HEDL CONTRIBUTION TO SRL FUEL
RECYCLE PROGRAM:
QUARTERLY REPORT FOR JANUARY,
FEBRUARY, AND MARCH 1977

J. F. Fletcher
August 1977

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Hanford Engineering Development Laboratory

Operated by the
Westinghouse
Hanford Company

A Subsidiary of
Westinghouse Electric
Corporation

for the United States
Energy Research and
Development Administration
Contract No. EY-76-C-14-2170

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EP

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	iii
LIST OF TABLES	iii
INTRODUCTION	1
MANAGEMENT SUMMARY	2
ECONOMIC STUDIES - Category 2	4
Objective	4
Introduction	4
Accomplishments and Status	4
Future Work	6
SPENT FUEL RECEIPT AND STORAGE - Category 3	11
Objective	11
Introduction	11
Accomplishments and Status	11
Spent Fuel Storage: Fuel Failure Analysis	11
Definitions	11
Fuel Failure Rate	12
Impact of Radioactivity Release	20
Canning of Failed Fuel	20
Radioactivity Released by Failed Fuel	21
Radioactivity Cleanup	21
Plant Design Assumptions	21
Identification of Failed Fuel Types	22
Location of Occurrence of Failures	22
Survey of Actual Utility Practices	22
Future Work	23
References	23
FUEL MATERIALS PREPARATIONS - Category 7	24
Objective	24
Introduction	24
Accomplishments and Status	24
Future Work	24

Table of Contents (Cont'd)

	<u>Page</u>
TECHNOLOGY TO REDUCE THE GENERATION OF TRU WASTES WITHIN THE NUCLEAR FUEL CYCLE - Category 8	25
Objective	25
Introduction	25
Accomplishments and Status	25
Future Work	25
ENVIROMENTAL EFFECTS - Category 9	28
Objective	28
Introduction	28
Accomplishments and Status	28
Future Work	29

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Comparison of Fuel Failure Rate/Year with Fuel Failure Rate/Operating Reactor	13

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.	Fabrication Requirements By Year	7
2.	Fuel Fabrication Plant Size Sequence	8
3.	Assumptions Used for Input Variables for Base Case	8
4.	Yearly Fabrication Costs	9
5.	Fabrication Cost By Plant	10
6.	Levelized FABrication Cost for a System of Plants Over All Years	10
7.	Revised Summary of Fuel Failure Trends	14
8A.	Inventory of Discharged BWR Fuel Assemblies	16
8B.	Inventory of Discharged PWR Fuel Assemblies	17
9A.	Reported Failed BWR Fuel Assemblies	18
9B.	Reported Failed PWR Fuel Assemblies	19
10.	Sample Listings of Drinking Water Supply Data	30

INTRODUCTION

The Hanford Engineering Development Laboratory is participating in the LWR Fuel Cycle Research and Development Program being directed by the Savannah River Laboratory. HEDL is currently contributing in five categories of the program:

- Category 2 - Economic Studies
- Category 3 - Spent Fuel Receipt and Storage
- Category 7 - Finishing Processes
- Category 8 - Reduce Generation of TRU Waste
- Category 9 - Environmental Effects

This is the fourth in a series of quarterly reports summarizing the work being done at HEDL. Contributions in each of the above categories during January, February, and March, 1977, are included. A management summary and detailed status report are provided for each of the categories.

MANAGEMENT SUMMARY

LWR Category

Summary

2

A sensitivity analysis on LMFBR fabrication costs was performed using the FUELCO computer program. Increasing the plant life from 15 years, as used in the base reference case, to 40 years had a negligible effect on the fabrication cost. Similarly, decreasing the depreciation time and pay-back period had a very small effect upon the levelized cost of fabrication. However, changes in the method of financing the fabrication facilities, such as converting from a bond-equity mixture to all equity or increasing the rate of return on the equity investment, appear to have a major effect and significantly increase the cost of fabrication.

3

Study objectives were redefined at SRL request to concentrate on historical data on condition of LWR spent fuel. Initial analysis of published literature indicates an average rate of failure (expressed as the percentage of discharged assemblies which contain one or more failed pins) of 21% over the fourteen years from 1962 through 1975. Average failure rates were found to be 29% for BWR fuel assemblies and 4.6% for PWR assemblies. Failure rates have declined markedly from the early 1970's when hydriding was caused by the water content in sintered UO_2 pellets. Canning of failed fuel assemblies is apparently not required by transportation regulations. However, preliminary indications are that the utilities are planning to can essentially all failed assemblies.

