticipated that future reactor siting will be facilitated through increased use of cooling towers (both wet and dry), cooling ponds, location of power plants on barges in off-shore locations, and through the development of nuclear energy centers.

4. Comment: (p. 2)

"The discussion of the routing of transmission lines is inadequate because it does not consider the lost timber and agricultural production caused by a proliferation of transmission lines and corridors."

Response:

The transmission requirements discussion you reference in your comments was supported by additional discussions in the Draft Statement. The impact of transmission line construction was given on pages 4.2-76 and 4.2-77 of the Draft Statement. Ecological effects and related impacts were discussed on pages 4.2-81 to 4.2-84. Since this Statement does not treat the characteristics of a particular site, it is not appropriate to discuss specific effects that are unique to a certain part of the country, such as the Pacific Northwest. These effects will be evaluated in the environmental statements prepared for specific plants, and will include the economic factors and benefit/cost analyses associated with timber and agriculture production when appropriate. Aesthetic and recreational values will also be considered. See Sections 4.2.2.3 and 4.2.4.1.2 of the Final Statement.

5. Comment: (p. 3)

"My conversation with an economist, who worked on the Ford Foundation Energy study, indicated that plots similar to Figure 5.2-3 have questionable validity."

Response:

In reference to your comments on the role of energy in economic growth, you will find an expanded discussion in Section 11.2 of the Final Statement on the energy demand projections used in the cost-benefit study. Assumptions and methodology leading to the several energy demand projections are explained and projections from other sources are discussed. Figure 5.2-3 depicts the relationship of GNP and per capita energy use only as an indicator of the role of energy in nations with strong, industrial economies.

Mid-America Coalition for Energy Alternatives

4950 Cherry Room 326, Kansas City, Missouri 64110 (816) 531-8711

April 24, 1974

Office of the Assistant General Manager
for Biomedical and Environmental Research
and Safety Programs,
U.S. Atomic Energy Commission,
Washington, D.C. 20545

Dear Sirs:

Our organization has reviewed the draft environmental impact statement entitled: "Liquid Metal Fast Breeder Reactor Program" (WASH-1535), and is submitting the following comments to be made a part of the review record and to be considered in preparation of the final statement. We think it is essential that extensive hearings be held before and following the issuance of the Final Environmental Impact Statement, in view of the gross deficiencies in the present draft statement, the inadequate time allowed for review and the extreme importance of the issues being decided.

I. General comments and Summary Points

A. Mechanics of the Statement

1. The AEC had inadequate preparation time for an analysis of this magnitude, as evidenced by inconsistent projection dates, great redundancy in presentation, poorly organized summations and comparisons of impacts and alternatives and superficial consideration of energy demand and supply alternatives.
2. Inadequate time was provided for the public and agencies to evaluate the report and to prepare well organized written responses of a quality, accuracy and thoroughness worthy of the magnitude of the decisions being weighed in the LMFBR program.

B. Scope and Content of the Statement

1. One of the greatest shortcomings of the draft statement is that estimates of environmental impact and hazards for radioactive materials in the fuel cycle are all minimal, based on unavoidable or "normal" releases. Only

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a very narrow range of accidents are considered and consequences are, even then, not always explicitly evaluated. As an outstanding example, the assumption that only about one millicurie per year of transuranics (per 1000 MWe) will be released, from a fuel cycle involving millions of curies of Pu, is neither conservative nor credible. It is everywhere assumed that the machines work, and the side effects from normal functioning are usually minimal. However, it is the extreme danger of the nuclear fuel cycle components, and the extreme consequences of major failures that we are most concerned with. To this concern the final impact statement should address itself.

2. The questions of sabotage, terrorism and safeguards are not fully, honestly and openly dealt with. Perhaps one of the most serious omissions is discussion of the consequences of the existence of the Retrievable Surface Storage Facility or the Noble Gas storage facility as a target for nuclear weapons.
3. Environmental impacts are minimized by assuming a 365-day cooling period for spent fuels before shipment. Yet shorter cooling times are planned and the base-case for cost-benefit analysis assumes a 120-day cooling.
4. The case for the LMFBR, and against some of the alternatives, is hopelessly biased by the narrow range of energy and electricity demand projections considered. Alternatives should be evaluated with demand scenarios ranging downward at least to a no-growth-in-per-capita-use case. The variation of only plus or minus 20% in the year 2020 demand, used in the economic analysis, is a practically trivial range for considering alternatives. Likewise the potential contribution of alternative supply systems and conservation practices are seriously downgraded by reference only to the base-case energy demand growth projections.
5. No discussion is presented of the environmental impacts, and trade implications, if the LMFBR or any other combination of energy supply systems enable the U.S. to achieve the projected growth in GNP to the year 2020. Of particular concern are the implications of a continued growth in energy intensive living on the natural world and the looming scarcity of a variety of basic minerals that the projected energy intensive growth of GNP would involve.
6. Finally, no attempt is made to evaluate a scenario in which a combination of alternate energy resources are developed with the same optimistic engineering and economic assumptions as are made for the LMFBR; in which energy demand is held at a nearly constant per-capita level; and in which maximum possible hazards of the nuclear fuel

cycle and its alternatives are presented for risk/benefit judgement.

II. Specific Questions and Comments

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4.1-13	When the base case of the economic analysis assumes spent fuel cooling of 120 days, and when announced goals of the AEC and industry are to eventually lower the cooling time to as little as 30 days, this chapter should include impacts, routine and accidental, for the short-cooling case, not just the much easier 365 day case.
4.1-19	Why is the RSSF proposed only to year 2000, while the NGSF is conceptualized to year 2020?
4.1-23	Table 4.1.4. seems to assume a linear rate of demand for depleted Uranium for FBR refueling from 2000 to 2030. Is this consistent with LMFBR growth projections from 2000 to 2020?
4.2-10	With the forecast that reactors will be located nearer population centers than at present, do estimates of accident and routine release hazards take this conservatively into account?
4.2-11	The plant and cooling pond area of 2,500 acres, plus only tens of acres per added unit does not seem conservative. In Kansas, two proposed nuclear sites are requiring 10,000 or more acres each.
4.2-18	It is stated that advanced design power plants will use 765-1,500 KV lines requiring right-of-way widths of 280-560 ft. Why assume 175 ft. right-of-way on page 4.2-76? Where is the cumulative total of land required for right-of-way to the year 2020 shown? Cumulative land for power plants to year 2020?
4.2-27	Shouldn't the engineering details of the active or passive core-restraint system be spelled out as they affect accident probabilities and consequences?
4.2-157	Even though AEC judges probability of class 9 accidents to be low, their environmental impact should be assessed. After all, if such basic behavior as swelling of LMFBR fuel and core materials can come as a recent surprise, perhaps estimates of accident probabilities are similarly fallible. Further, class 9 accidents consequences are relevant in

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4.2-157

terms of sabotage and war-related acts.

4.2-159

It is stated that the overall safety of the LMFBR cannot be assessed until design details not yet available are provided. This seems to be another reason to include worst-case estimates (as in WASH-740) for class 9 accidents.

4.2-163

Does the lower design pressure requirement for the LMFBR containment building (10 psi vs 60 psi for LWR's) imply a greater susceptibility to sabotage of acts or acts of war? (e.g. ability of containment to withstand shock wave from nearby chemical or nuclear bombs).

4.2-177

Confidence in tornado resistant design seems inconsistent with recent announcement of a 1-year, \$150,000 study of tornado effects to help establish design criteria for nuclear power plants and structures. (Nuclear News, March, 1974). What about tornado impact at other steps in the fuel cycle? Would 30 days, or even 365 days cooled spent fuel cask or rail car be immune to direct tornado impact? Would a liquid, high-level waste tank? Would PuOx fuel, in truck shipments, remain confined in a tornado incident?

4.2-195

It does not seem conservative to simply postulate that no major radioactive release can occur and hence ignore maximum possible consequences. Why would the Price-Anderson Act of 1957 be needed if the case is that compelling?

4.4-2

With stated goal of eventually handling 30-day cooled spent fuel, potential environmental impacts for this case should be discussed throughout the nuclear fuel cycle. The greater the ignorance of details of handling such fuel, the broader should be the scope of credible accidents discussed.

4.4-3

In view of uncertainties expressed here, can economics of LMFBR fuel reprocessing be reliably predicted?

4.4-4

How can routine releases of I_2 be guaranteed at the low values reported, when processes and technique have not been developed or tested? The environmental impacts discussed seem to be more nearly goals, rather than conservative, worst-case projections.

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4.4-14

The normal and accident impacts of sodium-cooled, short-decay spent fuel shipping should be discussed in view of announced goals.

4.4-52,53

These huge increases in volatile fission products for short-cooled fuel must be considered in looking at impact of shipping and reprocessing.

4.4-54

If short-decay time case cannot be meaningfully assessed then worst case consequences should be discussed. There is a consistent theme here of simply ignoring impacts of steps where knowledge is lacking.

4.4-55

What about accident effects at 30-120 days cooling? Why choose 180 as the shortest time for estimates when even 120 cooling is the base case assumption?

4.4-60-64

Similar calculations should be made for 30 day and 120 day cooling cases. Why assume a 20 fold improvement in particulate retention in LMFBR facilities. The report seems to be postulating improvements to support a desired design impact, rather than looking at conservative ranges of containment.

4.4-87

Accident consequences for 30 and 120 cooled fuel should also be estimated. Only assumes fuel assembly breakage or other accidents inside containment structures. What about accidents or breakage in open? What about H₂-O₂ explosions in the high-level liquid storage tanks? Consequences of such an accident have already been estimated (ORNL-4451)

4.5-3

Table 4.5.1 shows almost 600 Kg of PuO₂ per truck shipment. The highjacking implications of this should be discussed, especially since shipment is planned by common carriers.

4.5-25

Table 4.5.3.2. should show activities and thermal power for 30 day and 120 day cooled fuel since these are definitely under consideration.

4.5-48

What is the hijacking attractiveness to a terrorist of a truck shipment of almost 1 million curies of 85 Kr?

4.5-55

Maximum flame temperatures of 1475°F do not seem conservative in these days of massive shipments of a variety of high-energy materials.

4.5-58

The calculation of rupture margins does not seem conservative. Impurities, outgassing,

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4.5-58

etc. can increase internal pressure generated at high temperatures. Certainly sabotage could expose the PuO_2 to more severe conditions. Consequences should be discussed. It seems like a double standard to let the UO_2 leak a little bit, but to postulate or assert that no leakage of PuO_2 will ever occur.

4.5-63

Here again, with a lesser hazard than PuO_2 leakage is allowed to be postulated.

4.5-73

Table 4.5.5.6 lists category 5 accident probabilities as low as 8×10^{-13} per year yet includes no probability for PuO_2 release. A zero probability for PuO_2 release appears to be a willful distortion of true hazard estimation. Even if such low accident probabilities were realized, the problem of malevolent-act releases would likely dominate the hazard and should be estimated and discussed.

4.6-1/2

Storage of solidified high level wastes for thousands of years is not described.

4.6-16

Credible unnatural forces (war and sabotage) should also be provided for and discussed.

4.6-47

Consequences of cask rupture outside a containment building should be discussed.

4.6-47/48

How would spilled material be retrieved? How would airplane crashes into storage areas be handled in areas which are all remotely controlled?

4.6-50

No statement on type of compound, container and seal to be used for iodine; it is noteworthy that the 55 gal. drums mentioned for the others are not used here.

4.6-53

para. 2

"No credit is taken for containment provided by the packages once they are buried." If any alpha emitters are buried, it should be prevented that they become airborne. It is suggested that all alpha emitters be transmuted by neutron bombardment in a reactor.

4.6-48

Here again, where a very serious hazard is involved, it is assumed that engineering will make the event (meltdown) incredible. This avoids honest consideration of real dangers.

4.7-1

In the listing of areas from which plutonium might be released, the potential release from a storage site is not mentioned.

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4.7-2

Stack releases of 1 mCi alpha particles for 1000 MWE, which might contain 10^8 - 10^9 Ci, appear prayerfully small.

4.A-12

No consideration given to sinking of a barge.

4.E-6

The values for plutonium appear meaningless without specifying whether it is absorbed as a metal or as a particular salt. Probably a soluble salt is implied since values are higher in liver and bone than lung doses. But why is the GI dose even higher than the lung?

4.E-8

In Table 45, more total body radiation and tissue effects are assigned to Pu-239 after ingestion than after inhalation. This is contrary to absorption data which show a low retention and absorption from the gut and almost 100% retention from the lung.

4.G-51

Again, over-emphasis on plutonium effects on bone and liver, and insufficient consideration of the inhalation of metallic plutonium or plutonium oxide into the lung where its biologic half-life is greater than a human lifetime.

4.G-63

No consideration of teratogenic effects.

4.G-64

A somewhat cursory consideration only of the possibility that linear extrapolation actually is too conservative since at higher doses carcinogenesis is inhibited by killing some of the cells. Also there is no mention of an important scientific paper on this subject which would be required to better evaluate this problem. I am referring to Baum, Population Heterogeneity Hypothesis on Radiation Induced Cancer, Health Physics 25:97-104, 1973

4.G-69

Estimates are all minimal, based on unavoidable or "normal" releases. There are no accident assumptions and their consequences.

5-7

In Figure 5.2-1 and in many other figures, tables and discussions, a uniform presentation of projections to the year 2020 should be made.

5-7

Equally, if not more striking in Figure 5.2-3 is the enormous verticle range of GNP for a given per capita income, e.g., a range of about 50 to 130 millions BTU per capita for countries in the \$1,500-\$2,000 GNP per capita range. Two conclusions might be drawn: (1) Countries fall on different-slope

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- 5-7 lines of BTU vs GNP depending on life styles, values, habits, etc. or (2) there is a law of diminishing returns that causes the curve of BTU/GNP to curve up exponentially, e.g., from New Zealand to the U.S. Figure 5.2-3 which appears to play a key role in the future energy use projection that is the basis of the present report, can be used also to argue that the U.S. needn't commit itself to the projected increase in BTU/GNP to achieve continued well being.
- 5-9 Reversal of electrical rate structures should be considered here to alleviate burden on poor.
- 5-13 Capital requirements for adequate liability insurance should be estimated here, as an alternative to continued subsidy by the Price-Anderson Act. Such costs should be fully internalized in a study such as this one.
- 5-31 This impact statement does not honestly address the hazards of fission power if a "stable social order" ceases to exist for a time, either in the U.S. or in other countries to which export of our nuclear technology is targeted.
- 5-32 Having raised the issue of less political freedom with a Pu economy, some discussion of implications should be included.
- 5-33 Will our nuclear energy economy be abandoned if "international agreements and institutions to assure that the common good, is indeed, protected," do not come to pass? Can there ever be such a guarantee? Wilbrich and Taylor's book should be referenced and discussed.
- 6-1,2 Just because "reliable and precise quantitative information on the expected frequency of occurrence of major accidental releases in the LMFBR fuel cycle is not available at this time" does not justify not discussing their environmental impacts. It makes a mockery of NEPA to ignore consequences on the assumption that they can be engineered away, or that their probability is unknown. At the very least a "Farmer limit-line" discussion of releases should be included for every phase of the fuel cycle.
- 7-21 Deficiencies in sealing present-day containment vessels are alluded too. The impact of

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- 7-21 such sealing problems should be discussed in accident cases.
- 7-36 Why are the confinement factors for ^{131}I and ^{129}I different? Are these adequate for the 30-day cooled fuel case?
- 7-38 The general approach to impact discussion seems to be that where the hazard is really great, engineering is postulated to make the hazard "incredible" and, therefore, it can be ignored. Thus UO_2 and UF_2 are allowed to escape containment in hypothetical accidents but PuO_2 is not. Consequences of worst-case accidents should be discussed, even though of hoped for low probability.
- 7-41 What fractions of casks for LMFBR can likely be shipped by barge?
- 7-42 With regard to the RSSF, the statement that "the requirement for continued human action in no way weakens the safety of the surface storage approach to management of high-level waste" is an affront to common sense.
- Such advocacy of an expedient, recent solution to a long-neglected problem area destroys credibility with regard to the whole report.
- 7-55 Sabotage is mentioned in this concept, where it is least credible. Why is it not discussed at each step of the proposed fuel cycle?
- 7-64 It is stated that: "The possibility of sabotage of facilities resulting in radiological incidents must also be considered." Yet this is not done consistently throughout the report.
- 7-72 What about inherent sabotage protection for fuel cycle components other than the reactor?
- 9.1-2 Figure 9.1-1. Will fossil fuel peaking units really decrease so much, percentage-wise, relative to central station capacity?
- 9.1-4 If fossil fuel system capacity is increasing exponentially at year 2020, as shown in Figures 9.12 to 9.13, is this consistent with coal projections in Fig. 9.1-4 to 9.1-6? All projections should extend to 2020.
- 9.1-19 Curies of waste should be listed also. More important than volume.
- 9.1-21 The release numbers in Table 9.1-4 are whatever the AEC and the manufacturer's decide to engineer. Why bias the LWR in this way relative to LMFBR?

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9.1-32	Table 9.1-7. Why not contain the Krypton in the LWR and HTGR cases? Again seems to deliberately bias for the LMFBR.
9.1-34	Can Table 9.1-8 numbers be justified for 30 day cooled spent fuel?
9.1-69	How can one claim there will be less radioactive releases from LMFBR, except as a chosen design objective? If the LMFBR has truly "arrived", why so many unanswered design and process questions alluded to earlier?
9.2-5	If dismantling costs are presently 10-15% of construction costs, then a conservative assumption is that they will escalate at a large fraction of the discount rate percentage and will always be an appreciable fraction in cost-benefit analysis.
10-27	Some estimate should be made of the security-safeguards personnel likely to be needed in Pu-economy.
10-34	The argument about man-made artifacts is particularly specious. Of what relevance to the perpetual guardianship of high-level wastes is it that man-made artifacts were constructed with physical properties preventing physical deterioration for over 1000 years. It is more relevant to point out that man probably destroyed or dispersed all but a tiny surviving fraction of such artifacts.
10-35	What happens when a portion of the human race doesn't desire the safekeeping of these wastes? The question of nuclear sabotage of the incredibly spatially concentrated RSSF and NGSF should be addressed.
10-36	The minimum obligation to future generations of merely maintaining records of radioactive waste seems like a minimum morality indeed.
11.1-3	A more direct consideration of the first CEQ alternative should be given in detail. The idea that no action on the LMFBR necessitates supplying the projected amount of electricity needs by other systems is not in any sense part of their first alternative. It, in fact, forecloses the first alternative discussion: " <u>Whether</u> energy should be produced and <u>what level</u> of energy consumption is consistent with economic and environmental considerations."
11.1-4	How can decommissioning costs be so confidently

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- 11.1-4 dismissed in the face of similar uncertainties?
- 11.2-5 The low energy case, -20% of projected 2020 usage is not at all conservative. Substantial decrease in usage, (factors of 2-3) such as that postulated by the recent Ford Foundation Study, should be included in the cost/benefit analysis.
- 11.2-8 Three-hundred and sixty-five day cooling is treated as an exception in cost/benefit analysis, but is the assumed cooling period in discussing environmental impact. This seems like a convenient double standard to highlight favorable factors.
- 11.2-13 A case should be ran with optimistic uranium supply, low energy demand (factor of 2-3), 1991 introduction of LMFBR, high LMFBR capital costs, 365 day cooling and no carbide fuel.
- 11.2-14 Can a net savings of only 11% in the discounted cost of power be viewed as significant with all the design and process uncertainties of the LMFBR?
- 11.2-7 Does Table 11.2-5 assume 365 day cooling of fuel? What is included under insurance? Where is the Price Anderson Act discussed, and the hidden subsidy cost that it represents?
- 11.3-2 The impacts of alternative energy systems should be compared for the case of drastically lower energy use also, e.g., Ford Foundation "zero growth" case.
- 11.3-3 If the comparison of total impacts emphasizes only "common or everyday variety risks" the conclusion is foregone since the assumption is made that the LMFBR fuel cycle will be designed and operated to make impacts negligible.
- 11.3-13 Table 11.3-5 assumes 20 man-rem in reprocessing plant, vs 20 man-rem for the LWR. Why? Is the 30 day cooling case assumed here?
- 11.3-17 The "upper limits" of public health effects for the nuclear fuel cycles assume no serious accidents can occur. Is this normal usage of the term?
- 11.3-34 If the LMFBR replaces retired fossil capacity after year 2000, why does the fossil component in Figures 9.1-2 and 9.1-3 keep rising?
- 11.3-42 If these fatality numbers were really credible, then why is Price-Anderson necessary for nuclear and not for coal?

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11.4-1

The key alternative is left out, namely, reducing energy "needs" by conservation and other means. Here, as in many other places in WASH-1535, the presumed continued exponential growth (give or take a token 20%) in electricity use dominates the whole discussion.

11.4-2

A quite different lesson can be inferred from the recent oil "crisis"; e.g., look at the lives saved by speed and mileage reductions in auto travel and the potential benefits from a shift to bus, train and mass transit. Where, in this report, is a serious attempt made to determine the "future real need for energy"? The report seems to uncritically accept the historical increase!

11.4-3

Why lump solar energy recovery with fusion? One has been demonstrated and the other has not. One doesn't need as many central station solar electric plants if solar heating and cooling of buildings is applied. If Kansas City Power and Light projections are typical, one of the big future forces for increasing growth in demand will be for electrical space heating.