MANAGEMENT SUMMARY - cont'd

LWR
Category

Summary

7

Activities of this program beyond the first quarter of FY-1977 have been redirected toward analysis and advisory services. A review of the Preliminary Technical Data Summary was completed.

8

A Purchase Order has been issued to procure a low energy gamma assay system for use in monitoring alpha contaminated wastes at an industrial site. A cooperative Industrial/HEDL program for reduction of generated waste volumes by application of improved processing and waste assay techniques is in formulative status.

9

A modified version of the waste transport code WTRAN was developed and tested; this version provides analytical capability for 1600 grid areas (or 1600 irregular areas). Screening and evaluation of water supply data for Georgia and South Carolina continued.

LWR FUEL RECYCLE PROGRAM

ECONOMIC STUDIES - Category 2

J. F. Fletcher/E. M. Greene

Objective

To develop cost data on alternative means of closing the LWR fuel cycle. Data will be developed relating fuel fabrication, fuel reprocessing, and other pertinent steps in the fuel cycle.

Introduction

The objective of this study is to develop economic data relating to the fabrication step in the nuclear fuel cycle. Special attention will be given to effects of fabrication costs on the LWR fuel cycle for the incorporation into a fuel reprocessing conceptual design study. Fuel fabrication costs, including capital costs, will be calculated for construction of fabrication facilities for LWR UO_2 , LWR mixed oxide, and LMFBR fuels. This evaluation of fabrication economics is an essential tool in decisions concerning policy of fuel cycle development.

Accomplishments and Status - J. F. Fletcher, E. M. Greene

A sensitivity study was performed for LMFBR fuel fabrication costs using the computer program FUELCO. The code is applied to a reactor system in which the number of reactors varies with time affecting the need and throughput of fabrication facilities scheduled. By simulating a growth pattern for the fabrication facilities in a nuclear industry, it is possible to calculate the unit fabrication costs as a function of time. The program requires as input a series of cost constants and a complete schedule of fuel throughputs as a function of time. The cost equations associated with the cost constants describe the capital, operating, and hardware costs of an individual fabrication plant for mixed oxide LMFBR fuel.

Once FUELCO determines the fabrication plant sizes and associated fuel throughputs, the program uses the cost equations to calculate the capital, operating, and hardware costs for each fabrication plant constructed. By

using assumed rates of return and values for other economic parameters, the program calculates the levelized cost for each fabrication plant. The levelized cost is that constant price that the fabrication plant would need to charge if it is to recover its investment in the assumed time and with the assumed rate of return. The costs of the individual fabrication plants are then smeared, in order to determine a curve of fuel fabrication costs as a function of time that applies to the entire LMFBR fuel fabrication industry. Though the levelized unit costs of the various fabrication plants differ and the plant lifetimes overlap, the program establishes a curve by assuming that at a given time there is only a single fabrication cost for the LMFBR fuel. The cost smearing calculation is based on the premise that the overall return on investment for a given plant type will equal a specified rate but that individual plants may earn more or less depending on their positions in the price curve.

Fuel demand schedules for mixed oxide LMFBR cores up to the year 2000 had been prepared by the USERDA. The fuel demand schedules used in the reference case are shown in Table 1. The fabrication plant size sequence involves plants producing as much as 0.5, 1, 2, and 5 MT/day of mixed oxide and the sequence is shown in Table 2. Values for other variables required as input to FUELCO are shown in Table 3. These are the values used in the base case.

For the sensitivity analysis, six cases were investigated in order to determine the effect of the economic variables used in the base case. These six cases are listed below:

- Case 1: Increase equity rate of return to 25% from 16%.
- Case 2: Extend plant life to 40 years from 15 years.
- Case 3: Depreciation over 16 years with 40 year plant life.
- Case 4: Add 15% profit margin - no profit was assumed in base case.
- Case 6: Increase rate of return to 100% equity at 25%.