11.4-13

Again, seems to assume central station needs are immune to solar space heating and cooling. Why are not windpower and conservation mentioned at this point?

11.5-17

The concomitant benefit of developing and exporting expertise in solar, wind, and geothermal is ignored.

II.4-23

The "evidence" that the breeder should be viewed as a last resort is the concern about the unanswered questions of sabotage, Pu diversion and accumulation of high level wastes.

III-A-1

Is it really contended that present safeguards are adequate for protection against dedicated groups of suicidal terrorists and other low probability threats?

III-A-2

Yields and circumstances for use of illegal nuclear weapons can be predicted. The McPhee-Taylor series in the New Yorker should be referenced.

III-A-3

Cases of radiological weapons use should be postulated. One need not wait to know by experience the method and circumstance of use.

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III-A-3

It can be alleged that the RSSF, NGSF, and possibly high-level liquid waste storage tanks at fuel reprocessing plants do pose a possible new and significant threat to our national security. The effects of a high-yield nuclear weapon completely cratering, and dispersing in the atmosphere, the RSSF at year 2020 should be estimated and presented.

III-A-4

If conventional weapons detonation can damage nuclear facilities other than reactors, then the consequence should be estimated. Chester's studies at ORNL should be referenced in this context.

III-A-5

Are such dangers as Pu weapons manufacture and the operation of a Pu black market so credible that discussing them with only unclassified, available information will lessen our security?

III-B, 2-6

What spent-fuel cooling time is assumed if breeding by year 2010 sustains a 6% yearly electrical growth rate?

III-B, 3-13

Increase of only \$100 million for a 2000 MWe plant that has not yet been designed does not seem conservative!

III-B, 3-21

Why don't Table 3.3.5 and Table 11.2-5 agree?

III-B, 3-35

If projected values of study parameters represent such a consensus, then at least the 120-day cooling case should have been considered for fuel cycle impacts.

III-B, 3-41

What is the annual growth rate change to produce only a net variation of $\pm 20\%$ in projected year-2020 demand?

III-B, 3-43

It would be helpful to know how much capital costs of a 1000 MWe LMFBR would have to be changed to wipe out the cost/benefit advantage over LWR's for various assumed parameters.

III-B, 3-49

There seems to be more concern about direct costs of Pu inventories in relation to spent fuel cooling times than in estimates of hazards to the environment as a function of cooling time.

III-B, 3-60

The figures in the reference case for fossil mix do not match those given in Table 4.14.

III-B, 4-11

If single-loop cooling is contemplated then accident hazards and routine release should

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III-B, 4-11

be assessed in earlier discussions.

In Table 4.5 what cooling period for spent fuel is assumed?

III-B, 4-12

How will environmental impacts vary if we go to "very large units?"

III-B 4-18

What cooling time was assumed for shipping cost and reprocessing estimates?

III-B, 4-20

Why are fuel cycle times for LMFBR spent fuel shipping and reprocessing assumed to be faster than LWR case?

III-B, 4-30

What insurance costs are referred to? How would they differ without Price-Anderson or with new plans under consideration?

III-B, 4-31

The energy forecast assumption of Table 4.13 seriously biases alternative. The case of near-zero per capita energy use should be considered as well.

III-B, 4-32

Isn't there a recent trend toward higher energy use per GNP increment?

III-B, 4-33

Doesn't recent data show that total cost of electricity is rising faster than the general price level?

A-5

Is all this materials - engineering advance really more credible than solar energy storage and collection advances?

B-6

Access to a "virtually limitless supply of low-cost electricity," even if attainable, should not be assumed to be an unmitigated blessing. Adverse effects of cheap energy and energy-intensive applications deserve consideration in the broad focus that the LMFBR impact statement should achieve.

A.5-4,6

The treatment of the history and status of solar energy devices is unfairly shallow. Where are references to recent developments such as the NASA-Lewis patented solar heating-cooling home system, to name just one?

A.5-15

How can it be stated that solar cooling of buildings would not affect utility power system facilities in those large areas where peak load is dominated by summer heat waves?

A.5-21

What could solar energy contribute with a commitment of policy and financial backing equal to that being given the LMFBR?

A.5-30

Is the 15.5% capital charge consistent with the numbers used in Section 4 of Appendix

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A.5-30

III-B?

A.5-34

How minor will solar applications be by year 2000? Give feasible upper percent limits for replacing electric heating and air conditioning.

A.6-1

Here, as elsewhere, contributions of individual alternatives are made to look small when compared with projected exponential growth in electricity. If per capita energy and electricity use were held constant, how important could wind-power be?

C.1-1

The real conservation question is by-passed --namely, can we learn to live less energy-intensively, thus stopping the continued growth of per capita energy consumption.

C.7-6

A table should be shown summarizing the energy savings for each conservation measure and the contribution of each alternative, such as wind power. With several assumed energy growth forecasts, these alternatives can be put in truer perspective and real options discussed.

Respectfully submitted

Mid-America Coalition for
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UNITED STATES
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DEC 31 1974

Ms. Diane Tegtmeier
Co-chairperson,
Mid-America Coalition for
Energy Alternatives
4950 Cherry, Room 326
Kansas City, Missouri 64110

Dear Ms. Tegtmeier:

Thank you for your letter of April 24, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the other enclosure to this letter for response to your specific comments. Additional discussion regarding some of the major points you raised is provided below.

The NACEA concern

"... that estimates of environmental impact and hazards for radioactive materials in the fuel cycle are all minimal, based on unavoidable or normal releases."

was addressed in considerable detail in the Draft Statement (see, for example, Pages 4.2-152 to 4.2-195, 4.3-130 to 4.3-148, 4.4-101 to 4.4-103, 4.5-74 to 4.5-1-6, 4.6-47 to 4.6-49, 4.6-57 and 4.6-58, 4.6-67 and 4.6-68 and 4.6-69, all of which contain estimates of the environmental impact of accidental releases in the LMFBR fuel cycle). Additional information concerning accidental releases of transuranics and their relationship to normal releases is presented in Appendix II.G of the Final Statement. The impact of shipping and reprocessing LMFBR fuel for cooling times shorter than 365 days is also addressed in the Final Statement (see Section 7.3.4 and Appendix II.P respectively).

The NACEA concerns that

"The question of sabotage, terrorism and safeguards are not fully, honestly and openly dealt with. Perhaps one of the most serious omissions is discussion of the consequences of the existence of the Retrievable Surface Storage Facility or the Noble Gas Storage Facility as a target for nuclear weapons."

have been addressed in the Final Statement. You are referred to Sections 7.4.3, 7.4.4.1 and 7.4.5.2 for discussions of these concerns.

Ms. Diane Tegtmeier

2

The MACEA concerns regarding energy demand projections and the evaluation of alternatives are also treated in the Final Statement in Sections 6C and 11. The Final Statement considers a low growth rate energy demand curve which results in a 50% reduction in the year 2020 energy demand compared to the base projection.

The LMFBR Program proposes to provide the LMFBR as an option for the generation of electrical energy. At this point in time, the potential of the LMFBR to satisfy projected needs is promising. The engineering and economic assumptions for the LMFBR are not optimistic, but rather reflect projected LMFBR technology. Comparative economics and environmental impacts were defined for other alternatives in Chapter 8 of the Draft Environmental Statement (Section 6 in the Final Statement).

Evaluation of the environmental and economic impact of various total energy demand projections is beyond the scope of the LMFBR Program Environmental Statement, and is therefore not discussed.

We hope that this information and the enclosures are sufficiently responsive to your concerns. Thank you for your comments and for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to
Specific Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

Enclosure 1

AEC Staff Response to Comments by the Mid-America Coalition
for Energy Alternatives (MACEA)

1. Comment (page 3):

- 4.1-13 "When the base case of the economic analysis assumes spent fuel cooling of 120 days, and when announced goals of the AEC and industry are to eventually lower the cooling time as little as 30 days, this chapter should include impacts, routine and accidental, for the short-cooling case, not just the much easier 365 day case."

Response:

The impacts of reprocessing short-cooled LMFBR fuel are given in Appendix II.P of the Final Statement. Transportation of short-cooled fuel is discussed in Section 7.3.4 of the Final Statement.

2. Comment (page 3):

- 4.1-19 "Why is the RSSF proposed only to year 2000, while the NGSF is conceptualized to year 2020?"

Response:

Use of the RSSF is not proposed to extend only to the year 2000. As stated on page 4.6-27 of the Draft Statement, "The storage facility would be built in modules to meet increasing inventory requirements. The plan for expansion to a total of 165 storage basins by the year 2010 was illustrated previously in Figure 4.6.3. Approximately 10 percent spare basin capacity would be maintained at all times."

3. Comment (page 3):

- 4.1-23 "Table 4.1.4 seems to assume a linear rate of demand for depleted Uranium for FBR refueling from 2000 to 2030. Is this consistent with LMFBR growth projections from 2000 to 2020?"

Response:

Table 4.1.4 does assume a linear rate of demand for depleted Uranium for FBR refueling from 2000 to 2030 for reactors in operation by the year 2000.

4. Comment (page 3):

- 4.2-10 "With the forecast that reactors will be located nearer population centers than at present, do estimates of accident and routine release hazards take this conservatively into account?"

Response:

Population dose estimates from routine releases are based on regional studies extrapolated to the year 2000 (Section 9), thus taking into account the routine release risks for a time when nuclear electricity is expected to be the predominant source in the U.S. Population risks from reactor plant accidents are expected to be exceedingly small, but numerical estimates will have to await specific designs.

5. Comment (page 3):

- 4.2-11 "The plant and cooling pond area of 2,500 acres, plus only tens of acres per added unit does not seem conservative. In Kansas, two proposed nuclear sites are requiring 10,000 or more acres each."

Response:

The land required for additional units at a site would depend upon the method of cooling to be used by the additional units. As stated on page 4.2-11 - "If a cooling pond is used for the dissipation of waste heat, an additional 1000 to 2000 acres will be required for each reactor plant unit depending on specific site location and prevailing meteorological conditions."

6. Comment (page 3):

- 4.2-18 "It is stated that advanced design power plants will use 765-1,500 KV lines requiring right-of-way widths of 280-560 ft. Why assume 175 ft. right-of-way on page 4.2-76? Where is the cumulative total of land required for right-of-way to the year 2020 shown? Cumulative land for power plants to year 2020?"

Response:

The 175 ft. right-of-way is for a single 1000 MWe power plant with a 500-KV transmission line. The cumulative land requirements for LMFBR power plants and right-of-way through the year 2020 were not given in the Draft Environmental Statement but are found in Section 10 of the Final Environmental Statement.

7. Comment (page 3):

- 4.2-27 "Shouldn't the engineering details of the active or passive core-restraint system be spelled out as they affect accident probabilities and consequences?"

Response:

Core restraint systems (both active and passive) are discussed in the LMFBR plant accident discussion (Section 4.2.7.4).

8. Comment (page 3):

- 4.2-157 "Even though AEC judges probability of class 9 accidents to be low, their environmental impact should be assessed. After all, if such basic behavior as swelling of LMFBR fuel and core materials can come as a recent surprise, perhaps estimates of accident probabilities are similarly fallible. Further, class 9 accidents consequences are relevant in terms of sabotage and war-related acts.

9. Comment (page 4):

- 4.2-159 "It is stated that the overall safety of the LMFBR cannot be assessed until design details not yet available are provided. This seems to be another reason to include worst-case estimates (as in WASH-740) for class 9 accidents."

Response (To Comments 8 and 9):

It is not entirely correct to say that swelling came as a surprise. Swelling of metal fuel and voids in metallic cladding had been observed in the 1950's; the nature of voids in metallic cladding induced by fast neutrons was observed in the mid 1960s. It was somewhat surprising to find these voids produced without commensurate production of hydrogen or helium, but the appearance of voids and associated swelling was not a complete surprise.

HCDAs are discussed in Section 4.2.7.8 of the Final Statement, although it is the AEC's position that HCDA events are remote in possibility. HCDA events or other events of such a magnitude as to produce "WASH-740 type results" are extremely remote in possibility and the risks of such events are considered very small. However, they are discussed further in the Final Statement.

10. Comment (page 4):

- 4.2-163 "Does the lower design pressure requirement for the LMFBR containment building (10 psi vs 60 psi for LWR's) imply a greater

susceptibility to sabotage or acts of war? (e.g., ability of containment to withstand shock waves from nearby chemical or nuclear bombs)."

Response:

All other things being equal, a containment structure designed for 10 psi internal pressure would offer less resistance to a deliberate breaching attempt than a structure designed for 60 psi pressure. However, it would not be possible to conclude that an LMFBR is inherently less resistant to sabotage or an act of war than an LWR without a comparison of design details, which is not possible at this time because commercial LMFBRs have not yet been designed. In any event, it is intended that LMFBRs will be designed, constructed and tested to provide assurance of adequate resistance to credible unusual events, including acts of sabotage. Although resistance to acts of war is not a design criterion, a certain degree of protection against such acts will result from conformance with the other criteria.

11. Comment (page 4):

4.2-177 "Confidence in tornado resistant design seems inconsistent with recent announcement of a 1-year, \$150,000 study of tornado effects to help establish design criteria for nuclear power plants and structures. (Nuclear News, March 1974). What about tornado impact at other steps in the fuel cycle? Would 30 days, or even 365 days cooled spent fuel cask or rail car be immune to direct tornado impact? Would a liquid, high-level waste tank? Would PuOx fuel, in truck shipments, remain confined in a tornado incident?"

Response:

Criteria fully compatible with regulatory requirements for tornado resistance will be employed in LMFBR power plants and fuel cycle facilities. The study mentioned is an attempt to better define local and regional variations in tornado frequency and severity, as one means of better quantifying the very low risks of a severe tornado. It is expected that spent fuel casks and high level waste tanks would withstand tornado impacts. However, PuOx fuel might not remain completely confined in a tornado incident.

12. Comment (page 4):

4.2-195 "It does not seem conservative to simply postulate that no major radioactive release can occur and hence ignore maximum possible consequences. Why would the Price-Anderson Act of 1957 be needed if the case is that compelling?"

Response:

The discussion referred to has been considerably revised and expanded. Extensive analyses have been performed on consequences of severe accidents. These are cited in Section 4.2.7.8. The Price-Anderson Act was needed in the extremely unlikely event that the cost of damages that might result from a severe nuclear accident would exceed that amount of insurance currently available from private sources. However, as noted later in the response to comment no. 36, government indemnification may be phased out in the future with the industry assuming its own risks as the use of nuclear power increases.

13. Comments (pages 4-5):

- 4.4-2 "With stated goal of eventually handling 30-day cooled spent fuel, potential environmental impacts for this case should be discussed throughout the nuclear fuel cycle. The greater the ignorance of details of handling such fuel, the broader should be the scope of credible accidents discussed."
- 4.4-14 "The normal and accident impacts of sodium-cooled, short-decay spent fuel shipping should be discussed in view of announced goals."
- 4.4-52,53 "These huge increases in volatile fission products for short-cooled fuel must be considered in looking at impact of shipping and reprocessing."
- 4.4-54 "If short-decay time case cannot be meaningfully assessed then worst case consequences should be discussed. There is a consistent theme here of simply ignoring impacts of steps where knowledge is lacking."
- 4.4-55 "What about accident effects at 30-120 days cooling? Why choose 180 as the shortest time for estimates when even 120 cooling is the base case assumption?"
- 4.4-60-64 "Similar calculations should be made for 30 day and 120 day cooling cases. Why assume a 20 fold improvement in particulate retention in LMFBR facilities. The report seems to be postulating improvements to support a desired design impact, rather than looking at conservative ranges of containment."
- 4.4-87 "Accident consequences for 30 and 120 cooled fuel should also be estimated. Only assumes fuel assembly breakage or other accidents inside containment structures. What about H_2-O_2 explosions in the high-level liquid storage tanks? Consequences of such an accident have already been estimated (ORNL-4451)."

Response:

The impact of reprocessing short cooled fuel is treated in Appendix II.P of the Final Environmental Statement. Fuel elements are not handled in the open; hence, there would be no breakage in the open. Regarding the question concerning H_2-O_2 explosions in high level liquid (waste) storage tanks, various means (some of which were mentioned in ORNL-4451) are available for rendering such an event incredible. Therefore, that accident and its consequences were not discussed. A 20-fold improvement in particulate retention can be justified because of use of better filters, better filter installations, and better testing and monitoring practices in the future than existed in the past (see Final Environmental Statement for additional justification).

14.. Comment (page 4):

- 4.4-4 "How can routine releases of I_2 be guaranteed at the low values reported, when processes and techniques have not been developed or tested? The environmental impacts discussed seem to be more nearly goals, rather than conservative, worst-case projections."

Response:

There have been many tests which indicate that the recoveries that were indicated are attainable over a short period with streams that simulate process off-gas. Further development work may reveal some additional problems, but there is no reason to believe that a technical solution does not exist, or cannot be found, for this technical problem.

15. Comment (page 5):

- 4.5-25 "Table 4.5.3.2 should show activities and thermal power for 30 day and 120 day cooled fuel since these are definitely under consideration."

Response:

It is currently assumed that the spent LMFBR fuel will be cooled 360 days before shipping from the reactor site to a reprocessing site. It is further assumed that such fuel can be carried in a cask built to current regulatory standards and not create unacceptable consequences in the event that it is involved with an extremely severe accident that violates containment and some radioactive material is forced out into the environment (see Sect. 4.5.5.16 and 4.5.6.2). Such a cask might not be adequate for short cooled fuel and consequently short cooled fuel will not be shipped until adequate test information is available, which indicates that a spent fuel cask can

be designed which will not permit significant loss of material even under extremely severe accident conditions. Current cask development efforts, (discussed briefly in Sect. 7.3.4) provide a strong indication that such casks can be designed. This research and development program is not complete, however, and is expected to continue for a number of years at a substantial funding level.

16. Comment (page 5):

- 4.4.55 "Maximum flame temperatures of 1475°F do not seem conservative in these days of massive shipments of a variety of high-energy materials."

Response:

All packages were assumed to be subjected to an accident sequence more severe than the design-basis accident. In the case of fire, the duration for accident category 5, was assumed to be 2 hours, four times the time duration specified in the regulations. While it is true that real fires generally have a flame temperature of around 2000°F, real fires do not necessarily expose all surfaces to that temperature. The maximum temperature occurs approximately 30 in. above the burning surface. Experience with real casks tested in real fires have shown the difficulty in maximizing heat inputs to the cask. If the cask is lying in the pool of burning liquid, the bottom will be kept cool while the top is exposed to the flame. The temperature and emissivity specifications provide a reasonable method for estimating total heat input to a cask which would occur in most transportation fires. It is noteworthy that the AEC and the International Atomic Energy Agency, whose member countries are continually carrying out physical testing (including fire testing) of packages, believe that fire requirements are adequate.

17. Comments (pages 5-6):

- 4.5-3 "Table 4.5.1 shows almost 600 Kg of PuO₂ per truck shipment. The hijacking implications of this should be discussed, especially since shipment is planned by common carriers."
- 4.5-48 "What is the hijacking attractiveness to a terrorist of a truck shipment of almost 1 million curies of 85 Kr?"
- 4.5-58 "The calculation of rupture margins does not seem conservative. Impurities, outgassing, etc. can increase internal pressure generated at high temperatures. Certainly sabotage could expose the PuO₂ to more severe conditions. Consequences should be discussed. It seems like a double standard to let the UO₂ leak a little bit, but to postulate or assert that no leakage of PuO₂ will ever occur."

- 4.5-63 "Here again, with a lesser hazard than PuO₂ leakage is allowed to be postulated."
- 4.5-73 "Table 4.5.5.6 lists category 5 accident probabilities as low as 8×10^{-13} per year yet includes no probability for PuO₂ release. A zero probability for PuO₂ release appears to be a willful distortion of true hazard estimation. Even if such low accident probabilities were realized, the problem of malevolent-act releases would likely dominate the hazard and should be estimated and discussed."

Response:

Discussions relative to the consequence of sabotage of LMFBR materials in transport are presented in Section 7.4.5.5.2 of the Final Statement. Specifically, an interim assessment is provided of the amount of radioactivity which might be released to the environment as the result of hypothetical sabotage attack on shipments of each of the hazardous materials and products involved, assuming the use of currently approved packages. This assessment is intended to provide early guidance toward timely development of hardened packages or other consequences-minimizing actions which may be found necessary for the future.

Regarding the probability of malevolent-act (sabotage) releases from materials in transport, it is not clear that this "would dominate the hazard", as suggested by the comment on page 4.5-73. In certain cases, the possibility of a successful sabotage attack may be virtually eliminated by clustering of facilities. In all cases, it is intended to provide, through the "defense in depth" approach, safeguards measures sufficient in nature and number to assure that any residual risks to the public will be judged acceptably low. Section 7.4.8 of the Final Statement provides a description of the approach to development of future safeguards.

18. Comment (page 6):

- 4.6-1/2 "Storage of solidified high level wastes for thousands of years is not described."

Response:

The ultimate disposal alternatives to the RSSF (covered in Section 4.6) were discussed in summary form in Chapter 7 of the Draft Statement. The reports referenced in Chapter 7 provide comprehensive details of the analysis in progress.

19. Comment (page 6):

- 4.6-16 "Credible unnatural forces (war and sabotage) should also be provided for and discussed."

Response:

The Final Statement has been modified to discuss the threat and consequences of sabotage and war. In this regard, you are referred to Sections 7.4.3, 7.4.4 and 7.4.5 for discussions of these items.

20. Comment (page 6):

4.6-47 "Consequences of cask rupture outside a containment building should be discussed."

Response:

Radioactivity releases due to high level waste cask rupture are not considered (see Appendix II.N, pages II.N-18 and 19 of the Final Statement). Even at the end of a 2 hour fire, the hottest waste would have a temperature of only 1320° F, whereas the waste is exposed to temperatures of over 1600° F in its preparation. Therefore, the waste would remain stable, no decomposition products would form to increase internal pressures, canister welds would not crack, and no release of activity would occur following exposure of a waste cask to a fire. Fire exposure is considered to be the most stringent test of a cask's ability to maintain its integrity.

21. Comment (page 6):

4.6-47/48 "How would spilled material be retrieved? How would airplane crashes into storage areas be handled in areas which are all remotely controlled?"

Response:

Spilled material would be picked up with a remotely operated vacuum system and re-encapsulated. Remote decontamination facilities (spray nozzles, etc.) would be used to decontaminate the area.

The RSSF would not be in a commercial airline flight path and an airplane crash into the RSSF is considered a non-credible accident.

22. Comment (page 6):

4.6-50 "No statement on type of compound, container and seal to be used for iodine; it is noteworthy that the 55 gal. drums mentioned for the others are not used here."

Response:

As noted in the Draft Statement (page 4.5-64):

"Iodine is assumed to be converted to potassium iodide (KI) for shipment to a repository. The material would be placed into canisters which would, in turn, be placed into insulated shipping packages described in Fig. 4.5.4."

(Note - the insulated shipping package is a 55 gal. drum.)

23. Comment (page 6):

4.6-53 "'No credit is taken for containment provided by the packages
para 2 once they are buried.' If any alpha emitters are buried, it
 should be prevented that they become airborne. It is suggested
 that all alpha emitters be transmuted by neutron bombardment
 in a reactor."

Response:

MACEA correctly states that no credit is taken for package containment after wastes are buried. Authorization to operate a commercial land burial facility is based on an analysis of the nature and location of potentially affected facilities and of the site topographical, geographical, meteorological, and hydrological characteristics, and usage of ground and surface water in the general area, which demonstrate that buried radioactive waste will not migrate from the site. The alternative of transmutation is discussed in Section 7.3 of the Draft Statement. However, it is not intended that low level wastes would ever be transmuted.

24. Comment (page 6):

4.6-48 "Here again, where a very serious hazard is involved, it is
 assumed that engineering will make the event (meltdown)
 incredible. This avoids honest consideration of real
 dangers."

Response:

Information has been added to the Final Statement (pages 4.6-33 to 4.6-37) to help demonstrate that engineering will make this waste storage accident incredible.

25. Comment (page 6):

4.7-1 "In the listing of areas from which plutonium might be
 released, the potential release from a storage site is not
 mentioned."

Response:

See the revised versions of Section 4.7 and Appendix II.G in the Final Statement, where this information is now provided.

26. Comment (page 7):

- 4.7-2 "Stack releases of 1.9 mCi alpha particles for 1000 MWe, which might contain 10^{-10} Ci , appear prayerfully small."

Response:

The AEC believes the estimated releases are accurate as there are many physical factors operating against significant releases. Additional discussion concerning this release (now 0.36 mCi) is given in Appendix II.G of the Final Statement. Also see Sections 4.3.5.3 and 4.4.5.3.

27. Comment (page 7):

- 4.A-12 "No consideration was given to sinking of a barge."

Response:

Probably the least significant accident that could befall a spent fuel cask carried on a barge is that it sink. Barge shipping is one of the safest ways to transport casks since speeds are slow and they can effectively be kept away from large quantities of combustible materials. Sinking of the barge and cask would effectively remove it from any fire and at the same time maintain low external temperatures even if forced circulation coolant systems, which might have been employed, were destroyed. The act of sinking would impose insignificant additional forces, temperature increases or pressure increases (relative to what it will be capable of withstanding) on the cask and, therefore, will provide no possible mechanism for leakage. Large chlorine cylinders whose containment could be easily destroyed by relatively minor accidents have been sunk, and successfully retrieved, from the bottom of the Mississippi River. The act of sinking is therefore not expected to create leaks or pose any additional risk to the public.

28. Comment (page 7):

- 4.E-6 "The values for plutonium appear meaningless without specifying whether it is absorbed as a metal or as a particular salt. Probably a soluble salt is implied since values are higher in liver and bone than lung doses. But why is the GI dose even higher than the lung?"

Response:

An expanded discussion of the assumptions made in deriving dose conversion factors is given in Appendix II.E in the Final Statement, which notes: "To obtain dose-conversion factors for lungs, the inhaled material was assumed to be insoluble. For all other reference organs the inhalation dose-conversion factors are based on the assumption that the inhaled radionuclides are soluble in form." This maximizes the risk to each of the referenced organs, the lung being at greatest risk for inhaled insoluble compounds, with the other organs considered at higher risk following the inhalation of soluble compounds. The stated question is difficult to understand. The referenced table (Table II.E-4) clearly shows that the GI tract receives a dose several orders of magnitude less than does the lung. For example, with plutonium-239 the dose to the lung is 1.77 E2 or 1.77×10^2 or 177 rem/ μCi inhaled; the dose to the GI tract is 3.56 E-2 or 3.56×10^{-2} or 0.0356 rem/ μCi inhaled.

29. Comment (page 7):

- 4.E-8 "In Table 45, more total body radiation and tissue effects are assigned to Pu-239 after ingestion than after inhalation. This is contrary to absorption data which show a low retention and absorption from the gut and almost 100% retention from the lung."

Response:

Again we cannot agree with the comment. Comparison of the two tables shows, for example, that after inhalation of plutonium-239 the liver receives a dose of 8.96 E2 or 8.96×10^2 (Table II.E-4) or 869 rem/ μCi , whereas following ingestion of plutonium-239 the liver receives a dose of 1.06 E-1 or 1.06×10^{-1} or 0.106 rem/ μCi ingested.

30. Comment (page 7):

- 4.G-51 "Again, over-emphasis on plutonium effects on bone and liver, and insufficient consideration of the inhalation of metallic plutonium or plutonium oxide into the lung where its biologic half-life is greater than a human lifetime."

Response:

The referenced page was not intended to discuss health effects on bone, liver or lung. It discussed metabolic pathways by means of which inhaled or ingested plutonium reached the several organs of deposition. The inhalation of metallic plutonium is not considered since upon contact with air the plutonium forms plutonium dioxide. Since the lung is considered the critical organ after inhalation of plutonium dioxide, it comes under Compound Class Y of the ICRP Task Group Lung Model; the recommended

value of this model for the biological half-life is 500 days. We are not aware of any data supporting a biological half-life of "greater than a human lifetime" for plutonium dioxide. This subject matter and the model used to describe the behavior of insoluble particulates in the lung is discussed in Appendix II.G.4.

31. Comment (page 7):

4.G-63 "No consideration has been made of tertogenic effects."

Response:

Tertogenic effects might be caused by two methods: the mutagenic effect of radiation upon reproductive cells, and the effect of radiation upon multiplying and differentiating cells of the embryo and fetus. The former is considered in the report of the National Academy of Sciences-National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation. The genetic risk estimates of the BEIR Committee include mutational components of various conditions in their overall treatment of genetic risk. They also discuss their treatment of releases from nuclear power (pp. 40-50). Radiation effects upon the embryo or fetus could occur only if the transuranic elements crossed the placental barrier and were incorporated into the developing tissues. This is discussed in Appendix II.G.4 and in the references stated therein.

32. Comment (page 7):

4.G-64 "A somewhat cursory consideration only of the possibility that linear extrapolation actually is too conservative since at higher doses carcinogenesis is inhibited by killing some of the cells. Also there is no mention of an important scientific paper on this subject which would be required to better evaluate this problem. I am referring to Baum, Population Heterogeneity Hypothesis on Radiation Induced Cancer, Health Physics 25: 97-104, 1973."

Response:

The Environmental Statement refers to its dependence upon the NAS-NRC report on the Biological Effects of Ionizing Radiation (BEIR) report as the authoritative basis for use of the simple linear dose response relationship for the prediction of health consequences. That report discussed the alternative approaches to this question in extenso and concluded that the linear hypothesis is a conservative philosophy, while recognizing the arguments that were in conflict, including the "cell killing" hypothesis.

The reference report by Baum in Health Physics presents in detail one approach to dose-response analysis that is also included in the BEIR

report. It is not a new approach and the paper does not show the complete original data. If it had, the reader could judge for himself the manner in which the data can be fitted by almost completely contrasting equations without a statistically significant choice. The issue of "heterogeneity", per se, does not insure non-linearity, as data on genetically heterogeneous groups of experimental animals have not revealed any unusual responses. Finally, Baum himself presents a number of arguments that oppose his own thesis. Thus, at this time, the overwhelming weight of the evidence and the concern for public health protection support the BEIR report position.

33. Comment (page 7):

- 4.G-69 "Estimates are all minimal, based on unavoidable or 'normal' releases. There are no accident assumptions and their consequences."

Response:

An expanded discussion of anticipated normal releases from all segments of the nuclear fuel cycle, and of maximum credible accidents and their probabilities, is presented in Appendix II.G.1. Accidents are discussed in 4.2, 4.3, 4.4, 4.5 and 4.6 of the Final Statement.

34. Comments (pages 7-8):

- 5-7 "In Figure 5.2-1 and in many other figures, tables and discussions, a uniform presentation or projections to the year 2020 should be made."
- 5-7 "Equally, if not more striking in Figure 5.2-3 is the enormous verticle range of GNP for a given per capita income, e.g., a range of about 50 to 130 millions BTU per capita for countries in the \$1,500-\$2,000 GNP per capita range. Two conclusions might be drawn: (1) Countries fall on different slope lines of BTU vs GNP depending on life styles, values, habits, etc. or (2) there is a law of diminishing returns that cause the curve of BTU/GNP to curve up exponentially, e.g., from New Zealand to the U.S. Figure 5.2-3 which appears to play a key role in the future energy use projection that is the basis of the present report, can be used also to argue that the U.S. needn't commit itself to the projected increase in BTU/GNP to achieve continued well being."

Response:

It is not possible to extend all projections to the year 2020 because in some cases the information does not exist and in other cases such an

extrapolation is not particularly relevant to the topic discussed. (Both comments apply to Fig. 5.2-1).

Possible reasons for the large range of energy consumption in different countries with approximately the same per capita income are discussed in Section 5.2.1 of the Final Statement.

35. Comment (page 8):

5-9 "Reversal of electrical rate structures should be considered here to alleviate burden on poor."

Response:

In Section 5.2.2 of the Final Statement, the significance of the price of electricity for various income groups is considered.

36. Comment (page 8):

5-13 "Capital requirements for adequate liability insurance should be estimated here, as an alternative to continued subsidy by the Price-Anderson Act. Such costs should be fully internalized in a study such as this one."

Response:

Insurance costs supplementary to Price-Anderson coverage are included in the Cost-Benefit Analysis in Section 11.2. The Congress recently passed an extension of the Price-Anderson Act for a further 10 years beyond its scheduled expiration in 1977, but this legislation was vetoed by the President due to a constitutional infirmity in the bill not specifically related to the issue of government-backed insurance. It is anticipated that Congress will reconsider the legislation based on the President's suggestions. There is a general expectation, however, that government indemnification will eventually be phased out with the industry assuming its own risks as the use of nuclear power increases. During recent legislative hearings on the extension of the Price-Anderson Act (Nuclear Industry 5/75, pp. 6-9), proposals by two nuclear liability insurance pools for phasing out government indemnity were considered. However, it is impossible at this time to internalize insurance costs which do not exist.

37. Comments (page 8):

5-31 "This impact statement does not honestly address the hazards of fission power if a 'stable social order' ceases to exist for a time, either in the U.S. or in other countries to which export of our nuclear technology is targeted."

- 5-32 "Having raised the issue of less political freedom with a Pu economy, some discussion of implications should be included."

Response:

This is a valid concern. It is possible to construct any number of scenarios of disorders which may occur if "a stable social order" ceases to exist in the U.S. or abroad. It is impossible either to assess probabilities or completely protect against them. However, circumstances seem to mitigate against the choice of nuclear power stations or LMFBRs, in particular, as random targets in times of general chaos. Nuclear facilities are safeguarded and are at isolated locations. Very detailed information would be required to do massive damage at such sites. A value judgment must be made as to whether concerns such as these are sufficient to deprive society of the benefits of the development of nuclear power.

With regard to the issue of political freedom, the implications of the increasing Federal involvement in the internal operation of nuclear energy systems are considered in Section 5.4.2.3. The possible effects of the implementation of an effective safeguards program on personal liberties during both normal operations and hypothetical emergency situations are discussed in Section 5.4.2.1. It is concluded that loss of freedom and a Pu economy are not synonymous. Other technological developments (computers, for example) pose a far greater threat to personal liberties. Various measures exist in a democratic society to prevent erosions of freedom.

38. Comment (page 3):

- 5-33 "Will our nuclear energy economy be abandoned if "international agreements and institutions to assure that the common good, is indeed, protected," do not come to pass? Can there ever be such a guarantee? Wildrich and Taylor's book should be referenced and discussed."

Response:

In Section 5.4.3 the limitations of international nuclear energy agreements are discussed. The recent detonation of a nuclear device by India makes us aware that the problems of nuclear proliferation are with us today. In Section 5.4.3.1 an attempt is made to put into perspective the additional problems that would be created by the introduction of breeder reactors. Rather than abandon nuclear energy (it is rather late for this), a more constructive approach would be to attempt to secure adherence to international agreements which include inspection provisions and sanctions against violators.

39. Comment (page 8):

- 6-1,2 "Just because 'reliable and precise quantitative information on the expected frequency of occurrence of major accidental releases in the LMFBR fuel cycle is not available at this time' does not justify not discussing their environmental impacts. It makes a mockery of NEPA to ignore consequences on the assumption that they can be engineered away, or that their probability is unknown. At the very least a 'Farmer limit-line' discussion of releases should be included for every phase of the fuel cycle."

Response:

The environmental impact of accidents was treated in the following pages of the Draft Statement: 4.2-152 to 4.2-195, 4.3-130 to 4.3-148, 4.4-101 to 4.4-103, 4.5-74 to 4.5-106, 4.6-47 to 4.6-49, 4.6-57, 58 and 67, and others. This subject is discussed in even more detail in the Final Statement.

40. Comment (page 8):

- 7-21 "Deficiencies in sealing present-day containment vessels are alluded to. The impact of such sealing problems should be discussed in accident cases."

Response:

The referenced page did not refer to deficiencies in sealing containment vessels. It referred instead to difficulties in sealing those vessels. In this respect, the treatment of accidents in the Statement does include consideration of containment leakage. Radioactive material inside the containment vessel was assumed to leak out at the design containment leak rates specified in the Draft Statement (see Table 4.2.3.1). These leaks rates can be and are kept acceptably small.

41. Comment (page 9):

- 7-36 "Why are the confinement factors for 131-I and 129-I different? Are these adequate for the 30-day cooled fuel case?"

Response:

The confinement factors for 131-I and 129-I are different because simple retention of 131-I for a period of time results in its decay (8 day half-life). The decay of 129-I (1.7×10^7 year half-life) is too slow

to yield any noticeable benefit by in-plant holdup. (See Appendix II.F of the Final Statement).

42. Comment (page 9):

7-38 "The general approach to impact discussion seems to be that where the hazard is really great, engineering is postulated to make the hazard 'incredible' and, therefore, it can be ignored. Thus UO_2 and UF_2 are allowed to escape containment in hypothetical accidents but PuO_2 is not. Consequences of worst-case accidents should be discussed, even though of hoped for low probability."

Response:

The impact of accidents involving transportation was presented in Section 4.5 of the Draft Statement. A new Section (4.5.7) discussing consequences (and risks) of some worst-case accidents has been added to the Final Statement.

43. Comment (page 9):

7-41 "What fractions of casks for LMFBR can likely be shipped by barge?"

Response:

All LMFBR spent fuel shipping casks could be shipped by barge. However, due to travel time and site location considerations, only a small fraction would be shipped by barge.

44. Comment (page 9):

7-42 "With regard to the RSSF, the statement that "the requirement for continued human action in no way weakens the safety of the surface storage approach to management of high-level waste" is an affront to common sense."

"Such advocacy of an expediant, recent solution to a long-neglected problem area destroys credibility with regard to the whole report."

Response:

The AEC agrees with the MACEA view that, all other factors being equal, approaches which do not require perpetual surveillance may be safer since

the potential for human error would be reduced. The sentence has been revised in the Final Statement as follows - "The AEC feels that if management techniques can be developed which are equally safe and which would eliminate, or at least minimize, this requirement, they should be used."

45. Comments (page 9):

- 7-55 "Sabotage is mentioned in this concept, where it is least credible. Why is it not discussed at each step of the proposed fuel cycle?
- 7-64 "It is stated that: 'The possibility of sabotage of facilities resulting in radiological incidents must also be considered.' Yet this is not done consistently throughout the report.
- 7-72 "What about inherent sabotage protection for fuel cycle components other than the reactor?"

Response:

The Final Statement provides additional information on the subject of sabotage. In particular, Section 7.4.3 recognizes that sabotage is one of the classes of events which fall within the overall threat which must be dealt with, and Section 7.4.5.2 discusses the consequences of successful sabotage of nuclear facilities and transport. In the latter Section, it is pointed out that significant additional effort will be required to confirm the current premise that the consequences of facility sabotage are similar to those of facility accidents, and additional safeguards measures may be needed to assure that consequences of transport sabotage are held to acceptably low levels.

46. Comment (page 9):

- 9.1-2 "Figure 9.1-1. Will fossil fuel peaking units really decrease so much, percentage-wise, relative to central station capacity?

Response:

The numerical data in the projection are as follows:

<u>Year</u>	<u>Capacity Contribution, Percent of Total</u>	
	<u>Int. Comb Gas Turb.</u>	<u>Pumped Storage</u>
1970	5.5	1.1
1980	8.0	3.5
1990	7.7	4.5
2000	6.8	4.0
2010	5.5	3.3
2020	4.3	2.6

Thus, in 2020, the peaking capacity from Pumped Storage, Internal Combustion, and Gas Turbine facilities would approximate its present contribution.

47. Comment (page 9):

9.1-4 "If fossil fuel system capacity is increasing exponentially at year 2020, as shown in Figures 9.12 to 9.13, is this consistent with coal projections in Figure 9.1-4 to 9.1-6? All projections should extend to 2020.

Response:

Figures 9.1-2 and 9.1-3 depict capacity projections, while figure 9.1-4 depicts generation projections. It is expected that fossil fuel plants will operate at lower plant factors than nuclear plants (because the "variable" costs of fossil fuel plants are larger than for nuclear plants). Thus, even though there is an increase in coal-fueled capacity between 1990 and 2000, the generation does not increase substantially. It does increase after 2000.

48. Comment (page 9):

"Curies of waste should be listed also. More important than volume."

Response:

Volume units were used because they do not change with time, unlike the radioactive content which does. In response to your comment and others, Table 9.1-5 in the Final Statement lists curies of waste.

49. Comment (page 9):

"The release numbers in Table 9.1-4 are whatever the AEC and the manufacturer's decide to engineer. Why bias the LWR in this way relative to LMFBR?"

Response:

The LWR, LMFBR, and HTGR were treated on a consistent basis, with the possible exception of noble gas bottling at the reactor. If noble gas bottling were used at LWR's and HTGR's, the Krypton release would be reduced by about 20% at LWR's and 33% at HTGR's. The Xenon releases could be reduced to 1% of their values in the Draft Statement. Table 9.1-4 now reflects this.

50. Comment (page 10):

9.1-32 "Table 9.1-7. Why not contain the Krypton in the LWR and HTGR cases? Again seems to deliberately bias for the LMFBR.

Response:

This table has been revised in the Final Statement. Also see response above.

51. Comment (page 10):

9.1-34 "Can Table 9.1-8 numbers be justified for 30 day cooled spent fuel?"

Response:

They are not justified for 30-day cooled fuel. They are for 120-day cooled fuel, which is consistent with the assumptions in the cost/benefit study.

52. Comment (page 10):

9.1-69 "How can one claim there will be less radioactive releases from LMFBR except as a chosen design objective? If the LMFBR has truly 'arrived', why so many unanswered design and process questions alluded to earlier?"

Response:

The releases, on the whole, tend to be lower for the LMFBR because certain process variables tend to favor radionuclide retention in LMFBR systems. For example, the affinity of tritium for sodium permits "capture" and handling of the tritium as an easily contained solid. In other systems, it is presumed to diffuse through systems designed to contain other radionuclides.

The LMFBR has "arrived" in the sense that many of the development problems have been faced and solved and the emphasis now is on design and operation of a nearly full-size system. The same cannot be said for many of the alternatives. Naturally, some problems remain in LMFBR systems (as they do in coal and other systems) and in that sense, it is still developmental. Perhaps the key point is that industry feels it knows what the problems are, and can now turn to their solution.

53. Comment (page 10):

9.2-5 "If dismantling costs are presently 10-15% of construction costs, then a conservative assumption is that they will escalate at a large fraction of the discount rate percentage and will always be an appreciable fraction in cost-benefit analysis."