In order to meet the fabrication requirements as shown in Table 1, the FUELCO program scheduled 12 plants. The code calculates a fabrication

cost for each year of operation of each plant for a total of 29 years. Table 4 shows the yearly fabrication costs for each of the 29 years for each of the six cases analyzed as well as the base case. For each year, the costs are levelized over each plant that is in operation during that year. In Table 5, the fabrication costs are levelized over the 29 year period for each plant. The fabrication costs are shown for each plant for the six cases in the sensitivity analysis as well as the base case. For those cases involving 40-year plant lives, the very low throughput that occurs in the later plants results in high fabrication costs. For these cases the fabrication cost decreases in the early plants, but increases in the later plants due to the decrease in throughput.

The overall fabrication cost for each of the cases, levelized over all 29 years and over all plants in the system are summarized in Table 6. The fabrication cost increases only slightly for those cases involving changes in the plant life, Cases 2, 3, and 5. Case 4 which incorporated a 15% profit margin increased the fabrication cost by 15%. The fabrication cost increased significantly for those cases involving increases in the rate of return, Cases 1 and 6. Increasing the rate of return to 100% equity at 25% over the base case to 70% equity at 16%, increased the levelized fabrication cost from \$382/kg to \$507/kg. Thus, it can be concluded that the financial arrangement of the fabrication facility has a significant effect on the fabrication cost which would be charged.

Future Work

Capital cost requirements for fuel fabrication facilities will be analyzed, and the potential for capital cost savings from co-location of fuel cycle facilities will be investigated.

TABLE 1
LMFBR FABRICATION REQUIREMENTS, METRIC TONS/YEAR

<u>Year</u>	<u>Metric Tons/Year</u>
1992	42
1993	14
1994	75
1995	114
1996	137
1997	175
1998	215
1999	230
2000	280
2001	465
2002	779
2003	1040
2004	1302
2005	1564
2006	1825
2007	2087
2008	2349
2009	2611
2010	2872
2011	3205
2012	3538
2013	3871
2014	4204
2015	4538
2016	4871
2017	5204
2018	5537
2019	5870
2020	6203

TABLE 2

FUEL FABRICATION PLANT SIZE SEQUENCE

<u>Given Plant To Be Operated</u>	<u>Plant Size MT/Day @ 100% CF</u>
First Plant	0.5
Second Plant	0.5
Third Plant	1
Fourth Plant	1
Fifth Plant	2
Sixth Plant	2
Seventh Plant (and each succeeding plant)	5

TABLE 3

ASSUMPTIONS USED FOR INPUT VARIABLES
FOR BASE CASE

<u>Variable</u>	<u>Assumed Value</u>
Equity Rate of Return	16%
Bond Rate of Return	9%
Equity Fraction	0.7
Plant Life	15 years
Depreciation	15 years
Capacity Factor	75%

TABLE 4
YEARLY FABRICATION COSTS/\$KG

Year	Case						
	Base	1	2	3	4	5	6
1992	584	691	569	566	672	594	805
1993	569	673	557	554	654	581	784
1994	558	660	548	545	641	571	769
1995	546	646	539	536	628	562	752
1996	535	632	529	526	615	552	736
1997	524	618	521	518	602	543	719
1998	516	608	514	511	593	536	707
1999	499	588	509	506	574	530	683
2000	483	567	505	502	555	526	658
2001	463	544	493	490	533	514	630
2002	446	522	481	479	513	501	604
2003	429	501	466	463	493	485	578
2004	415	483	454	451	477	472	555
2005	404	469	442	440	465	460	539
2006	397	460	430	428	456	447	528
2007	388	449	419	217	446	436	515
2008	379	438	411	409	436	427	502
2009	371	428	405	403	426	420	489
2010	364	420	400	398	419	415	480
2011	358	413	393	391	412	408	471
2012	352	406	386	384	405	400	463
2013	346	399	378	376	398	392	455
2014	342	394	372	370	394	386	450
2015	338	389	368	366	388	381	443
2016	333	383	363	361	383	376	436
2017	329	377	360	358	378	373	429
2018	325	373	357	355	374	370	424
2019	323	370	355	353	371	368	421
2020	321	368	353	352	370	367	418

TABLE 5
FABRICATION COST, \$/KG, BY PLANT

Plant	Case						
	Base	1	2	3	4	5	6
1	531	628	518	515	611	540	732
2	496	583	492	490	571	513	676
3	415	484	415	412	477	431	557
4	379	437	384	382	436	398	498
5	349	401	353	351	401	365	457
6	351	404	357	355	404	370	460
7	333	383	348	347	383	361	436
8	339	391	347	345	389	359	446
9	317	363	370	368	365	384	412
10	328	376	475	472	377	495	429
11	324	370	600	596	373	627	419
(12)	(617)	(730)	(773)	(778)	(710)	(810)	(850)