Response:

The cost-benefit analysis primarily compares the difference in costs between two all-nuclear power generating systems which supply a fixed portion of the electric energy demand. One case has the LMFBR available as an option, the other does not. There is little difference between decommissioning costs for the different reactor types.

54. Comment (page 10):

10-27 "Some estimate should be made of the security-safeguards personnel likely to be needed in Pu-economy."

Response:

A discussion of the security-safeguards personnel requirements is given in Section 7.4.9 of the Final Statement. Estimates of numbers of personnel needed are included.

55. Comment (page 10):

10-34 "The argument about man-made artifacts is particularly specious. Of what relevance to the perpetual guardianship of high-level wastes is it that man-made artifacts were constructed with physical properties preventing physical deterioration for over 1000 years. It is more relevant to point out that man probably destroyed or dispersed all but a tiny surviving fraction of such artifacts."

Response:

This point has merit; the argument has been removed from the Final Statement.

56. Comment (page 10):

- 10-35 "What happens when a portion of the human race doesn't desire the safekeeping of these wastes? The question of nuclear sabotage of the incredibly spatially concentrated RSSF and NGSF should be addressed."

Response:

It is assumed that the human race will act rationally and reasonably with respect to the safekeeping of nuclear wastes. Nevertheless, the question of nuclear sabotage of the RSSF and NGSF is discussed in Sections 7.4.1.2 and 7.4.1.4 of the Final Statement.

57. Comment (page 10):

- 10-36 "The minimum obligation to future generations of merely maintaining records of radioactive waste seems like a minimum morality indeed."

Response:

The sentence in the Draft Statement was intended to read: "... obligations passed on to (or acquired by) future generations would involve the keeping of records...". See Section 5.4.2.2 of the Final Statement. This is not a matter of morality. It is simply the minimum requirement to insure against any possible intrusion into a radioactive waste disposal site. When an ultimate disposal method is decided on and utilized, it is going to place the waste in an inaccessible place. It will take a high technology to put it there and it will take a high technology to intrude on it. Certainly a society with the capability for intrusion should have the capability to maintain records to avoid intrusion. Conversely, if a future society lacks the capability to maintain records it is highly improbable that they will have the technology to permit inadvertent intrusion on a waste disposal site.

58. Comment (page 10):

- 11.1-3 "A more direct consideration of the first CEQ alternative should be given in detail. The idea that no action of the LMFBR necessitates supplying the projected amount of electricity needs by other systems is not in any sense part of their first alternative. It, in fact, forecloses the first alternative discussion;

"Whether energy should be produced and what level of energy consumption is consistent with economic and environmental considerations."

Response:

The effect of different levels of electricity needs on LMFBR benefits was treated by including sensitivity cases with electricity consumption above and below the base case projection. The Final Statement extends the lower side of this range to 50% below the base projection of year 2020 electricity use.

Discussion of the role of energy in economic growth is included in Section 5, which shows relations between energy and the GNP.

59. Comment (pages 10-11):

- 11.1-4 "How can decommissioning costs be so confidently dismissed in the face of similar uncertainties?"

Response:

Decommissioning costs are discussed in Section 9.2. The present worth of future decommissioning costs would be only about 1% of the original construction costs for future LMFBRs.

60. Comment (page 11):

- 11.2-5 "The low energy case, ~20% of projected 2020 usage is not at all conservative. Substantial decrease in usage, (factors of 2-3) such as that postulated by the recent Ford Foundation Study, should be included in the cost/benefit analysis."

Response:

The Final Statement includes cases with electricity demand in the year 2020 which are 50% lower than the base case.

61. Comment (page 11):

- 11.2-8 "Three-hundred and sixty-five day cooling is treated as an exception in cost/benefit analysis, but is the assumed cooling period in discussing environmental impact. This seems like a convenient double standard to highlight favorable factors."
- 11.2-13 "A case should be ran with optimistic uranium supply, low energy demand (factor of 2-3), 1991 introduction of LMFBR, high LMFBR capital costs, 365 day cooling and no carbide fuel."

Response:

The shorter (120 days) cooling time was used as the base case since that approximately represents the AEC goal in fuel recycle development programs. The effect of a longer cooling time on LMFBR benefits was tested in some of the case variations. While the shorter cooling time produces additional benefits ample to justify the fuel cycle R&D, it is not essential to the economic success of the LMFBR.

Cases similar to the one described were run and included in the Final Statement.

62. Comment (page 11):

- 11.2-14 "Can a net savings of only 11% in the discounted cost of power be viewed as significant with all the design and process uncertainties of the LMFBR?"

Response:

It should be noted that this 11% saving is based on a heavily discounted stream of future benefits. The undiscounted benefits in the base case amount to about 1.7 trillion dollars, or about 25% reduction in the undiscounted cost of power. A rate of return analysis shows this to be equivalent to an effective 14% yearly rate of return on the R&D investment. These results indicate that the savings are significant and adequate to justify the R&D costs.

63. Comment (page 11):

- 11.2-7 "Does Table 11.2-5 assume 365 day cooling of fuel? What is included under insurance? Where is the Price Anderson Act discussed, and the hidden subsidy cost that it represents?"

Response:

Table 11.2-5 applies to the base case comparisons (case 3 versus 1) and therefore assumes 120 days cooling of the spent fuel. Case 30 versus case 1 shows the discounted benefit to be reduced by about \$4 billion (~ 6%) when 365-day cooling is assumed.

The insurance includes nuclear liability insurance and property insurance premium costs.

64. Comment (page 11):

- 11.3-2 "The impacts of alternative energy systems should be compared for the case of drastically lower energy use also, e.g., Ford Foundation 'zero growth' case."

Response:

This section (11.3-2) of the report deals with the unit annual impacts of individual generating plants and therefore is not based on any energy growth projection. The zero energy growth case is discussed from the viewpoint of energy conservation in Section 6C.

65. Comment (page 11):

- 11.3-3 "If the comparison of total impacts emphasizes only 'common or everyday variety risks' the conclusion is foregone since the assumption is made that the LMFBR fuel cycle will be designed and operated to make impacts negligible."

Response:

We have attempted to identify and evaluate all the risks and impacts associated with building and operating the LMFBR. The effects shown in this section result from a comprehensive study and are believed to realistically represent the effects from the LMFBR. The LMFBR fuel cycle will indeed be designed and operated in such a way that risks and hazards are minimized. Any other course would be unacceptable to the AEC and the public.

66. Comment (page 11):

- 11.3-13 "Table 11.3-5 assumes 20 man-rems in reprocessing plant, vs 20 man-rems for the LWR. Why? Is the 30 day cooling case assumed here?"

Response:

The values actually shown for dose received in fuel reprocessing are 20 man-rems for the LMFBR and 30 man-rems for the LWR. As noted in Tables 11.3-3, 11.3-4, and 11.3-5 of the Draft Statement, all systems assume the same value for reprocessing dose per unit of fuel reprocessed, namely 1 man-rem per metric ton of fuel. Since the LMFBR requires processing of only two-thirds as much fuel as the LWR, the dose is only 20 man-rems versus 30 man-rems for the LWR. These dose rates assume about 365 days fission product decay prior to reprocessing.

67. Comment (page 11):

- 11.3-17 "The 'upper limits' of public health effects for the nuclear fuel cycles assume no serious accidents can occur. Is this normal usage of the term?"

Response:

The public health effects result mostly from the impacts of day-to-day operation. Reactor and service facilities for nuclear plants are designed to make the probability of serious accidents very small and to protect the public from accident consequences. Therefore, the average contribution of accidents to public health effects is predicted to be exceedingly small in comparison to the effects from routine operations.

68. Comment (page 11):

11.3-34 "If the LMFBR replaces retired fossil capacity after year 2000, why does the fossil component in Figures 9.1-2 and 9.1-3 keep rising?"

Response:

As described on pages 11.3-33 and 11.3-34 of the Draft Statement, this section considered three simplified "scenarios", which represent a modification from the cost/benefit assumptions used in Section 11.2. These simplified scenarios were selected to represent the range of views suggested by various individuals, from a no-fission-energy case to a very large commitment to the LMFBR. The fossil component shown in Figures 9.1-2 and 9.1-3 is the 40% of total electrical capacity which was assigned to fossil and other systems in the cost/benefit studies.

69. Comment (page 11):

11.3-42 "If these fatality numbers were really credible, then why is Price-Anderson necessary for nuclear and not for coal?"

Response:

The bases for the fatality statistics are discussed in Sections 9 and 11 and in the referenced supporting material. These statistics are supported by the experience to date and indicate that society is paying a high price, indeed, for the use of coal.

70. Comment (page 12):

11.4-1 "The key alternative is left out, namely, reducing energy 'needs' by conservation and other means. Here, as in many other places in WASH-1535, the presumed continued exponential growth (give or take a token 20%) in electricity use dominates the whole discussion."

Response:

See replies to comments on 11.1-3 and 11.2-5.

71. Comment (page 12):

- 11.4-2 "A quite different lesson can be inferred from the recent oil 'crisis': e.g., look at the lives saved by speed and mileage reductions in auto travel and the potential benefits from a shift to bus, train and mass transit. Where, in this report, is a serious attempt made to determine the 'future real need for energy?' The report seems to uncritically accept the historical increase!"

Response:

The referenced section of text discusses the impact of inadequate planning with resultant disruptions, not the impact of reduced energy usage. Speed limits could have been reduced before the 'oil crisis', if the public demanded.

72. Comment (page 12):

- 11.4-3 "Why lump solar energy recovery with fusion? One has been demonstrated and the other has not. One doesn't need as many central station solar electric plants if solar heating and cooling of buildings is applied. If Kansas City Power and Light projections are typical, one of the big future forces for increasing growth in demand will be for electrical space heating."

Response:

On page 11.4-3 of the Draft Statement, the energy systems were categorized in two broad groups, those presently being used (such as LWR and fossil systems) and those which may be available in the future. Clearly, solar energy for central station electric plants falls in the second broad category, although solar conversion has been applied in special circumstances. On pages 11.4-13 and 11.4-1 of the Draft Statement, the possible role of solar heating and cooling of buildings was discussed. By limiting nuclear power to 60% of the projected electricity needs, and using variations on the base case projections, the possible role of solar should be adequately covered.

73. Comment (page 12):

- 11.4-13 "Again, seems to assume central station needs are immune to solar space heating and cooling. Why are not windpower and conservation mentioned at this point?"

Response:

These topics are adequately discussed in Sections 6A.6.1 and 6C, respectively.

74. Comment (page 12):

11.5-17 "The concomitant benefit of developing and exporting expertise in solar, wind, and geothermal is ignored."

Response:

While there may be possibilities for exporting technology and/or equipment for these systems, that has no bearing on the subject of whether to import LMFBR technology.

75. Comment (page 12):

II.4-23 "The 'evidence' that the breeder should be viewed as a last resort is the concern about the unanswered questions of sabotage, Pu diversion and accumulation of high level wastes."

Response:

These questions have been considered, and they are believed not to provide "evidence" for holding the breeder as a last resort.

76. Comment (pages 12-13):

III-A-1 "Is it really contended that present safeguards are adequate for protection against dedicated groups of suicidal terrorists and other low probability threats?"

Response:

The adequacy of present safeguards is discussed in Section 7.4.7.6 of the Final Statement. It is indicated that the present system might not be effective against large, heavily armed forces. It is possible to imagine that such a force could be composed of suicidal terrorists, but this is judged to be highly improbable.

77. Comment (pages 12-13):

III-A-2 "Yields and circumstances for use of illegal weapons can be predicted. The McPhee-Taylor series in the New Yorker should be referenced."

- III-A-3 "Cases of radiological weapons use should be postulated. One need not wait to know by experience the method and circumstance of use.
- III-A-5 "Are such dangers as Pu weapons manufacture and the operation of a Pu black market so credible that discussing them with only unclassified, available information will lessen our security?"

Response:

The manufacture and use of illegal nuclear weapons are discussed in Section 7.4.5.1 of the Final Statement. It is agreed that the adversary may be able to predict the yield and circumstances attendant upon detonation of an illegal weapon; the AEC cannot predict these factors with certainty. However, the subject is treated on a speculative basis in Section 7.4.5.1. The same is true for the use of a radiological weapon. Regarding the manufacture of a plutonium weapon, the AEC agrees that this is a credible possibility, and its safeguards system has been and will be designed using this premise.

Section 5.4.2.1 of the Final Statement discusses the problem of a potential black market in plutonium.

78. Comments (pages 12-13):

- III-A-3 "It can be alleged that the RSSF, NGSF, and possibly high-level liquid waste storage tanks at fuel reprocessing plants do pose a possible new and significant threat to our national security. The effects of a high-yield nuclear weapon completely cratering, and dispersing in the atmosphere, the RSSF at year 2020 should be estimated and presented.
- III-A-4 "If conventional weapons detonation can damage nuclear facilities other than reactors, then the consequence should be estimated. Chester's studies at ORNL should be referenced in this context.

Response:

Section 7.4.4.1 of the Final Statement expresses the AEC's belief that an enemy nuclear attack limited to U.S. nuclear fuel cycle facilities is not credible, because it would leave U.S. retaliatory forces and other war fighting resources intact. Considering an overall strategic attack, it is concluded that the consequences of attack on fuel cycle facilities would be a relatively small increment of the overall consequences.

Chester's studies on the vulnerability of nuclear reactors to nuclear attack have been referenced and discussed. For the reason stated above,

foreign enemy use of conventional weapons against nuclear facilities is not considered credible, and estimation of consequences is not considered to be warranted.

79. Comment (page 13-14):

III-B, "What spent-fuel cooling time is assumed if breeding by
2-6 year 2010 sustains a 6% yearly electrical growth rate?"

Response:

Fuel cycle times for all calculations are tabulated in Table 4.9 in Draft Statement. Post-irradiation storage times for LWR, HTGR and LMFBR fuel were assumed to be 150, 90 and 120 days, respectively.

80. Comment (page 13):

III-B, "Increase of only \$100 million for a 2000 MWe plant that has
3-13 not yet been designed does not seem conservative!"

Response:

The capital cost differential between the early 1300 MWe LMFBR and the 1300 MWe LWR was calculated to be \$85/KWe and was conservatively set at \$100/KWe in the cost-benefit analysis. The nuclear steam supply system represents about 25% of the total; the remainder is fairly standard. Additional details are given in Section 11.2 of the Final Statement.

81. Comment (page 13):

III-B, Why don't Table 3.3.5 and Table 11.2-5 agree?"
3-21

Response:

Table 11.2-5 was incorrect; necessary corrections have been made in the Final Statement.

82. Comment (page 13):

III-B, "If projected values of study parameters represent such a
3-35 consensus, then at least the 120-day cooling case should have been considered for fuel cycle impacts."

Response:

Appendix II.P, which pertains to the impact of reprocessing at 120- and 30- day preprocessing decay times, has been added to the Final Statement.

It is unlikely that spent LMFBR fuel cooled 180 days or less will be shipped in casks of present design (see Section 7.3.4 of Final Statement) and thus the impact of transporting 180 day cooled fuel is not addressed.

Other fuel cycle impacts (i.e. during fuel fabrication or waste management) are relatively insensitive to cooling time.

83. Comment (page 13):

III-B, "What is the annual growth rate change to produce only a net
3-41 variation of $\pm 20\%$ in projected year-2020 demand?"

Response:

The annual growth rate varies by about $\pm 10\%$.

84. Comment (page 13):

III-B, "It would be helpful to know how much capital costs of a 1000
3-43 MWe LMFBR would have to be changed to wipe out the cost/
 benefit advantage over LWR's for various assumed parameters.

Response:

Section 11.2.4 of the Final Statement describes the effects of capital cost assumptions on benefits. Even with no "learning" the LMFBR is competitive.

85. Comment (page 13):

III-B, "There seems to be more concern about direct costs of Pu
3-49 inventories in relation to spent fuel cooling times than in
 estimates of hazards to the environment as a function of
 cooling time."

Response:

Short-lived isotopes contribute heavily to shipping hazards so cooling time is important. Plutonium radioactivity varies little with cooling time, but as a valuable material it has high inventory charges.

86. Comment (page 13):

III-B, "The figures in the reference case for fossil mix do not
3-60 match those given in Table 4.14."

Response:

The values on p. 3-60 are incorrect in the Draft Statement; they have been corrected in the Final Statement.

87. Comment (page 13):

III-B, "If single-loop cooling is contemplated then accident hazards
4-11 and routine release should be assessed in earlier discussions.

"In Table 4.5 what cooling period for spent fuel is assumed?"

Response:

Contemplation of single-loop cooling assumes elimination of need for the intermediate loop. At this time, the intermediate loop is necessary and was accounted for in the economic and environmental analyses.

LMFBR spent fuel cooling time was assumed to be 120 days. The capital costs listed in Table 4.5 are relatively insensitive to cooling time assumptions.

88. Comment (page 14):

III-B, "How will environmental impacts vary if we go to 'very large
4-12 units'?"

Response:

They will probably vary linearly with power level for LMFBR power plants and with throughput for fuel fabrication and fuel reprocessing plants.

89. Comment (page 14):

III-B, "What cooling time was assumed for shipping cost and
4-18 reprocessing estimates?"

Response:

Fuel cycle times for all calculations are listed in Table 4.9 of the Draft Statement. LMFBR post-irradiation cooling time was assumed to be 120 days.

90. Comment (page 14):

III-B, "Why are fuel cycle times for LMFBR spent fuel shipping and
4-20 reprocessing assumed to be faster than LWR case?"

Response:

The post-irradiation cooling times are chosen to minimize shipping costs. The cooling time for LMFBR fuel was extended from 30 to 120 days to eliminate incremental shipping and reprocessing plant expenditures related to short-lived isotopes. The reprocessing time consists of pre- and post- reprocessing inventory times in addition to the actual reprocessing time. LMFBR fuel has high inventory costs associated with contained plutonium, thus the post-reprocessing inventory time is reduced from 10 days to 5 days.

91. Comment (page 14):

III-B, "What insurance costs are referred to? How would they differ
4-30 without Price-Anderson or with new plans under consideration?"

Response:

The insurance costs discussed on p. 4-30 of the Draft Statement covered property insurance. Please refer to the response to your comment numbered 36 in this letter for discussion of insurance costs without Price-Anderson indemnification.

92. Comment (page 14):

III-B, "The energy forecast assumption of Table 4.13 seriously
4-31 biases alternative. The case of near-zero per capita energy
use should be considered as well."

Response:

An energy demand curve reflecting a 50% reduction in the year 2000 demand is considered in the Final Statement as a sensitivity study.

93. Comment (page 14):

III-B, "Isn't there a recent trend toward higher energy use per
4-32 GNP increment?"

Response:

Yes, and if the trend continues the energy demand may be greater than estimated in Table 4.13.

94. Comment (page 14):

III-B, "Doesn't recent data show that total cost of electricity is
4-33 rising faster than the general price level?"

Response:

Recent electricity price increases have been due largely to fossil fuel price increases, influenced by the quadrupling of foreign oil prices within the past year. This trend will favor those systems of electricity production which are relatively insensitive to fuel costs.

95. Comment (page 14):

A-5 "Is all this materials - engineering advance really more credible than solar energy storage and collection advances?"

Response:

While it would be speculative to say in which technology the projected advances are more likely to be achieved, it has been shown in the Environmental Statement that the LMFBR is at a more advanced stage of technological development than several of the other energy sources considered, such as solar energy. Thus, the anticipated further advances in LMFBR materials engineering represent the consensus of very detailed program planning that has been undertaken in the past and continues to be revised as the technology changes. While advances in solar energy storage and collection technology may also be expected, it appears that those projected for LMFBR materials engineering represent reasonable extrapolation of current technology and planning, and can be considered at least as credible, if not more so, as the more speculative projected advances in solar energy technology.

96. Comment (page 14):

B-6 "Access to a "virtually limitless supply of low-cost electricity," even if attainable, should not be assumed to be an unmitigated blessing. Adverse effects of cheap energy and energy-intensive applications deserve consideration in the broad focus that the LMFBR impact statement should achieve."

Response:

Although we would agree that a limitless supply of low cost energy may not be an "unmitigated blessing", history has shown that the availability of energy is closely linked to a nation's economic growth. It would appear that energy availability, assuming adequate protection of the environment, is more of a blessing than not. Nevertheless, the need to use less energy is fully discussed in Section 6C, and several views both favoring energy conservation and citing its limitations are discussed in Section 6C.7.

97. Comment (page 14):

A.5-4,6 "The treatment of the history and status of solar energy devices is unfairly shallow. Where are references to recent developments such as the NASA-Lewis patented solar heating-cooling home system, to name just one?"

Response:

The treatment of solar energy, although believed to have been adequate in the Draft Statement, has been expanded in the Final Statement to reflect the views of the several commenters and to address in greater detail the development plans for solar energy as projected by several government and industry planning bodies. Solar heating and cooling systems are discussed in Sections 6A.5.3.4 and 6A.5.5.

98. Comment (page 14):

A.5-15 "How can it be stated that solar cooling of buildings would not affect utility power system facilities in those large areas where peak load is dominated by summer heat waves?"

Response:

The statement on page A.5-15 of the Draft referred to the general condition that buildings equipped with solar electric systems would still require an external source of power for use on cloudy days. In the particular situation referred to in the comment, it is clear that some reduction in peak level requirement could be achieved, provided that a large number of homes and commercial and industrial enterprises on the utility's power system were equipped for solar cooling.

99. Comment (page 14):

A.5-21 "What could solar energy contribute with a commitment of policy and financial backing equal to that being given the LMFBR?"

Response:

It is probably true that with far greater financial backing solar energy could contribute more and sooner to meeting the Nation's energy requirements than currently anticipated. However, the same thing can be said about almost any technically feasible energy concept, including the LMFBR. The real question is not "will money help", but "how can the limited funding available be utilized in such a manner as to produce the greatest likelihood of success in developing new energy sources?" A related issue is that the amount of money which can prudently be spent on a developing

technology depends heavily on whether the technology is at an early stage of development (such as essentially scientific exploration of basic energy conversion principles), as in the case of solar energy, or whether it has reached the stage of being ready for demonstration power plant construction, as in the case of the LMFBR. Clearly the latter situation will require larger amounts of funds. It might also be mentioned that if the more advanced program is not pursued and if the alternative energy sources were not realized, then the cost to society would be too large to measure in dollars alone. These issues are discussed further in the Perspectives section of Section 6 in the Final Statement.

100. Comment (page 15):

A.5-30 "Is the 15.5% capital charge consistent with the numbers used in Section 4 of Appendix III-B?"

Response:

The fixed capital charge rate used by the NSF-NASA Solar Energy Panel is about 10% higher than the charge rate computed from economic parameters used in the cost-benefit analysis in Appendix III-B of the Draft Statement. Appendix III-B used a cash flow method which explicitly employs each of the cost components which are sometimes combined into a fixed charge rate. A fixed charge rate on depreciable capital based on the economic data in Appendix III-B would be 14.3%, as was shown in Table 4.2. The economic parameters used to compute this data are based on average electric utility financing data for 1972, the last full year for which data were available when the study was initiated. You may wish to refer to the referenced NSF-NASA Panel report for further information on the basis on which their fixed capital charge rate was obtained.

101. Comment (page 15):

A.5-34 "How minor will solar applications be by year 2000? Give feasible upper percent limits for replacing electric heating and air conditioning."

Response:

As now reported in the Final Statement (Section 6A.5.8), the impact of solar energy on total electricity production is expected to be about 2%, at least until the year 2000. The extent to which solar energy may be used to replace electric heating and air conditioning will depend on the success of research and development activities and on the resulting economics of solar heating and cooling systems. Section 6A.5.5 of the Final Statement shows that projections of the portion of building thermal energy supplied by solar power range from 10% to 30% by the year 2000.

102. Comment (page 15):

- A.6-1 "Here, as elsewhere, contributions of individual alternatives are made to look small when compared with projected exponential growth in electricity. If per capita energy and electricity use were held constant, how important could wind-power be?"

Response:

The projected contribution from wind power is believed to be small regardless of the base of electric energy requirements used. As discussed in Section 6A.6.1.3, the NSF-NASA Solar Energy Panel has projected the market penetration, even following a successful development program, to be only about 1% of total electrical production by the year 2000. Even if per capita energy use were held constant, which does not appear to be likely, wind power would not be a significant contributor to our electric power requirements. There are other more optimistic projections made for wind-power. The Sub-Panel IX group projects that about 19% of our electrical needs could be met in the year 2000 by windpower. This figure corresponds to the maximum available wind energy estimated by the NSF-NASA panel, and the AEC does not believe this to be a realistic possibility.

103. Comment (page 15):

- C.1-1 "The real conservation question is by-passed -- namely, can we learn to live less energy-intensively, thus stopping the continued growth of per capita energy consumption?"

Response:

The willingness of people to live less energy-intensively, even to the point of accepting changes in life-styles, is carefully examined in Sections 6C.6-8 of the Final Statement. It is clear that some energy conservation measures can be instituted and net savings will be made in an area that is so dependent upon countless individual decisions for its success. It is a goal to be reached for - but it is not a prudent basis for planning to meet future energy needs.

104. Comment (page 15):

- C.7-6 "A table should be shown summarizing the energy savings for each conservation measure and the contribution of each alternative, such as wind power. With several assumed energy growth forecasts, these alternatives can be put in truer perspective and real options discussed."

Response:

A table has now been included in Section 6C.7 showing the energy savings that might result from successful implementation of conservation measures proposed in the several studies discussed in that section. Projected energy contributions from the several alternative energy technologies discussed are examined in the individual sections in Section 6 describing each technology. The subject of various energy growth forecasts is included in Section 11.

R 1, Box 267, Toney, Ala 35773
24 April 1974

Office of the Assistant General Manager for
Biomedical and Environmental Research and Safety Programs
U.S. Atomic Energy Commission, Washington, D.C. 20545

Dear Sir:

The March 1974 Draft Environmental Statement, WASH-1535, Liquid Metal Fast Breeder Reactor Program, could be described as a blueprint for the perpetual pollution of the planet.

The Statement makes it clear that the subject program will, through fuel cycle and transport releases of plutonium-239 and other transuranic elements, repetitively contaminate global air, soil, water, and man himself for up to half a million years. Known methods for containment of the lethal wastes cover no more than a hundred years. It is self evident that a prime consideration of this and alternative programs should be the environmental and genetic heritage of future generations.

The cancer risk factors in the Statement fail to make clear the now known fact that one particle of plutonium-239 can cause fatal lung cancer, since its characteristic of irradiating only a small volume of lung tissue makes the dosage a million to ten million times larger than if distributed uniformly throughout the lung.

Radiation charts shown in the Statement should carefully differentiate between benign radiation and the lethal radiation destructive to all organic life.

It is noted that the estimate of contamination of roots, surface foliage, animal food chains, and aquatic systems by transuranic elements may have little relationship to reality. Admittedly, "Sufficiently detailed and accurate knowledge regarding the many factors which influence the movement of these elements through the environment over the periods of hundreds to tens of thousands of years during which they may enter man through the ingestion pathway is not available."

Certainly, it is disconcerting to note that, as a result of radionuclide releases from normal operation of the LMFBR fuel fabrication plant, "The estimated total-body dose to a person involved in crop production utilizing irrigation will increase from 0.059 to 0.098 milirem/year as a result of exposure to the contaminated ground surface." Please relate this to the statement that "...plant material (and other food) achieves concentrations equal to 10% of the soil concentrations on a fresh or wet weight basis."

The time allowed for review of this crucial document is woefully inadequate. However, the Statement itself will condemn the LMFBR program to men of insight and vision dedicated to the service of humanity.

Sincerely,

Neva Dawkins

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Ms. Neva Dawkins
R1, Box 267
Toney, Alabama 35773

Dear Ms. Dawkins:

Thank you for your letter of April 24, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information.

Your concerns regarding particle lung dose effects associated with single particles of plutonium-239 (and other transuranics) are discussed in Section 4.7 and Appendix II.G.6 of the Final Statement, and in the references provided therein. The conclusion of these analyses is that empirical evidence to date indicates that the nonuniform dose distribution of plutonium particles in the lung is not more hazardous and may be less hazardous than if the plutonium were uniformly distributed. This, together with the fact that national and international radiation standards setting bodies, while acknowledging the problem, have not yet recommended any method other than that employing the mean organ dose, provides the bases for the conclusion given in the Final Statement. "Radiation charts" in the Statement do not "differentiate between benign radiation and the lethal radiation destructive to all organic life" because no amount of radiation, no matter how small, is assumed to be benign, and because all levels shown in the "charts" were well below levels known to be lethal.

The sentence in the Draft Statement

"The estimated total-body dose to a person involved in crop production utilizing irrigation will increase from 0.059 to 0.098 millirem/year as a result of exposure to the contaminated ground surface."

referred to the fact that agricultural workers would receive 0.039 millirem/year* (in addition to the total of 0.059 millirem/year** resulting from all exposure pathways) due to direct exposure to the irrigated land surface. These dose levels are much smaller than that due to natural background radiation (about 130 millirem/year), and are therefore not of major significance.

*Page 4.3092 of the Draft Statement

**Page 4.3-91

Ms. Neva Dawkins

2

The statement -

"...plant material (and other food) achieves concentrations equal to 10% of the soil concentrations on a fresh or wet weight basis."*

referred to the conservative assumptions made regarding the uptake of plutonium and other transuranics via the root uptake pathway (one of the ingestion pathways) by present and future generations in the United States and Canada. This does not refer to doses to individuals, which would be extremely small in this case.

We hope this information is adequately responsive to your concerns. Thank you for your comments and for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement,
LMFBR Program (WASH-1535)

Jon Legakes
20 Fifth Street
Valley Stream, New York 11581

JL/ew

April 24, 1974..

re L.M.F.B.R. Draft Statement

Mr. W. H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Sir:

After reading your L.M.F.B.R. Program Draft Environmental Statement, the choice for nuclear power as an alternative to fossil fuels is very tempting economically. Since enough research and finances have been put into its development, we could immediately begin building nuclear power plants and very likely avoid possible economic difficulty caused by fossil fuel shortages. Up to this point, I would agree that we should "go nuclear," except for the fact that we are not ready to deal effectively with such long-lived, extremely dangerous wastes, among other things.

The draft statement is much too optimistic in assuming that A.E.C. safety measures are completely effective. The absurd suggestions of putting these wastes in space, ice-sheets, or ocean beds are all too reminiscent of throwing one's garbage out the window or sweeping one's dirt under the rug. It just doesn't work and always catches up with you sooner or later. How often do we hear how effective and safe a project "could be" "should be," or "can be" "if" certain precautions are taken? And how often are we very far from the mark of safety when it comes right down to the actual or real situation, especially when money is involved? I am not questioning your intelligence or integrity as an Atomic Energy Commission; simply witness continuous oil spills, sewage problems, exhaust emissions, industrial wastes that still badly pollute our environment; witness the power of the auto industry to delay exhaust control deadlines from 1975 to 1976 and still they push for 1977.

I do question what shade of rose your glasses are colored; especially when after each chapter segment the expected level of radiation seeping into the environment is always below the minimum standards. Your effectiveness in dealing with accidents and possible problems is very good on paper, but

Mr. W. H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research
Atomic Energy Commission

putting the program in operation involves so many other processes and people to work them; i. e., commercially built and operated reactors and accidents resulting from negligence or unintentional but faulty judgment; security problems on an international scale; security problems on a national scale, such as terrorists, destructive political groups or individuals; transport accidents, possible theft and hijacking. The draft program is, therefore, much too optimistic and we should wait before we make any irreversible commitments for nuclear energy. We are in no position to leave a legacy of long-lived, extremely dangerous wastes to ourselves, our children, and future generations for thousands of years to come, especially that we might develop an energy source five or ten years sooner than much safer alternatives can be developed.

The alternatives to be given priority over all others are solar, wind, fusion and fuel cells. Within five years all new houses and even commercial buildings could use solar energy for heating and cooling with fossil fuel as a back-up system when needed. Electricity would be supplied from current hydroelectric and fossil fuel plants. Within ten to fifteen years electricity could also be produced with solar energy. Conventional houses could be given tax breaks for conversion to solar heat and electric. Where possible, wind could be used to produce electricity, too.

Fuel cells and fusion are other alternatives for industrial, commercial and larger scale residential use. All the fossil fuels saved would then be used in areas where solar energy or another alternative needed more development, such as cars, trucks, and large-scale residential needs. Enormous energy savings can be made with better insulating of homes and buildings and other conservation practices. All government buildings, schools, supermarkets, shopping centers, and the like could greatly reduce waste lighting and heating, as they have been during the recent "crisis." School programs for young people and old for that matter must stress the need for lifestyles less wasteful and many unnecessary gadgets discouraged; i. e., electric toothbrushes, electric scissors, electric hair dryers, etc. We abuse so much of our energy, it's a crime.

So much could be done within the present fossil fuel system that possible economic problems would be balanced out in the five, ten, fifteen and twenty-year periods solar energy research will need to become feasible for large-scale electric

Mr. W. H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research
Atomic Energy Commission

production. It is already feasible for home and building heating and cooling. Since solar energy could not be used exclusively, just as no system could, fuel cells, fusion and even wind power, methane, and geothermal could be developed to make up for near future solar energy limitations. Fossil fuel is always available as a back-up system. With residential and commercial-industrial power needs making up approximately 65 per cent to 70 per cent of our total energy used, much could be done with solar power for both new structures and even converting old structures, since within five to ten years of operation, the new solar or wind-energy systems pay for themselves in fuel and electric savings.

At the present time, there are solar home-heating systems that provide 75 to 80 per cent of home energy needs in northern climates, even for long periods of cloudy days. What remains to be done is mass produce these systems to be competitively priced and socially acceptable. The only thing holding back the solar possibility is FINANCE. Farmers with animals could easily produce enough methane from manure to pay for the initial investment (approximately \$15,000) in a methane generator in three or four years of operation. There is a good deal of information on such systems already. With all the energy used by modern agriculture, that would constitute considerable fossil fuel savings.

The main problem with these alternative electricity producers is long-term storage. Currently the National Science Foundation is financing research at the University of Wisconsin. Much of the money put into nuclear research and development needs to be channeled into small and large scale solar energy production, storage systems, methane generators and the like. I recall a news item that said the original billions of dollars allocated by the government for alternative energy systems was cut to 50 million. NO WONDER THE DRAFT STATEMENT CLAIMS NOT ENOUGH RESEARCH HAS BEEN DONE. What do you, as an Atomic Energy Commission, expect from individuals and small groups who are struggling and still, in spite of short funds, succeed in producing feasible alternatives when necessary funds are taken out of larger scale, government funded alternative energy projects by the government itself. It seems the nuclear system is the government's too-favored pet, and all other systems must suffer for it.

This is not to imply that nuclear reactors must be scrapped completely. At the present time, there are just too many serious problems connected with making a commitment

Mr. W. H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research
Atomic Energy Commission

to nuclear energy as the prime source of our energy. We must put forth our efforts in development of solar and fusion energy, cleaner and more efficient fossil fuel technologies and even methane, wind and geothermal energy. Much has already been done in these non-fission fields. Now it is up to the A.E.C. and other government agencies to take the very serious responsibility of making a decision in favor of obviously safer and cleaner technologies in the highest interest of the people of not only our country, but the entire world and all the future generations to come.

Respectfully submitted,

A handwritten signature in cursive script, appearing to read "Jon Legakes".

Jon Legakes

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Mr. Jon Legakes
20 Fifth Street
Valley Stream, New York 11581

Dear Mr. Legakes:

Thank you for your letter of April 24, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. Please see the other enclosure to this letter which provides further information on the points you raised.

Thank you for your thoughtful comments and for your interest in the LMFBR Program.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Program

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement,
LMFBR Program (WASH-1535)

Enclosure 1

AEC STAFF RESPONSE TO SPECIFIC COMMENTS BY MR. JON LEGAKES1. Comment:

"...we are not yet ready to deal effectively with such long-lived, extremely dangerous wastes... ..We are in no position to leave a legacy of long-lived, extremely dangerous wastes to ourselves, our children, and future generations for thousands of years to come..."

Response:

The AEC believes that the handling and storage of radioactive wastes will be amenable to engineering solution in the short term. This matter is discussed in Section 4.6 of the enclosed Final Statement, which indicates:

"The near-term waste management program for high-level waste discussed in this statement assumes retrievable surface storage for safekeeping until a safe and acceptable ultimate storage method has been selected and tested. . . .

Current regulations indicate that wastes other than high-level wastes can be disposed of in commercial burial grounds. In the case of cladding hulls, noble gas cylinders, and long-lived alpha-emitting plutonium and other transuranic wastes, future regulations will probably require storage in repositories. Development programs are going forward to identify the most appropriate methods of disposal for these materials."

Future alternatives for the disposal of radioactive wastes are discussed in Section 7, where such methods as geological storage, extra-terrestrial disposal, and transmutation are discussed. The AEC believes that the nuclear industry is able to deal effectively with wastes being produced by currently operating nuclear facilities, and is confident that the industry will be able to handle those larger quantities of wastes expected to be generated in the future.

2. Comment:

"Your effectiveness in dealing with accidents and possible problems is very good on paper, but putting the program in operation involves so many other processes and people to work them; i.e., commercially built and operated reactors and accidents resulting from negligence or unintentional but faulty judgment; security problems on an international scale; security problems on a national scale, such as terrorists, destructive political groups or individuals; transport accidents, possible theft and hijacking. The draft program is, therefore, much too optimistic and we should wait before we make any irreversible commitments for nuclear energy."

Response:

The issues mentioned are indeed worthy of close scrutiny, and are being carefully assessed in the development of the LMFBR. They are discussed at length in the enclosed Final Statement. Please see Section 4.2.7 for a discussion of reactor safety and accidents, Section 7.4.3 for information related to security problems on a national scale, and Section 7.4.4.2 for information related to sub-national acts in other countries.

With regard to the comment that we should wait before making any irreversible commitments to nuclear energy, the AEC does not believe that any such commitment is being made. As discussed in the Perspectives section in Section 6 of the enclosed Final Statement, the LMFBR Program is a research and development program with the goal of developing a viable energy production option. Whether or not that option is exercised will depend upon the relative merits of this energy option as compared to other options available. It is axiomatic that no energy option, LMFBR included, should be exercised if it is unsafe or environmentally unsound regardless of any other advantages the option might exhibit. As in any research and development program, if the LMFBR does not meet the criteria imposed upon it or realize the potential expected, it can and will be terminated or reoriented. LMFBR research and development thus in no way represents an irreversible commitment to nuclear energy.

3. Comment:

"The alternatives to be given priority over all others are solar, wind, fusion and fuel cells. Within five years all new houses and even commercial buildings could use solar energy for heating, and cooling with fossil fuel as a back-up system when needed. Electricity would be supplied from current hydroelectric and fossil fuel plants. Within ten to fifteen years electricity could also be produced with solar energy. Conventional houses could be given tax breaks for conversion to solar heat and electric. Where possible, wind could be used to produce electricity, too."

"Fuel cells and fusion are other alternatives for industrial, commercial and larger scale residential use. All the fossil fuels saved would then be used in areas where solar energy or another alternative needed more development, such as cars, trucks, and large-scale residential needs."

Response:

The alternatives you mention certainly appear to have some attractive features from an environmental standpoint. However, they all suffer from limitations in one or more of the areas of cost, state of knowledge, availability and practicality. For example, fusion power has not as yet

established scientific feasibility and is not expected to contribute substantially to the Nation's energy resources until sometime in the next century (See Section 6A.1.6). Fuel cells are not an independent source of new energy, but rather a more convenient or more efficient conversion device for transformation of other energy sources into new and perhaps more useful applications. For example, it could be used as a means of energy storage for variable and interruptible energy sources such as the solar and wind power options you cite, or as a means of transforming the energy from a fuel such as coal into a more easily transportable and mobile form. (See Section 6B.6).

The dilute, variable and interruptible nature of solar energy makes the cost of installing solar energy systems much higher than conventional forms of electric power production. Thus they require substantial research and development to bring these costs down into a competitive range. The schedule you suggest for the use of solar power in home heating of all new homes and commercial buildings is quite optimistic considering the high costs and the need for conventional standby furnaces and given the many social, legal and institutional problems associated with establishing this form of heating for the many individual states. (See the Summary of Section 6, and Section 6A.5).

Similarly, the production of electricity by solar energy may prove to be technically achievable and in fact is being done on a small scale today where cost is not a major factor, primarily in space applications. However, considering the state of technology and the projected economics of solar power, it is most unlikely that more than a few percent of our electrical requirements, if that, will be met by solar energy before the end of this century. Please refer to Section 6A.5 for a more complete discussion of this point.

4. Comment:

"Enormous energy savings can be made with better insulating of homes and buildings and other conservation practices. All government buildings, schools, supermarkets, shopping centers, and the like could greatly reduce waste lighting and heating, as they have been during the recent "crisis." School programs for young people and old for that matter must stress the need for lifestyles less wasteful and many unnecessary gadgets discouraged; i.e., electric toothbrushes, electric scissors, electric hair dryers, etc. We abuse so much of our energy, it's a crime."

Response:

Your comments on the potential for energy conservation are well taken. We agree that all worthwhile conservation measures should be implemented, and

discuss this subject in detail in Section 6C. Please note especially the relationship between the reduced energy demand that may be achieved by conservation and the remaining need for alternative technologies, as discussed in Section 6C.7. Conservation measures requiring changes in lifestyles are also discussed in this section.

5. Comment:

"Much of the money put into nuclear research and development needs to be channeled into small and large scale solar energy production, storage systems, methane generators and the like. I recall a news item that said the original billions of dollars allocated by the government for alternative energy systems was cut to 50 million. NO WONDER THE DRAFT STATEMENT CLAIMS NOT ENOUGH RESEARCH HAS BEEN DONE. What do you, as an Atomic Energy Commission, expect from individuals and small groups who are struggling and still, in spite of short funds, succeed in producing feasible alternatives when necessary funds are taken out of larger scale, government funded alternative energy projects by the government itself. It seems the nuclear system is the government's too-favored pet, and all other systems must suffer for it."