TABLE 6
LEVELIZED FABRICATION COST
FOR A SYSTEM OF PLANTS OVER ALL YEARS

<u>Case</u>	<u>Levelized Fab. Cost, \$/Kg</u>
Base	382
1. Equity Rate of Return 25%	442
2. 40 Year Plant Life	397
3. Depreciation Over 16 Years	395
4. 15% Profit	439
5. Payback Period 10 Years	413
6. 100% Equity at 25%	507

SPENT FUEL RECEIPT AND STORAGE - Category 3

J. F. Fletcher/L. D. Jacobson, C. W. Funk

Objective

To evaluate historical data on the incidence and characteristics of failures of LWR fuel, and to determine the effect of failed fuel on the design of receiving facilities at an LWR fuel reprocessing plant. This program has been redirected from the tasks reported in the last quarterly report.

Introduction

The assimilation of data on failed LWR fuel from available literature, started earlier, continued throughout the quarter and was intensified to meet new schedules for task completion. A nationwide survey of utilities, spent fuel storage facilities, and vendors of LWRs and of LWR fuels was started during the quarter to augment those data and to obtain information on actual practices of utilities and storage facility operators as regards failed fuel.

Accomplishments and Status

Spent Fuel Storage: Fuel Failure Analysis - C. W. Funk

Definitions

"Fuel rod" consists of a single cladding tube loaded with solid ceramic fuel pellets. The term is synonymous with fuel pins.

"Fuel assembly" is a package of fuel rods (49 to 225 rods per assembly). The term is synonymous with fuel element.

"Leaker" type failures release fission gas but do not release solid fuel. The failure mode is usually the result of wet fuel reacting with Zircaloy cladding to form hydriding pustules penetrating the cladding. This failure mode usually releases a pulse of fission gas followed by decay of gas release and possible self sealing.

"Breached" type failures are defined in this report as those more gross than leakers, implying rupture of cladding and spillage of solid fuel.

"Failed" Fuel for the purpose of this report is limited to leaker and breached type failure that release radioactivity and/or transuranic material. Fuel that malfunctioned from mechanical or chemical causes that have not resulted in release of radioactivity are specifically excluded from the "Failed" fuel definition.

"Failure Rate" of spent fuel is the percentage ratio of failed assemblies (including both breached and leakers) to the annual inventory of discharged fuel assemblies in a given calendar year.

Fuel Failure Rate

The fluctuation of failure rate is shown in Figure 1a during the history of LWR Commercial Power Operation. The maximum failure rate peak of 86% in 1973 is the result of the low number, 586, of discharged fuel assemblies and high number, 505, of failures in BRW's as shown in Table 7. The 1973 peak also coincides with the clad-fuel interaction discussed in the Failure Mode Section. The secondary peak of 50% fuel failure rate in 1970, see Figure 1a, corresponds to a dramatic increase of given new plants coming on line in addition to the six operating in 1969. This peak corresponds to a period when problems of fuel design and fabrication were encountered and more severe thermal shock conditions occurred because of frequent scrams. An overview suggests an average fuel failure rate of 21% (29% for BWR fuel, 4.6% for PWR fuel) over the 14 years from 1962 through 1975.

These failure rates, based on the number of fuel assemblies containing failed rods or pins, are considerably larger than the frequently quoted fuel failure rates of 0.01 to 0.06%^(1,2) for rods or pins. Fuel failure accountability on the fuel assembly basis includes a large number of intact rods in the "failed" category; at the most a fuel assembly containing from 49 to 225 rods may have 2 or 3 rods which have actually failed.

The failure analysis was conducted on the basis of fuel assemblies for several reasons: 1) Cask line unloading operations at the reprocessing plant would be accomplished with fuel assembly size packages--presuming no disassembly at reactor sites; 2) fuel failure in the literature is available as fuel assemblies for BWR's and rods for PWR's. PWR rod data are more

Figure 1b
FUEL ASSEMBLY
FAILURE RATE
PER OPERATING
REACTOR YEAR

Figure 1a
FUEL ASSEMBLY
FAILURE RATE
PER YEAR FOR
BWR & PWR

FIGURE 1. Comparison of Fuel Failure Rate/Year with Fuel Failure Rate/Operating Reactor

TABLE 7

REVISED SUMMARY OF FUEL FAILURE TRENDS

Calendar Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	Overall
Operating Reactor	2	2	2	6	6	6	6	6	11	13	15	18	24	29		
Discharged Fuel Assemblies per Year																
BWR	190	0	116	293	99	206	213	196	111	422	881	340	840	1393		5300
PWR	76	76	76	156	36	40	36	76	180	64	245	246	361	787		2455
Total	266	76	192	449	135	246	249	272	291	486	1126	586	1201	2180		7755
Failed Fuel Assemblies per Year																
BWR	10	15	-	25	-	13	-	33	112	154	213	505	193	237		1510
PWR								4	32	-	31	2	43	2		114
Total	10	15	-	25	-	13	-	37	144	154	244	507	236	239		1624
Ratio Failed: Discharged F/A																
BWR	.053	-	-	.085	-	.063	-	.168	1.009	.365	.242	1.485	.230	.170	$\frac{1510}{5300} =$	.285
PWR								.053	.178	-	.127	.008	.119	.002	$\frac{114}{2455} =$	.046
Weighted Average	.038	.197	-	.056	-	.053	-	.136	.495	.317	.217	.865	.197	.110	$\frac{1624}{7755} =$	.209

easily converted to PWR fuel assembly equivalents than to converting BWR fuel assembly data to BWR rods that are not specifically identified as leaking or failed.

A more adequate failure rate estimate compensates for the number of reactors on line. The rate of failed fuel assemblies per year can be divided by the number of operating reactors to provide a future projection for additional plants coming on line as shown in Figure 1b. Examination of this trend should be limited to after 1969 when the statistics are improved by a larger number of reactors.

A second reason to exclude failed fuel prior to 1969 is that the major portion of this old spent fuel is reported⁽²⁾ to have been processed at West Valley and would not impact a future reprocessing plant.

The 1970-1973 peaks continue to be apparent but improved operations and fuel quality reduce the failure rate per operating year with two data points suggesting more confidence in post 1975 results of about <0.5% failed fuel assemblies per operating reactor.

Although data of 1976 failures and discharge rates could improve the confidence in this trend, lag time in publishing reactor experience has prevented these data from being incorporated at present. Extension of such data in 1976 may be justified if it cannot be established prior to report publication.

The sources of the above results can be traced from the plot of percent fuel failure rates in Figure 1 to the values in Table 7. These are derived from the discharged fuel inventory Table 8A BWR and Table 8B PWR, and failed fuel summary in Table 9A BWR and Table 9B PWR. The failed fuel summary has been extracted from reactor fuel experience.⁽³⁾

TABLE 8A

INVENTORY OF DISCHARGED BWR FUEL ASSEMBLIES

Reactor \ Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Dresden -1	190	0	96	200	0	96	96	96	0	96	0	96	0	96
Big Rock Pt.			20	20	20	30	42	38	23	30	30	32	32	32
Humboldt Bay				57	63	0	75	62	44	0	48	0	28	40
Pathfinder				16	16	80	0	0	0	0	0	0	0	0
Genoa									15	15	15	15	15	15
Dresden -2									29	215	509	0	144	0
Oyster Creek -1										49	136	49	49	40
Nine Mile Pt. -1										17	31	104	148	200
Millstone -1											112	0	115	115
Monticello												20	116	348
Dresden - 3												24	33	113
Quad Cities -1													140	140
Pilgrim -1													20	110
Quad Cities -2														144
Browns Ferry -1														0
Peach Bottom -2														0
Browns Ferry -2														0
Peach Bottom -3														
Yearly Total	190	0	116	293	99	206	213	196	111	422	881	340	840	1393
Cumulative Total	190	190	306	599	698	904	1117	1313	1424	1846	2727	3067	3907	5300

TABLE 8B

INVENTORY OF DISCHARGED SPENT PWR FUEL ASSEMBLIES

Reactor \ Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Yankee-Rowe	76	76	76	36	36	0	36	36	36	0	36	0	36	36
Indian Point				120	0	40	0	40	40	0	0	40	0	0
San Onofre -1									52	0	52	53	0	52
Conn. Yankee									52	52	52	52	0	52
Ginna -1										12	61	48	20	40
Pt. Beach -1											44	0	77	43
Robinson -2												53	52	52
Turkey Pt. -3													52	50
Surrey -1													33	0
Pt. Beach -2													48	0
Maine Yankee													43	217
Oconee -1														60
Vermont Yankee														100
Surry -2														33
Turkey Pt. -4														52
Indian Pt. -2														0
Palasades														0
Oconee -2														0
Prairie Is -1														0
Zion -1														0
Yearly Total	76	76	76	156	36	40	36	76	180	64	245	246	361	787
Cumulative Total	76	152	228	384	420	460	496	572	752	816	1061	1307	1668	2455