Response:

Your comments on the relative funding between nuclear energy, solar energy, and other alternative technologies reflect understandable concern. The question of which technologies to pursue vigorously and which should be relegated to lower levels of effort requires some engineering judgement and is often grounds for debate. Suffice it to say that the decisions that have been reached over the years have taken into account all appropriate factors such as status of the technologies, relative chances of achieving technical and economic fruition, research and development required and the costs thereof, postulated environmental impacts, resource availability, cost-benefit analyses, etc. We believe that the emphasis that has been placed on nuclear fission is appropriate and will lead to substantial benefits for the Nation in years to come. Other Nations have come to the same conclusions as they have considered their future energy needs. For a further understanding of the bases on which energy R&D decisions are made, you may wish to refer to "The Nation's Energy Future," (WASH-1281), A Report to the President of the United States by the Chairman, U.S. Atomic Energy Commission, December, 1973. The fiscal year 1975 budget for all government supported energy R&D draws heavily on the recommendations of this report, which outlined a 5 year, \$10 billion, energy R&D program. This program forms the basis for current government planning and, as noted, initial funding is already being provided along these lines. We do not know the basis for your remark that the research effort on alternative energy systems has been cut to \$50 million; a multi-billion

dollar program is already underway. You are referred to Perspective on Alternative Technology Options in Section 6 of the Final Statement for additional discussion of the relative funding for different research and development programs.

6. Comment:

"At the present time, there are just too many serious problems connected with making a commitment to nuclear energy as the prime source of our energy. We must put forth our efforts in development of solar and fusion energy, cleaner and more efficient fossil fuel technologies and even methane, wind and geothermal energy. Much has already been done in these non-fission fields. Now it is up to the A.E.C and other government agencies to take the very serious responsibility of making a decision in favor of obviously safer and cleaner technologies in the highest interest of the people of not only our country, but the entire world and all the future generations to come."

Response:

The AEC agrees with your general conclusion that alternative energy technologies should be developed. We recognize that this Nation's energy requirements are of such magnitude that they can be met only through a broadly based program utilizing all feasible energy sources. At the same time, it is our belief that nuclear energy represents the most viable and attractive energy source in terms of economics, current and near-term availability, magnitude of energy resources, technical feasibility, environmental impact, and other factors that must be considered in evaluating the pros and cons of potential power supplies. There are problems in the application of nuclear energy, just as there are problems in the development and application of other energy sources, but we believe that these problems are solvable. The AEC is making every effort to address and resolve these problems, and believes it will be successful to the benefit of the Nation's energy requirements and economic growth. We are hopeful that your reading of the enclosed Environmental Statement will lead to an understanding of the bases for these conclusions.

April 26, 1974

Office of the Assistant General Manager
 Biomedical and Environmental Research and Safety Programs
 U. S. Atomic Energy Commission
 Washington, D.C. 20545

Dear Sir:

I have attached my comments on WASH-1535. While they involve over 30 handwritten pages, they are very brief, and do not begin to show my feelings toward the Draft Statement. In my opinion it is a very low quality document for the sole purpose of satisfying a court order in the hopes that the ~~govt~~ Court will be more impressed with its volume than its content. I hope this is not the case. If the broad, sweeping and unsupported, or unsupportable statements were removed from the Draft, little would remain.

Thank you for the consideration of my comments.

Yours sincerely

Dr. Chauncey K. Ford
 108 N. Pershing Ave.
 York, Pa. 17403

LMFBR Draft Comments

Pages 4.1-3 to 6 all contain references to a man-rem dose. Such a number, without reference to the average dose and the population receiving the dose is meaningless. Furthermore, since the releases of radioactivity come from essentially point sources, even calculating an "average" dose is risky because of the non-uniformity of the dose. This is illustrated in Table 4.2.5.5, where the magnitude of the dose decreases by a factor of 10 between 1 and 4 miles from the release point, another factor of 10 between 4 and 20 miles, and a factor of 4 between 20 and 50 miles, for a total drop of a factor of 400. No average can meaningfully convey this range of ~~the~~ variation in data, unless the extremes in the data are specified. The situation is not clarified by inventing a unit as the "man-rem" to further hide any useful information, ~~and~~ of course, it is quite possible that the man-rem unit is used with the intent of confusing data and the reader.

Section 4.1.4 avoids mentioning when all the criteria for the LWR program is to compare, and avoids facing the "every independence" desire of President Nixon. It appears to be independent

of foreign energy sources, we must be able to show we have enough resources in the U.S. for our foreseeable needs. This has not been done with regards to uranium.

Section 4.2.1 refers to the licensing process of the AEC, which is currently under review by the Joint Committee on Atomic Energy. The entire process may be changed, including the mandatory review by the ACRS, if the industry has its way. This process cannot be relied upon to approve and authorize safe, reliable nuclear powerplants. The Enrico Fermi plant was licensed through this process, and was a colossal failure. Few of the other licensed nuclear powerplants have ever lived up to their reported 80% capacity factor for even one year.

An independent review of the AEC licensing process "Citizen Group Uses of Scientific and Technological Information in Nuclear Power Cases", by Etkin and Kasper found many ^{serious} deficiencies ~~in it~~. These ~~same~~ deficiencies are not being remedied by either the industry or the AEC's recommendations to the Joint Committee, and can be expected to become more serious in the future.

Table 4.2.3.1 is very evasive as to hard data on LMFBR plants, for reasons explained. As the

reader to supply the same uncertainties in this Table to all the other data, including projections, in the Draft Statement? There are some numbers of critical importance in this Table which should be well known, but appear not to be. Not even the breeding ratio is accurately given, and the "docking time" is conveniently left out. Perhaps rather than a Demo plant, EBR-IV should be built at NRTS in Idaho (EBR-III was misnamed The Enrico Fermi plant) so that a more solid grip on the required input data can be had.

Section 4.2.5.2.1 on thermal wastes ignores the strong likelihood of "nuclear parks" coming into existence, with 10 to 40 nuclear, commercial, clustered in a relatively small area and the effect of their combined thermal releases on the local biota and local climate. The report itself ignores the impact of the anticipated LMFBR (and LWR) thermal releases on the climate of the nation by the year 2020.

Section 4.2.5.3, while not having the benefit of accurate data on the actual ~~conditions~~ plant design, purports to accurately predict the fission product release rate from the reactor, and hence, it has to man. Of indeed, the HEC can accurately predict what comes out of a plant when they are

conducted such a follow-up after operation of the reactor. The AEC has not conducted ^{thorough} health monitoring programs for those who live in, work in, or go to school in buildings built the uranium mine tailings in Utah and Colorado. And so on. Reliance on isolated radiation detection and on calculations carefully avoids the possibility that other than the desired answer will be obtained.

Page 4.2-158 The words of the last quoted paragraph sound soothing, as they are supposed to, but as the LWR program approaches maturity (or is said to approach it) the AEC still has not furnished experimental data to show that the 10 CFR 100 criteria can be met. They still have definitively proved that the ECCS will perform their designed tasks. For a 1 in a million chance for a plant to have an accident exceeding the guideline, the odds are that it is 1 in 1000 for 1000 plants operating, and 1 in 25 over their 40 year lifetime. A 1 in 25 chance for a serious accident is inordinately close to a certainty that a serious accident will occur. The only remaining questions are when, where, and how bad?
Will the LMFBRs have back-up safety systems as good as the ECCS?

Section 4.2.7.3 The first sentence of this section appears rather ludicrous in view of the ECDS program still unresolved, the recent report of the ACRS on pressure vessel integrity, and the various problems in the past history of the U.S. breeder program with core melt-downs, explosion, and so on.

Page 4.2-160 and 161. The high thermal conductivity of liquid sodium is nice, and it is nice if no pumping power is needed to prevent melt-down, but little attention is paid to the possibility of flow blockage and subsequent overheating, as happened at Fermi.

While the concentration of fission products is higher in the LMFBR, as is the concentration of short-lived isotopes, it is not necessarily the total ~~amount~~ amount of fission products that counts. If the fission products are released to the environment, it is the biological activity on which count, many are short-lived, and many are long-lived.

Page 4.2-161 and 2. An reference to "major power operation" as they are called, as the "initial ~~negative~~ temperature coefficient" sufficiently negative to prevent or a core melt-down? Would the Doppler broadening of neutron capture cross sections due to a temperature rise be sufficient to prevent a power excursion? Could the two work

together present a "major power excursion", "core ~~exhaustion~~", or "core rearrangement"? Why is a discussion of core melt down or ~~core~~ disassembly not thoroughly discussed?

Section 4.2.7.7 ~~§~~ contains a very superficial discussion of various accidents which demand a thorough review needed. No mention of time scales, or sequences of possible events is made. No mention is made of the possible events leading to a breaching of the containment and the consequences thereof.

Section 4.3 ^{4.4} As the tempo of terrorist actions continues to rise throughout the U.S., and the world, it is not comforting to realize that the AEC is continuing to ignore the possibility that a terrorist, or band of terrorists may turn their attention to the exceedingly vulnerable segments in the nuclear fuel cycle.

Page 4.4-25, last paragraph. Why will reprocessed uranium ~~be~~ not be recycled to LMFBR reactors? Is it because the uranium contains a negligible quantity of ^{235}U or producing isotopes of decay product which will make rehandling expensive and difficult? Is this another hidden cost of the LMFBR program?

Figure 4.5.1 is similar to Figure A.16 of WASH-1099.

But some of the losses of the WASH-report have consequently been changed, to "to disposal." Maybe this will be the case, and maybe not. Past histories suggest that there will be significant losses, if experience at Appelo, Pa. is any indication. It is also interesting to note that the numerical uncertainties mentioned earlier have disappeared for this figure.

Table 4.5.4.1 contains more confusion factors, designed to conceal the real doses from the public.

Appendix H. B. The assumption is made that the general population, a rural population, is 100 ft from road waste containers. While this may be true on most interstate highways, on many roads in rural Pennsylvania, and other states, where such shipments can reasonably be expected to be made (as are now scheduled to be so made for HLW's or HTW's), many residents live much closer than 100 ft from the road center. Perhaps 15 ft would be more reasonable cut-off.

Figure 5.2-1 Surely the AEC could do better than / Operational data !!

Page 5-11. re: "intelligent management of our resources."
 Much here hinges on the definition of the word
 "intelligent." If "intelligent" resource management
 is meant the maximization of profit, with little
 regard for present or future environmental ^{or societal} ~~port~~
 resource uses, or resource availabilities, then
 our present policies, and those advocated by this
 Draft must be considered "intelligent." If on the
 other hand, one considers intelligent resource
 management to minimize environmental and societal
 costs and to maximize present and future uses and
 availabilities of our resources, then present
 and anticipated policies of resource management,
 including the LMFBR program, cannot be
 considered intelligent. With stable societies
 historically lasting for a few hundred years, at the
 most, a couple of thousand, and geological upheavals
 and climatic change taking place in the 50,000 to
 1,000,000 year time scale, it seems completely rational
 and insane to commit society to a course of action
 which must be maintained for this kind of time
 scale. And for what purpose? Avoid to a line
 poverty and suffering on a world-wide basis? At least
 to do so in the U.S.? Is this even a conceivable
 action on which to base a policy, given all the social and
 economic decisions? Of course not! These decisions
 are made solely for private gain. But intelligent resource

resource management (as in the context of the definition given in Webster's Dictionary) ~~may perhaps involve decision making on grounds broader than private economic gain.~~ Responsible resource management (again, Webster definition for responsible) might also imply changes in present policies.

Section 5.3.1 avoids mentioning the method by which the electric utility industry hopes to be affected by the LILFBR program - by profits. Perhaps the projected profit, due to the introduction of the breeder, should be compared with the hypothetical benefits to be accrued by the public.

Sec. 5.3.1.1 contains projected economic requirements of the utility industry. No mention is made of the effect of these needs on the rest of the boron community, nor is mention made of the requirements of the industry after the year 2000.

Page 5-17 must be considered in the light of the general observations of WASH-1250 ^{par. 3-19} regarding electric utility ~~industry~~ management and reactor:

"Electricity management, in the most part, has been a low-level management of distribution between the organization and customers, with little or no consideration of the power plant and

The traditional controls employed in operating fossil fuel power plants.

2. In a number of cases, there appears to be insufficient management participation and involvement in the day-to-day operation of the facility - particularly safety related activities.

3. Fully effective quality assurance programs have not been sufficiently developed or implemented.

Whether or not the utilities and their managers can grasp the complexities of LWR's remains to be seen, yet it is said the industry is approaching. The operation by these same people of LMFBRs is disquieting.

While it is nice ~~from~~^{from} public relations point of view to be concerned with an "image" of social responsibility many members of the public, long familiar with the utilities disregard of the attitudes of the public due to discriminatory rate structures, eminent domain proceedings and secrecy about future plans, would prefer to see a real change in the utilities social responsibility, not just a polished image.

Page 5-23 Apparently, the author of the last paragraph has not yet read "Study of Quality Verification and Budget Impact" Task Force Report to the Director of Regulation, Jan, 1974. These ~~high~~ high standards referred to in the draft are, to a certain extent, nonexistent. High standards mean primarily one thing - high costs.

And LWRs are expensive enough with the standards where they are. Applying standards with the sole intent of making reactors safe would price them out of the market.

Section 5.4.1 Reference is made to energy requirements. No substantive showing has been made ~~that~~ as to what the nation's energy requirements. Many projections have been made by those who stand to gain financially by the achievement of the projection, and these have been echoed by the particular governmental agencies involved, but these are only projections. Perhaps they should be made ~~independently~~ independently of the energy industry and the energy agency.

Page 5-31 first full paragraph. Some rather sweeping statements are made, with no support offered, of the radioactive waste problem as "really intractable" why does it remain unsolved? Why must we spend money to build temporary engineered storage facilities? Is it because the waste problem has no present solution, and must therefore be passed to a future generation? Many details to the solution of this really tractable problem are lacking.

Section 6.2.1.2. The second paragraph of this section leaves many unanswered questions.

Who insures the discharge system will be well designed? Experience with LWRs suggests a lack of quality design in this area. And who determines what level of damage to the "aquatic environment" are ecologically "acceptable"? Does anyone know how much damage to any ecosystem is "acceptable" to whom?

Page 7-17 It seems incredible that underground can be passed off because the technology does not exist to go from an 80 foot cavern to a 140 foot cavern. This is a little less than a factor of 2 in linear dimension. When it is considered that the jump in power from EBR-II (20 MWs) to Fermi (scaled down to 60 MWs) was a larger factor, and the jump to the first breeder Deane (400 MWs) immediately preceded the first production plant (Pressurized), such a statement staggers one's imagination. But this on top of the fact that the entire Dept. statement does not make mention of how much plutonium has been bred in the U.S. breeder program or how much, say, EBR-II or Fermi bred.

Page 7-21 The argument that the red, etc., minerals and underground mining have not been demonstrated over a long time is rather interesting. That same

concept can be applied to almost any phase of the LWR and LMFBR programs. The long term workability (on the order of one reactor lifetime) of many components of reactors has not been demonstrated. Nor has the long term integrity of pressure vessels. Of course, the short term workability of the ECCS has not been demonstrated. Nor have many design features of the HTGR or the LMFBR. Nor have methods of long term waste disposal been demonstrated. But such inadequacies have not slowed the reactor programs. It should also be noted that the adequacy of long-term above-ground siting licenses needs to be desired, and that many needs remain.

Section 7.4.3.1 The state of the licensing business has been mentioned earlier. But the glowing words of praise for the rigid AEC rules, regulations, and inspection must be viewed in the light of, among other things, the GAO report "Improvements Needed in the Program for the Protection of Special Nuclear Materials", B-164105, Nov. 7, 1973. Numerous very serious deficiencies in the AEC rules and inspection were found. When they come out the AEC requires fissile materials to receive the protection that their monetary value would dictate, but alone the diversion threat, then the public will know that the AEC is at least partially aware of the problems fissile materials can

course.

Page 7-71 lower paragraph. The expectation that a fence, a guardhouse, or an armed guard or two could repulse an attack by even half a dozen reasonably well organized men is pathetic. The reliance on these to do so is all but criminal. It seems inconceivable that a person with some explosives knowledge and a rudimentary knowledge of a reactor could not render its safety systems inoperative, if they are not naturally so, and then destroy the reactor. It also seems inconceivable that an airplane hijacker could not release much of the radioactivity contained in a fuel reprocessing plant with one well guided crash. Perhaps the author of this section should read the first part of the testimony of Dr. Bruce L. Welch before the Joint Committee on Atomic Energy, on March 28, 1974.

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Pages 7-72 and 73 Material Control and Accountability. Again, the words sound fine, but reports that a few hundred kilograms of U-235 have already shown up missing at just one reprocessing plant (in G. P. L. I. are disconcerting. Some discussion of past accountability and penalties for failures would be appropriate. The fact that an inventory is to be conducted ~~monthly~~ annually is meaningless unless something is done with the results.

Page 7-74 Since the dividing line between credible and incredible accidents is arbitrary, it might be illuminating to know the difference between a "credible" threat and an "incredible" threat.

Section 7.4.3.4 The past history of the AEC should be reviewed with regard to special nuclear materials inspections and enforcement. ~~The AEC should be~~

Where is Chapter 8?

Sec 9.1.1.2 Again, independent projections should be used. Projections made by those who stand to gain become goals for the appropriate government agency. Perhaps it should be explained that the swiftly rising curves soon become almost perfectly vertical unless the horizontal axis is changed. Since projections are made to the year 2020, a comparison of installed capacity from 1870 to 2020 might better show how fast things will change in the future. The argument ~~that~~ that environmentalists want to change everybody's life style to a previous standard should be considered in the light of the "intertemporal" argument for a fixed growth rate as depicted in Fig 9.1-1, where doing nothing (i.e., the public doing nothing) results in a drastic change in life-

style, without the public having been so informed. Nor are the effects of these changes in life-style (the new affluence, the new availability of leisure time, and the new inflation and unemployment figures) ~~at all~~ examined with regard to their effect on society as a whole.

Figures 9.1-8, 1-9, and 1-10. No explanation is given why all of a sudden no new plants are built after the year 2020. Why not? Does this imply the utility industry plans to stop expanding after 2020?

Table 9.1-13 uses an apparent 75% capacity factor for electricity generation for LMFBRs. Figure 4.5.1 uses 80%. Which figure is the one to be used for projection purposes? There a number of other instances where both figures are used. Should not one figure be used for all calculations?

Page 9.1-70 Maybe the AEC considers that the breeder has "arrived," but being as the FFTF has yet to operate and cost overruns are in the neighborhood of 400%. The first Demo plant (EBR-II??) is already experiencing serious cost escalation because the ground is even broken. And, in the absence of plutonium production data, it seems hard to say that the breeding concept itself is proven, let alone saying

The technology for large scale energy production has "arrived." Many problems still exist in the LWR program, and if it has "arrived," it is only in spite of the problems.

Table 10.1 An 80% annual capacity factor and a 70% lifetime capacity factor are mentioned, whereas, as mentioned before, an apparent capacity of 75% is used in Figure 9.1-13. Which is the "real" figure, or can the reader take his choice? Or a variety of values being projected so that one may be close to that realized?

Table 10.3 successfully muddles data to hide the portion of U.S. production that is committed to breeder (and LWR) construction. It also hides the dependence of the U.S. on foreign materials production.

Page 10-31 Perhaps the author of the paragraph in the middle of page 5-31 (mentioned earlier) should get together with the author of the first paragraph on page 10-31. Some fundamental differences here ~~are~~ should be ironed out.

Page 11.2-15 An 80% capacity factor is used again. If this figure is achieved, on the average, by the reactors involved, and the other assumptions ~~are~~ are valid,

it may be possible that the mentioned benefits will be realized. But the cost of a major accident, earlier than to be reasonably probable in the time frame under consideration, could easily wipe out all benefits, real and imagined.

However, there is another side to these assumptions, and that has to do with the realization of the anticipated capacity factors. Experience to date suggests that 80% is unrealistic, and that 60% maybe more practical. If any rate, if it is assumed that the revenues derived from a plant operating at an 80% capacity factor are those necessary to cover costs, interest payments, and profit, then if the plant does not operate at 80%, but at a lower value, then the revenues will decrease, as costs may be reasonably expected to stay constant (or increase) while the plant is down. This down revenue must eventually be passed on to the ratepayers as an increase in rates. For instance, assume a 1000 MWe plant operates 7000 hrs a year (80% capacity factor) and the average sale price of the electricity is 3¢ per kilowatt (a probable value in the near future, a certainty by 2000). Then the annual gross income from the plant is

$$1000,000 \text{ kw} \times 7000 \text{ hrs} \times \$0.03/\text{kwh} = \$210,000,000$$

Similarly, a year's operation at a 70% capacity

factor produces

$$6130 \text{ hrs} \times 1,000,000 \text{ kw} \times \$0.03/\text{kwh} = \$184,000,000$$

in revenues, while a year at 60% yields

$$5250 \text{ hrs} \times 1,000,000 \times \$0.03 = \$158,000,000$$

in returns. Now, if a plant is expected to produce the \$210,000,000 in revenues, but yields only, say, \$184,000,000, then at least most of the difference remains as costs which must be paid, and profit, which must be maintained. This \$26,000,000, then, or at least most of it, must be obtained from the utilities rate payers as increased rates. The \$26,000,000 must then be considered an added cost to consumers because ^{the plant} ~~it~~ did not live up to expectations. If this ~~best~~ level of operation is maintained over the plant lifetime, the added cost to consumers is

$$\$26,000,000 \times 40 \text{ years} = \$1,040,000,000,$$

a sizeable burden.

Since LWRs have, in general, fallen far short of the 80% capacity factor, there is little reason to expect the LMFBR to achieve it. To date, LWRs, on the average, have only nudged 60% from the lower side, and a number of years have averaged around 55%.

The Draft Statement gives little guidance for choosing an operating capacity factor, ~~for~~ as pointed out earlier. So I will use an 80% figure as the planning goal, and follow the assumptions used above.

One LMFBR, operating 7000 hrs/year (80%), electricity costs of \$0.03/kwh would operate (as above) \$210,000,000

Let me now assume exemplary behavior on behalf of the LMFBR, and assume that, over the 20 year interval from 2000 to 2020, 400 of them operate at an average capacity factor of 70%, a figure greater than the LWRs have ever achieved.

The burden on the ratepayer will be

$$\$26,000,000 \times 400 \times 20 = \$208,000,000,000.$$

This includes ~~but~~ only of a portion of the operating LMFBRs in 2020, and assumes a rather low price for electricity. This figure exceeds all calculated benefit for the breeder calculated in Section 11.2.

If the LMFBRs average only 60%, as LWRs do now (through 1971) only occasionally, the burden would be twice as great, and it could also be greatly increased by the figures for those breeders introduced after 2000. It is therefore a very conservative figure, and strongly suggests that the breeder, as indicated in the Draft Statement, will be a financial failure.

Pages 11.2-20 and 21. For reasons outlined above, most of these conclusions are imaginary and will undoubtedly never be realized.

The unquantifiable benefits on page 11.2-21 are equally fanciful. Below are ~~comments~~ comment numbers to coincide with ~~page~~ this page.

1. Our resources are scanty, but racing to-day them out of the ground will not justify efficient

use.

2. Is it necessary that a premium market be established for plutonium from LWRs? Is it necessary to the economics of LWRs that plutonium be purchased at a premium price?
4. That the "virtually limitless supply of economical electricity" will really be economical has yet to be established. There are good reasons for serious doubts.
5. Same as above (4)
6. In reality, coal combustion will grow even with the LMFBR, as shown in Figures 9.1-2, 9.1-3. This statement, without considerable qualification and explanation, must be considered false.
7. Could not all these facilities be put to more humane use than just grinding out money-making machines to overcharge the poor and ~~under~~ undercharge the industries for their energy?
8. It has yet to be shown that any commodity offered at an economical price encourages thrift and conservation. Quite the opposite is observed.
9. The massive increase in energy usage will drain the underdeveloped countries, among others, of their resources, which will aggravate world tensions. The large scale U.S. usage means those resources will not be available to poorer countries because

the U.S. can pay premium prices with minor disruptions, while poor countries cannot pay premium prices for raw material without major economic complications. It is the old story of the rich getting richer and the poor getting poorer. Industrial development is needed to a far lesser extent in many countries than food development. This statement in the Draft must be considered largely false.

Table 11.3-7 Back to a 75% capacity factor

Table 11.3-8 And now we switch from the effect of one 1000 mwe plant to a gigawatt year of generation. One consistent set of units would be more understandable.

Section 11.3 squares the probability of a serious accident. From figure 9.1-3, it is assumed that by 2000, 1300 gigawatts of nuclear capacity will be installed, or the equivalent of 1300 - 1000 mwe plants. Considering the 1 in 1,000,000 chance ~~per~~ per plant per year, discussed earlier, then for just these plants operating between 2000 and 2020, the chance of a major accident is

$$20 \times 1300 \times \frac{1}{1,000,000} = \text{about } \frac{1}{40}$$

or a 1/40 chance that, due to these reactors, there will be a major accident. Such an accident would

be expected to drastically change most of the conclusions of this entire report, and such an accident cannot be ruled out. No evidence has been offered to suggest that this accident cannot happen. The apparently acceptable odds (acceptable to the AEC!) of 1 in 1,000,000 accident per reactor per year poses an enormous burden on the public. A further discussion of the consequences are in order.

Figures 11.3-2 and -3 ignore fossil fuel plants.

Section 11.4.1 totally ignores the questions fundamental to the whole energy problem. Who determines what the "future energy needs" are? Who these decision maker, primarily responsible to? What is the relationship (if any) between energy consumption and standards of living (as opposed to standard of consumption or GNP)? (Until these (and many more) are fully answered, the AEC, through this Draft Statement can only be considered a captivity agency, a captive of the industry it is to regulate, along with promote.

Section ~~11.4.1~~ 11.4.2 As mentioned earlier, without plutonium production data, the breeder concept remains unproven.

Page 11.4-13 A number of sweeping condemnations of solar energy are made without the benefit of references. No mention is made of wind-powered generators or of sea-thermal power plants. Neither requires any advances in technology. Neither produces radioactive waste. Neither is capable of a catastrophic accident as are fission reactors. The cost estimates vary largely because of the particular bias of the individual agency making the estimate. If the AEC were to admit that other technologies were more attractive economically than nuclear power, it would look very bad for promoting nuclear. So it is not surprising that other, cleaner, safer, and quite possibly more economical generation schemes are dismissed readily by the AEC. In addition, no case has been made for the necessity of large, central station power facilities.

Page 11.4-20 and 21 Many statements made on those two pages are unsupportable. The testimony of Mr. Frank Parnowski of the AEC before the Joint Committee on Atomic Energy, March 5, 1974 should be reviewed with regard to uranium resources. The situation may be critical even before the breeder is scheduled for introduction. The AEC last year proposed the relaxation of import restrictions on foreign uranium as between 1977 and 1987. Antecedent to this, the support, conflict, and construction of the LMFBR are made on the basis of unsupportable assumptions. It also is dependent for initial charges of plutonium.

on LWRs. Few comments on the availability of plutonium from this source have been made.

Page 11.4-23 first full paragraph. The impression is given that the country has little choice other than deploy thousands of expensive breeders. Such statements ~~are~~ are thoroughly unsupportable. There are viable alternatives which would not need fine volumes of hedging, false assumption, and so on to show that there will be only a small impact.

Page III-A-3 Detachable That the AEC does not consider an attack centered on nuclear facilities to be credible is appalling. They offer an enemy a number of advantages for a nuclear attack.

1. Large scale disruption of energy supply. Since we have been committed to the construction of large central power stations, it takes ~~to~~ fewer bombs to knock out more energy sources on which we are very dependent, and expected to become more so.
2. Large scale civil disorder could follow such an attack. Rather than millions of dead, there would be millions of scared, homeless, and ~~poor~~ hungry civilians, a far more difficult problem for a government to handle. If the fission product from the Peach Bottom complex and the proposed Fort St. Vrain HTGR are released with the

wind blowing toward Philadelphia or New York City, it seems inconceivable that mere disruption and disorder would result even if the bombs hit these cities. The thought of 20 million people trying to leave the New York City area in, say, 12 hours, is a frightening prospect. Retaliation would not matter to these 20 million. And a few more bombs at other reaction could cause similar disruptions for Washington, D.C., Baltimore and Philadelphia.

It would take a far deeper and more convincing argument than Hasboken presented to suggest that surface nuclear power plants (or, worse yet, nuclear parks) are not now a clear and present threat to national security.

Page III-B 2-7 Last full paragraph. It is interesting to note that a lowering of the energy demand diminishes the imaginary breeder benefits. Perhaps the concept of "zero energy growth as discussed in" Exploring Energy Choices", by the Ford Foundation. Such a concept may pose tremendous problems for those who depend on massive energy consumption and waste for their economic survival, but perhaps the ultimate decision should be made by all who will be affected.

Section III-B 3.38.3 Again, considerations should be given to the ideas in "Exploring Energy Choices". It may be possible to organize the goals of the U.S. to other than the maximization of profit today (and minimization of waste) to goals in which all the public may benefit.

Page III-B 3-57 Last paragraph. To say that nuclear and fossil fuels compete in the market is naive and ridiculous. It ignores the reality of the \$20 billion or so which the public has invested in fission research; it ignores the tremendous subsidy offered the nuclear industry by the Price-Anderson Act, and it ignores the ~~growing~~ ~~monopolizing~~ monopoly of coal, petroleum, natural gas, geothermal, and uranium are areas by the largest oil companies. Without the refusal of these oil companies to open ~~oil~~ ^{oil} reserves and ~~sell~~ ^{sell} available oil, the recent drastic increases in prices in coal and oil would not have occurred. Then nuclear energy ~~even~~ ^{even} with Price-Anderson, would be unable to compete with oil and coal. When will the AEC look into the question of energy resource monopolies?

Table III-B 4.4 This table neatly summarizes the inexcusably low caliber of input data in the entire Draft Statement. Not only does this table ignore the reality of reactor cost escalation, which can and normally do double over the construction period, but it assumes initial costs which are lower by a considerable margin than today's estimated costs. For instance, the estimated costs to complete theimerick Station in Pennsylvania are about \$550 per kilowatt. This is significantly higher than the \$470 figure in the table. Similarly, for Fulton Generating Station, an HTGR, the projected costs by the owner, Philadelphia Electric Co. are \$645 per kilowatt, over 50% higher than that estimated for an HTGR. I suggest that \$800 per kilowatt would be initially a conservative estimate of its capital costs. And history suggests that whatever the cost is, it will not decrease with time, but will drastically increase. Which it is possible that design standardization may slow this increase, no evidence has been presented in the Draft to suggest that it will be halted, or even reversed, as in the case of the LMFBR.

Figure P-1 This figure typically distorts reality. The year is 1974 and LWR research continues, and will continue for at least a few more years due to

problems which the AEC and the industry were to lax in solving years ago. There is little reason to believe the situation will not be repeated with the HTGR and the LMFBR. One would hope that at least a ~~few~~ few successful years of operation of a LMFBR Demo-plant would ~~precede~~ precede the "commercialization" of the Breeder. Such a hope appears fanciful, though, with the memory of the Enrico Fermi plant still fresh.

Section A interestingly, contains no mention of heavy-water moderated reactors, as the CANDU reactors of Canada. They are fueled with unenriched uranium, require no spent fuel reprocessing, UF₆ plants or enrichment plants, extract more energy from a ton of U₃O₈ than do LWRs, can be refueled while in operation, are available in ^{new} standardized designs, and show characteristically high capacity factors.

Page A.1.6-4/42 The possible benefits of the fusion process dwarf those imagined benefits of any form of the fission ~~to~~ process, breeder or breeder. Why not spend the money requested for the breeder on fusion? A spark of sanity is shown by the realization that small, modular (laser) fusion plants would be worthwhile.

Section C.6 It comes as no surprise that, in a set of volumes dedicated to the justification of the consumption of more electricity, no matter what or how frivolous the use, the last 22 pages, only 1% of the total, are dedicated to a very shallow discussion of energy conservation. This is typical of the low caliber of investigation of important issues the public has grown to expect from the AEC. For instance, the section ignores the influence of utility company rate structures and promotional practices on consumption patterns. This thereby assumes that consuming patterns originate from a spontaneous demand within the public. This is an utter falsehood.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 31 1974

Dr. Chauncey Kepford
108 N. Pershing Avenue
York, Pennsylvania 17403

Dear Dr. Kepford:

Thank you for your letter of April 26, 1974 commenting on the Atomic Energy Commission's Draft Environmental Statement on the Liquid Metal Fast Breeder Reactor (LMFBR) Program. The Statement has been revised where appropriate in response to the many comments received, and a copy of the Final Statement is enclosed for your information. The other enclosure to this letter provides responses to the specific points you raised.

Your interest in the LMFBR Program is appreciated.

Sincerely,

James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs

Enclosures:

1. AEC Staff Response to Specific Comments
2. Final Environmental Statement, LMFBR Program (WASH-1535)

Enclosure 1

AEC STAFF RESPONSE TO SPECIFIC COMMENTS BY DR. CHAUNCEY KEPFORD1. Comment (p. 1):

"Pages 4, 1-3 to 6 all contain references to a man-rem dose. Such a number, without a reference to the average dose and the population receiving the dose, is meaningless. Furthermore, since the releases of radioactivity come from essentially point sources, even calculating an "average" dose is risky because of the non-uniformity of the dose. This is illustrative in Table 4.2.5.5, where the magnitude of the dose decreases by a factor of 10 between 1 and 4 miles from the release point, another factor of 10 between 4 and 20 miles, and a factor of 4 between 20 and 50 miles, for a total drop of a factor of 400. No average can meaningfully convey this range of variation in data, unless the extremes in the data are specified. The situation is not clarified by inventing a unit as the "man-rem" to further hide any useful information. Of course, it is quite possible that the man-rem unit is used with the intent of confusing data and the reader."

Response:

Actually, the man-rem dose has much more significance than you attribute to it. It is derived by taking into consideration the exposed population and the individual doses as a function of distance from the source. The methodology involved is outlined in Appendix 4.I of the Draft Statement. It gets around the difficulty you point out in dealing with a range of data by deriving a number representative of the radiation dose accumulated by the exposed population (usually taken to be those living within a 50 mile radius of the source). The population man-rem dose is, in fact, used to estimate potential health effects among the exposed population and, thereby, probably constitutes the most useful information displayed.

2. Comment (pp. 1, 2):

"...we must be able to show we have enough resources in the U.S. for our foreseeable needs. This has not been done with uranium."

Response:

With the timely development of the LMFBR the current estimated resources of low-cost uranium will be adequate for several centuries. Estimates of uranium resources and projected uranium utilization for several power system scenarios are given in Sections 6A.1.1.2 and 11.2.

3. Comment (p. 2):

"[The AEC reactor licensing] process cannot be relied upon to approve and authorize safe, reliable nuclear power plants."

Response:

As stated and explained in Section 4.2.1 of the Final Statement: "AEC regulations require that peaceful uses of atomic energy not result in undue risk to the health and safety of the public." The AEC regulatory procedure requires compliance with a comprehensive set of rules of procedure safety criteria, codes and standards prior to construction, during operating and at decommissioning. Full public participation is afforded at public hearings. Obviously, no system can absolutely guarantee the public health and safety, but the AEC regulatory process represents a most thorough and conscientious striving toward that goal.

4. Comment (pp. 2-3):

"Table 4.2.3.1 is very evasive as to hard data on LMFBR plants, for reasons explained. Is the reader to supply the same uncertainties in this Table to all other data, including projections, in the Draft Statement?" "Not even the breeding ratio is accurately given, and the 'doubling time' is conveniently left out."

Response:

A complete discussion of all reactor characteristics and fuel cycle costs in the cost-benefit analysis is included in Section 11.2.3 of both the Draft and Final Statements. The discussion of projected LMFBR breeding performance has been expanded in the Final Statement in Appendix A of Section 11.

5. Comment

(p. 3)

Section 4.2.5.2.1 on thermal wastes ignores the strong likelihood of "nuclear parks" coming into existence, with 10 to 40 nuclear power plants clustered in a relatively small area and the effect of their combined thermal releases on the local biota and local climate. The report itself ignores the impact of the anticipated LMFBR (and LWR) thermal releases on the climate of the Nation by the year 2020."

(p. 4)

"Section 4.2.5.4 does not elaborate on the climate effect of the released heat due to the program plan."

Response:

The Draft Statement referenced the potentially serious problem of meso-scale weather modification from energy parks as follows:

1. W. C. Ackermann, Ref. 79 of Section 4.2.
2. Hanna & Swisher, Ref. 81 of Section 4.2.
3. Carson, Ref. 67 of Section 4.2.
4. J. E. Carson, "Meteorological Consequences of Thermal Discharges from Nuclear Power Plants - Research Needs," Cooling Tower Environment - 1974, AEC Critical Review Series (1974).

Such "Heat Island" effects could be generated by a large group of steam-electric plants using any heat source. Before such energy parks are created, the AEC would analyze the potential for large-scale weather modifications from such large heat sources.

6. Comment (pp. 3, 4):

"Section 4.2.5.3, while not having the benefit of accurate data on the actual plant design, purports to accurately predict the fission product release rate from the reactor, and hence, its dose to man. If indeed, the AEC can accurately predict what comes out of a plant when they are not too sure what goes in and what its design details are, then the abilities of this organization are truly phenomenal."

Response:

The AEC estimates for release rates are based on the plant radwaste system described on pages 4.2-46 to 4.2-65 of the Draft Statement. The estimates, not predictions, were made on the best available information to provide a basis for evaluating environmental effects. They are not very different from comparably equipped LWRs (see Table 9.1-6 in the Final Statement).

7. Comment (p. 4):

"Section 4.2.6.3 on the radiation monitoring program must be revised in the context of the past performance of the AEC." "Reliance on isolated radiation detectors and on calculations carefully avoids the possibility that other than the desired answers will be obtained."

Response:

LMFBR monitoring programs will be based on current LWR programs described in Section 4.2.6.3 and on future programs, as they develop. Monitoring programs will be consistent with the regulatory concept of maintaining public exposure at levels as low as practicable. Radioactivity releases may be so low that limits of detection will preclude their observation in the environment. Therefore estimates of population exposure may depend on source term measurements and environmental models.

8. Comment (p. 5):

"The words of the last quoted paragraph [p. 4.2-158 of the DES] sound soothing, as they are supposed to, but as the LWR program approaches maturity (or is said to approach it) the AEC still has not furnished experimental data to show that the 10 CFR 100 criteria can be met. There still is no definitive, proof that the ECCS will perform their designed tasks. For a 1 in a million chance for a plant to have an accident exceeding the guidelines, the odds are that it is 1 in 1000 for 1000 plants operating, and 1 in 25 over their 40 year lifetime. A 1 in 25 chance for a serious accident is inordinately close to a certainty that a serious accident will occur. The only remaining questions are when, where, and how bad? Will the LMFBR's have back-up safety systems as good as the ECCS?"

Response:

On page 4.2-158 it is clearly stated that "accidents not included in the design basis envelope should have an average recurrence interval of at least a thousand years for all nuclear plants combined" (emphasis added) and "the regulatory staff uses the safety objective that the risk to the public from all reactor accidents should be very small compared to other risks of life such as disease or natural catastrophes." Once in a thousand years is not in the AEC's view "inordinately close to a certainty that a serious accident will happen."

As indicated in 4.2.7.3 and 4.2.7.5, reliable and dependable protective systems will be employed.

9. Comment (p. 6, 7):

Comments were offered on Section 4.2.7.3, indicating insufficient treatment of safety issues. Examples "Why is a discussion of core meltdown or disassembly not thoroughly discussed?"; "...little attention is paid to the possibility of flow blockage and subsequent overheating, as happened at Fermi."

Response:

Section 4.2.7.3 was intended only to point out a number of general features of the LMFBR as an aid in discussion of the significance of potential accidents treated in later sections. However, in recognition of the comments received, this section has been extensively revised and expanded. Specific safety issues are defined and discussed.

10. Comment (p. 6):

"While the concentration of fission products is higher in the LMFBR, as is the concentration of short-lived isotopes, it is not necessarily

the total amount of fission products that counts. If they are released to the environment, it is the biologically active ones which count, many are short-lived, and many are long-lived.

Response:

The total amount of critical ("biologically active" or important in terms of dose) radionuclides is indeed important. However, it should be noted that all fission products are biologically active to some extent. The important point to be considered is that the LMFBR has a potential for lower total radiation dose from its entire fuel cycle than other reactor concepts, as described in Section 9 of the Final Statement.

11. Comment (pp. 6,7):

"In reference to 'major power excursions' as they are called, are the 'initial temperature coefficients' sufficiently negative to prevent a core meltdown? Would the Doppler broadening of neutron capture cross sections due to a temperature rise be sufficient to prevent a 'power excursion,' 'core disassembly,' or 'core rearrangement'? Why is a discussion of core meltdown or disassembly not thoroughly discussed?

Response:

These topics are discussed in Section 4.2.7.7 of the Draft and Final Statements.

12. Comment (p. 7):

"Section 4.2.7.7 contains a very superficial discussion of serious accidents where a deep and thorough one is needed. No mention of time scales, or sequences of possible events is made. No mention is made of the possible events leading to a breaching of the containment and the consequences thereof."

Response:

This section has been extensively revised. For reasons cited in Section 4.2.7, it is judged that events leading to a breaching of the containment are extremely remote in possibility and the risks of such events considered so low as to warrant their omission in the Final Statement.

13. Comment (p. 7):

"As the tempo of terrorist actions continues to rise throughout the U.S., and the world, it is not comforting to realize that the AEC is continuing to ignore the possibility that a terrorist, or band of terrorists may turn their attention to the exceedingly vulnerable segments in the nuclear fuel cycle."

Response:

The AEC safeguards program recognizes the potential for attempted terrorist activities as described in Section 7.4.3 of the Final Statement.

14. Comment (p. 7):

"Why will recovered uranium not be recycled to LMFBR reactors?"

Response:

Uranium recovered from reprocessing of spent fuels can of course be used for fueling of LMFBRs. Any residual radiation level in the uranium will be so slight that fuel fabrication processes or costs will not be affected. However, today there are about 250,000 tons of depleted uranium in storage as a byproduct of uranium enrichment operations. This stockpile is projected to increase severalfold during the rest of this century, even with rapid introduction of the LMFBR. There appears to be a slight economic advantage to using enrichment plant tails stockpile; it is stored as the fluoride, which is more simply converted into fuel-grade dioxide. Thus, it appears likely that the diffusion plant tails stockpile will be largely depleted before uranium from a reprocessing plant is used on a large scale for LMFBR fuel. Eventually, of course, all uranium recovered at reprocessing plants will be recycled.

15. Comment (p. 8):

"Figure 4.5.1 is similar to Figure A.16 of WASH-1099. But some of the losses of the WASH report have conveniently been changed to "disposal."

Response:

"Loss" and "disposal" flows both represent losses from the fuel cycle, in the sense that the material is not recycled.

16. Comment (p. 8):

"The assumption is made that the general population, or resident population, is 100 ft. or more from rad-waste containers." "Perhaps 15 ft. would be a more reasonable cut-off."

Response:

This assumption of 100 feet is not thought to be unreasonable. As noted on page II. I-12 of Appendix I to Volume II of the Final Statement, doses to onlookers (people located closer than 100 ft. to the containers) were also included.

17. Comment (p. 9):

"With stable societies historically lasting for a few hundred years, at the most, a couple of thousand, and geological upheavals and climatic changes taking place in the 5000 year to 1,000,000 year time

scale, it seems completely ridiculous and insane to commit society to a course of action which must be maintained for this kind of time scale."

Response:

The near-term waste management program adopted by the AEC for high-level waste calls for safekeeping for as long as necessary pending the development of more permanent disposal methods. A development program on disposal in certain types of geological formations is going forward, which would reduce surveillance and maintenance requirements to essentially negligible proportions.

18. Comment (p. 10):

"Perhaps the projected profits, due to introduction of the breeder, should be compared with the hypothetical benefits, to be accrued by the public."

Response:

Utility profits are regulated by government agencies. Changes in power generating costs have traditionally been passed on to customers in the form of altered electric energy rates.

19. Comment (p. 10):

"Section 5.3.1.1 contains projected economic requirements of the utility industry. No mention is made of the effect of these needs on the rest of the borrowing community, nor is mention made of the requirements of the industry after the year 2000."

Response:

Values for 2020 were shown in Table 5.3-1 of the Draft Statement. The LMFBR does not dramatically influence total utility industry financial requirements for plant purchases. The LMFBR does allow decreased capital expenditures for mining, milling and enrichment facilities.

20. Comment (p. 10):

"Whether or not the utilities and their managers can grasp the complexities of LWRs remains to be seen, yet it is said the industry is approaching [maturity]. The operation by these same people of LMFBRs is disquieting."

Response:

Safe reactor operation is assured by AEC regulatory procedures; it is not a matter of conjecture. Utilities have established a satisfactory operating history.

21. Comment (p. 12):

"Applying standards with the sole intent of making reactors safe would price them out of the market."

Response:

LWR safety standards have not eliminated LWRs as viable, competitive steam generating plants. Application of LMFBR safety standards are not expected to significantly impact LMFBR viability.

22. Comment (p. 12):

"No substantive showing has been made as to what are the Nation's energy requirements. Many projections have been made by those who stand to gain financially by the achievement of the projections, and these have been echoed by the government agency involved, but these are only projections. Perhaps they should be made independently of the energy industry and the energy agency."

Response:

Energy projections used in the Final Statement are defined in Section 11.2.3 and compared to other energy projections. The range of energy predictions in the Final Statement has been expanded to include a 50% decrease from the base projection. Most of the sources referenced in Section 11 would not gain financially by the achievement of a projection.

23. Comment (p. 12):

"If the radioactive waste problem is 'readily tractable,' why does it remain unsolved?"

Response:

The near term waste management program that has been adopted by the AEC for high-level waste calls for retrievable surface storage for safekeeping as long as desired. This is a solution to the near-term waste storage problem. However, having a near-term solution does not exclude searching for potentially better solutions for ultimate disposal. A development program on disposal in geological formations is going forward, which would lessen surveillance and maintenance requirements.

24. Comment (p. 13):

"Who insures the discharge system will be well designed?" "And who determines what level of damage to the 'aquatic' environment are ecologically acceptable?"

Response:

Each plant constructed must comply with NEPA, Federal, state, and local regulations and be subject to review by AEC regulatory procedures.

25. Comment:

(p. 13)

"It seems incredible that underground [siting] can be passed off because the technology does not exist to go from an 80 foot cavern to a 140 foot cavern. This is little less than a factor of 2 in linear dimension."

(p. 13, 14)

"The argument used that seals, etc., needed for underground siting have not been demonstrated over a long term is rather interesting." "It should also be noted that the adequacy of long term above-ground siting leaves much to be desired, and that many seals leak."

Response:

Section 7.2.6.5 in the Final Statement (formerly 7.2.6.2 in the Draft Statement) examines the pros and cons of underground siting as a means of mitigating adverse environmental impacts. The concept is not "passed-off". Section 7.2.6.5 concludes that "...it is difficult to foresee whether the net effect at underground siting would be of greater or lesser environmental impact, as compared with surface siting."

26. Comment (p. 14):

"... the glowing words of praise for the rigid AEC rules, regulations, and inspections must be viewed in the light of the GAO report 'Improvements Needed in the Program for the Protection of Special Nuclear Material', B-164105, Nov. 7, 1973. Numerous very serious deficiencies in the AEC rules and inspections were found."

Response:

The GAO report mentioned in this comment was discussed in the Draft Statement (page III-A-4), and is discussed in more detail in the Final Statement (Appendix IV.A).

27. Comment (p. 15):

"... reports that a few hundred kilograms of U-235 have already shown up missing at just one reprocessing plant (in Apollo, Pa.) are disconcerting. Some discussion of part accountabilities and penalties for failures would be appropriate."

Response:

This is apparently a reference to an incident widely reported in 1965 involving a difference between the bookkeeping account and the physical inventory of about 100 kgs. The technical term for the book-physical inventory difference is "material-unaccounted-for" or MUF.

Because the quantity of nuclear materials cannot be measured exactly, a difference between the book and physical inventories is expected to occur, and accordingly, a non-zero MUF is a normal occurrence. In addition to measurement errors, MUF can also result from the physical inventory not reflecting quantities of material adhering to process equipment, or from other unmeasured losses of theft.

The MUF at the Apollo, Pennsylvania plant was generated during the period from plant start-up in 1957 to 1965. It was identified as a result of an AEC inspection of the facility during a period of low inventory. The AEC concluded that the MUF resulted from underestimated quantities in discards and burials and hold-up in process equipment, piping, filters, etc.

When observing a particular MUF value, the basic question arises, "is this a reasonable value, or is a potential problem situation reflected which justifies investigation?" The answer to this question could be based on an intuitive professional judgment without any formal evaluation. The answer could also be based on comparison with past experience. This can be accomplished, in some instances, by using control charts maintained on the basis of an assumption that past experience is an acceptable basis for comparison, i.e., the past is considered to be "in control". The most rigorous approach to answering the question is by evaluating the MUF in the context of the statistical propagation of the uncertainties associated with the measurements of the quantities which affect the material balance. The underlying rationale of this approach is that if MUF exceeds what can reasonably be expected to result from measurement uncertainties, an investigation as to the causes is warranted. The total uncertainty which is used as the basis of comparison is referred to as the "limits of error of MUF" (LEMUF).

AEC amendments to the Code of Federal Regulations now provide criteria for periodic physical inventory taking and statistical MUF evaluation that will prevent the accounting practices that permit large MUF to go undetected or unevaluated for extended periods.

28. Comment (p. 16):

"Since the dividing line between the credible and incredible accidents is arbitrary, it might be illuminating to know the difference between a 'credible' threat and an 'incredible' threat."

Response:

As used in the Environmental Statement, a 'credible threat' is meant to be one whose likelihood of occurrence is evident or substantial, and an 'incredible threat' is one whose likelihood of occurrence is negligible. In both cases, professional judgment is used in arriving at the assessment of credibility, taking into account the difficulties faced by an adversary in bringing a particular threat to full realization, and other factors. Section 7.4.5.2.1 of the Final Statement illustrates the reasoning process involved in the discussion of nuclear bomb sabotage of a nuclear facility. As stated in that section, the AEC recognizes an obligation to continue to examine the factors which enter into these judgments of credibility, and that present judgments may change in the future.

29. Comment (p. 17):

"No explanation is given why all of a sudden no new plants are built after the year 2020."

Response:

The year 2020 is the study cut-off date.

28. Comment (pp. 17, 18):

Several comments point out the use of more than one capacity factor used in the Draft Statement, Chapters 4, 9 and 10.

Response:

Capacity factors for LMFBR plants will probably follow a curve similar to the "Base Loaded Plant" curve in Figure 11.2-36 of the Final Statement. The cost/benefit analysis uses the curve shown as described in Section 11.2.3. The capacity factor is not constant over the life of a plant. The use of capacity factors in the range of 70% - 80% does not significantly alter the calculations specifically referenced in the comments.

30. Comment (p. 18):

"Table 10.3 successfully muddles data to hide the portion of the U. S. production that is committed to breeder (and LWR) construction. It also hides the dependence of the U. S. on foreign materials production."

Response:

Table 10.3 in the Draft Statement shows the relationship of LMFBR material requirements to the annual world and U. S. consumption of elemental materials.

31. Comment (pp. 17-21):

"[The negative benefit for the LMFBR strongly suggests that the breeder, as laid out in the Draft Statement will be a financial failure." This conclusion is based on estimates of increased costs due to operation of LMFBRs at 70% capacity factor rather than 80%.

Response:

There is no reason to expect LWR or LMFBR plant factors to be lower than large fossil plants. Current experience indicates that the availability of LWRs is comparable to that of large coal-fired plants, although not as good as the expected 80% plant factor. The availability of LWRs is expected to improve with experience and with further implementation of stringent quality assurance programs. Similarly, we are confident that careful design and thorough quality control will lead to LMFBR plants which will operate at high plant factors.

The "extra cost" associated with low plant factor is properly computed by the "replacement energy" cost. About half of the sales price of electricity is contributed by costs of transmission and distribution, meter reading, etc. Further, only part of the generation plant cost is sensitive to plant factor. Today, replacement energy costs typically fall in the range 5-10 mills/kwhr (0.5 - 1 cent/kwhr). (All costs in the cost-benefit analysis are in constant, mid-1974 dollars. Costs are computed using the capacity factor for curves described in Section 11.2.3).

Therefore, if a power plant experienced a plant factor of 70% instead of 80%, replacement energy purchased at 1 cent/kwhr would reduce revenues by \$8.7 million at most, not \$26 million. Furthermore, the LMFBR cannot logically be expected to operate at a lower plant factor than the LWR or fossil-fueled plant. Thus, the benefit, the difference between power cost with and without the LMFBR, would not be drastically reduced by the plant factor reduction assumed above.

32. Comment (pp. 21-23):

"Pages 11.2-20 and 21. For reasons outlined above, most of these conclusions are imaginary and will undoubtedly never be realized.

The unquantifiable benefits on p. 11.2-21 are equally fanciful."

Below are comments numbered to coincide with this page.

1. Our resources are scanty, but racing to drag them out of the ground will not justify efficient use.

2. Is it necessary that a premium market be established for plutonium from LWRs? Is it necessary to the economics of LWRs that plutonium be purchased at a premium price?
4. That the "virtually limitless supply of economical electricity" will really be economical has yet to be established. There are good reasons for serious doubts.
5. Same as above (4).
6. In reality, coal combustion will grow even with the LMFBR, as shown in Figures 9.1-2, 9.1-3. This statement, without considerable qualification and explanation, must be considered false.
7. Could not all these facilities be put to more humane uses than just grinding out moneymaking machines to overcharge the poor and undercharge the industries for their energy?
8. It has yet to be shown that any commodity offered at an economical price encourages thrift and conservation. Quite the opposite is observed.
9. The massive increase in energy usage will drain the underdeveloped countries, among others, of their resources, which will aggravate world tensions. The large scale U.S. usage means those resources will not be available to poorer countries because the U.S. can pay premium prices with minor disruptions, while poor countries cannot pay premium prices for raw materials without major economic complications. It is the old story of the rich getting richer and the poor getting poorer. Industrial development is needed to a far less extent in many countries than food development. This statement in the Draft must be considered largely false."

Response:

The quantifiable conclusions follow from the results described in Section 11.2.4 based on the assumptions in Section 11.2.3.

The unquantifiable benefits are not as susceptible to numerical evaluation as the costs and benefits outlined in Section 11.2.3 of the Draft Statement. However, the potential benefits are identifiable with early introduction of the breeder. The Final Statement summarizes the unquantifiable benefits with the advantageous safety and environmental features of the breeder in to Section 11.2.

Responses to each of your comments on the "unquantifiable" benefits follows, under the numbering scheme used in your comments.

1. The efficient use of uranium resources referenced by the conclusion refers to the uranium use curve of the projected nuclear industry with the LMFBR available. As shown in the Final Statement, cumulative uranium use with the breeder is always less than without the breeder.
2. It is probably not necessary in terms of the economic viability of the LWR industry for the LWR produced plutonium to have a premium market. However, it can result in lower LWR fuel cycle costs.
4. "A virtually limitless supply of economical electricity" is a potential benefit resulting from deployment of the LMFBR. The potential for this benefit can be readily discerned from the results of the cost-benefit analysis.
6. All internal sources of energy are now and will be required in the near future to be utilized to the maximum extent possible within reasonable economic and environmental limits to reduce the impact on the balance of payments due to foreign oil purchases. However, if nuclear power with breeders is much more economic than fossil fueled power plants at a time when the nuclear industry is capable of providing the total electric power needs of the Nation, it is reasonable to expect that fossil power plants will be gradually phased out. This would not occur until after the turn of the century.
7. The facilities referenced are geared to produce LMFBR technology which has a potential to greatly reduce total electric power costs through 2020. LMFBR technology does not "overcharge the poor" or "undercharge the industries". Low power costs can selectively benefit low-income groups who not only spend a larger share of their income on energy but stand the most to gain from economically available electricity as a basic labor-saving resource.
8. If nuclear powered electric energy offers a lower cost alternative to fossil fuel produced energy, the fossil fuels can be conserved.
9. Point 9 in the Draft Statement noted the potential for international cooperation based on technology exchange and economic interaction. Industrial development in other countries does not imply development of industry which is unresponsive to their needs. The industry appropriate for a developing country may be production of agricultural equipment and fertilizer.

33. Comment (p. 23):

"Section 11.3 ignores the probability of a serious accident." "...the chance of a major accident is ... about 1/40 ..."

Response:

On page 4.2-158 of the Draft Statement it is clearly stated that "accidents not included in the design base envelope should have an average recurrence

interval of at least a thousand years for all nuclear plants combined" and "the regulatory staff uses the safety objective that the risk to the public from all reactor accidents should be very small compared to other risks of life such as disease or natural catastrophes."

34. Comment (p. 24):

"Section 11.4.1 totally ignores the questions fundamental to the whole energy problem. Who determines what the "future energy needs" are? Who are these decision makers primarily responsible to? What is the relationship (if any) between energy consumption and standard of living as opposed to standard of consumption or GNP?"

Response:

Elasticity of energy demand based on goals and policy is discussed in Section C of Chapter 8 in the Draft Statement. Chapter 11 of the Draft Statement discussed the projected economics of the LMFBR. Evaluation of the LMFBR economics includes a comparison of power cost savings with government R&D costs. The respective costs are predicated on a responsibility by the utility industry to supply energy at a rate consistent with historic trends. Responsible and prudent planning cannot be based on arbitrarily selected energy demand goals. Energy conservation as an alternative has not been ignored. Quite the contrary, energy conservation as a technical alternative and as an important variant in LMFBR incentive is discussed in the Final Statement. The Final Statement evaluates the environmental effects of the LMFBR as a viable option for electric energy generation. There is no intent to either exclude or understate the potential for reduced energy demand.

35. Comment (p. 25):

"A number of sweeping condemnations of solar energy are made without the benefit of references. No mention is made of wind powered generators or of sea-thermal power plants." "In addition, no case has been made for the necessity of large, central-station power facilities."

Response:

A detailed discussion of the potential of solar energy as an alternative technology option is contained in Section A.5 of Chapter 8 in the Draft Statement. Likewise, wind power, ocean thermal gradients, tidal energy and synthetic fuels are discussed in Section A.6. Evaluation of alternative technology options in Chapter 8 of the Draft Statement included considerations of potential contributions to small, decentralized energy needs (e.g. space heating and water heating).

36. Comment (p. 25):

"The [uranium] situation may be critical even before the breeder is scheduled for introduction." "[The LMFBR] also is dependent for initial charge of plutonium on LWRs. Few comments on the availability of plutonium from this source have been made."

Response:

The Draft Statement discussed projected uranium usage and plutonium production and usage for the conditions analyzed in the cost-benefit analysis in Sections 3.3.5 and 3.3.7 of Appendix III-B. As pointed out in the Draft Statement, cumulative mined uranium requirements are always reduced when the LMFBR is available. Requirements of plutonium for initial core loads of early LMFBRs can be met with plutonium produced by uranium-fueled LWRs. The Final Statement describes uranium and plutonium utilization in Section 11.2.4.

37. Comment (p. 26):

"The impression is given [in the first full paragraph on p. 11.4-23] that the country has little choice other than deploy thousands of yet unproven breeders."

Response:

The quoted paragraph states an incentive for continuing to consider the LMFBR as a viable electric energy generation option. The text cites the relative maturity of the LMFBR in comparison to the controlled thermonuclear reactor and concludes: "Thus, foreclosure or postponement of the breeder program while awaiting an alternative technology entails a considerable risk: the Nation could end up with neither breeder reactors nor an alternative source."

38. Comment (p. 26):

"That the AEC does not consider an attack [as an act of war] centered on nuclear facilities to be credible is appalling."

Response:

Section 7.4.4.1 in the Final Statement discusses the vulnerability of nuclear facilities to acts of war.

39. Comment (pp. 27. 28):

Effects of diminished and zero energy growth on LMFBR benefits should be considered.

Response:

The Draft Statement considered the effects of increased and decreased electric energy demand [$\pm 20\%$ in 2020] on the LMFBR benefits. In addition the Final Statement considers a case in which electric energy demand is decreased by 50%, in 2020, indicative of successful energy conservation measures. The Ford Foundation preliminary report, "Exploring Energy Choices," is explicitly referenced in Section 11.2.3.

40. Comment (p. 28):

"To say that nuclear and fossil fuels compete in the market is naive and ridiculous. It ignores the reality of the \$20 billion or so which the public has invested in fission research, it ignores the tremendous subsidy offered the nuclear industry by the Price-Anderson Act, and it ignores the growing monopoly of coal, petroleum, natural gas, geothermal, and uranium ore areas by the largest oil companies."

Response:

Nuclear and fossil fuels compete in the electric power generation market today. The competition was extended to the year 2020 by projecting future cost trends (in constant mid-1974 dollars) of both fossil and nuclear fuels and plants. Rising fossil fuel costs and limited natural gas supplies are increasing the competitive advantage of nuclear fuels. The costs utilized for fossil and uranium fuels are based upon estimates to recover the fuels irrespective of the industrial firm engaged in the recovery.

41. Comment (p. 29):

"This table [Table III-B-4.4] neatly summarizes the inexcusably low caliber of input data in the entire Draft Statement. Not only does this table ignore the reality of reactor cost escalations, which can and normally do double over the construction period, but it assumes initial costs which are lower by a considerable margin than today's estimated costs."

Response:

Alternative generating plant types are compared in the cost-benefit analysis on the basis of constant, mid-1974 dollars. In addition, all plant selection strategies over the lifetime of the study are compared on the basis of present worth value. As you indicate, construction costs in current dollars would increase for all plants as a function of time.

The mid-1974 capital costs in the Draft Statement are consistent with the raw data which you reference. The current dollar cost of an LWR in 1981 would be about \$560/kw comparable to your figure of \$550/kw for the Limerick Station. The cost is composed of \$420/kw in mid-1974 dollars

with an addition \$140/kw due to escalation during construction. Similarly, 1981 capital costs for an HTGR would be about \$560/kw. This is about 15% lower than the \$645/kw cost you quote for the Fulton Station.

However, the economies of scale between a 1160 MWe plant (Fulton) and the 1300 MWe plants (Draft Statement assumed capacity) would decrease the Fulton cost to about \$590/kwe. This is only 5% higher than the \$560/kwe implied by Table III-B.4-4.

Reduction of constant dollar capital costs due to the "learning curve" of a relatively new industry are explained fully in Section 11.2.4.2 where your comments are referenced.

42. Comment (p. 30):

"Interestingly, [Section A of Chapter 8] contains no mention of heavy-water moderated reactors, as the CANDU reactors of Canada."

Response:

As stated in The Perspectives section of Section 6 in the Final Statement, "...energy systems which may have application in other countries with different economic structures, and which have been considered but bypassed in the United States in favor of other energy production systems, are not discussed..." Please see the Perspectives section for further elaboration of this point.

43. Comment (p. 30):

"The possible benefits of the fusion process dwarf those imagined benefits of any form of the fission process, burner or breeder. Why not spend the money requested for the breeder on fusion?"

Response:

There is no guarantee that fusion will ever be a viable electric energy generation source, thus there is obviously no guarantee that fusion will be available in time to preclude the LMFBR. As stated previously, foreclosure of the LMFBR option based on the promise of early fusion development is not commensurate with responsible, prudent planning to meet the Nation's energy needs.

44. Comment (p. 31):

"For instance, the section [C.6 of Chapter 8] ignores the influence of utility company rate structures and promotional practices on consumption patterns. This thereby assumes that consuming patterns originate from a spontaneous demand with the public. This is an utter falsehood."

Response:

Section 11.2 of the Final Statement discusses the influence of rates on electric energy demand.