TABLE 9A

REPORTED FAILED BWR FUEL ASSEMBLIES

Reactor \ Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Dresden -1	10	15	-	25	-	13	-	33	28	41	49	28	-	-
Big Rock Point		-	-	-	-	-	-	-	-	-	-	-	-	-
Humboldt Bay				-	-	-	-	-	-	-	-	-	-	11
Pathfinder				-	-	-	-	-	-	-	-	-	-	-
Genoa									-	-	-	-	-	-
Dresden -2									84	41	2	-	-	-
Oyster Creek -1										44	58	80	-	-
Nine Mile Pt. -1										28	104	28	-	-
Millstone -1												232	-	-
Vermont Yankee												56	-	-
Monticello												81	160	-
Dresden -3													33	113
Quad Cities -1													-	-
Pilgrim -1													-	-
Quad Cities -2														113
Yearly Total	10	15	--	25	--	13	--	33	112	154	213	505	193	237
Cumulative Total	--	25	25	50	50	63	63	96	208	362	575	1080	1273	1510

*Failed = Released radioactivity (Breached Cladding and Fission Gas Leakers)

- = Reactor operating but no failures reported

TABLE 9B
REPORTED FAILED* PWR TYPE FUEL ASSEMBLIES

Reactor \ Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Yankee-Rowe	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indian Point				-	-	-	-	2	-	-	-	-	-	-
San Onofre -1	-	-	-	-	-	-	-	2	-	-	2	-	-	-
Conn Yankee								Few	-	-	-	-	-	-
Ginna -1									32	-	4	-	-	-
Pt. Beach -1											25	-	-	-
Robinson -2												-	-	-
Turkey Pt. -3												2	-	-
Surry -1													-	1
Pt. Beach -2													-	-
Maine Yankee													43	-
Oconee -1														1
Vermont Yankee														-
Surry -2														-
Turkey Pt. -4														-
Annual Total	-	-	-	-	-	-	-	4	32	-	31	2	43	2
Cumulative Total								4	36	-	67	69	112	114

*Failed = Released radioactivity (Breached Cladding and Fission Gas Leakers)

- = Reactor operating but no failures reported.

Impact of Radioactivity Release

Breached cladding failures are more significant in their impact on equipment decontamination requirements than leaker failures. Spilling of the fuel pellets would contribute to alpha contamination, which is smearable and requires more extensive decontamination procedures than fission product gas. Moreover, breached cladding failures can become enlarged during successive operations of the fuel cycle such as in-reactor irradiation, movement to and residence in reactor water storage pools, during cask loading and transportation and during interim water storage prior to digestion. In contrast, the radioactive contamination release from gas leakers becomes progressively less with successive stages of the fuel cycle, because of depletion of the finite gas quantities available in a rod, decay of the pin internal pressure and potential leak plugging by corrosion products. Because of the uncertainty of clad plugging, and the possible reopening of the original leak, contamination by leakers is not predictable enough to be relied on for control of additional contamination.

Canning

Transportation requires containment of any radioactivity within the shipping cask. This requirement has led to various interpretations of the guideline: 1) that canning will not be needed to contain leakers within the cask; 2) that canning of leakers may be required due to the economics of decontamination. This difference in interpretation needs to be resolved.

Canning presents some specific problems. Sealed cans require quality control on sealing integrity, sufficient weight to overcome any fuel buoyancy of gas containing cans in storage basins. Vented cans would not contribute to control of fission gas release in shipment casks. Canning also increases the bulk of fuel assemblies package shipments thereby increasing the number of cask shipments. HEDL estimates indicate this increase of bulk could double the number of shipments to accommodate leaking fuel assemblies.

The increase in shipping cost may justify alternatives: 1) throwaway of leakers or breached fuel would reduce decontamination operation costs as well as shipping costs; 2) disassembly of failed fuel rods from assemblies at reactor sites could reduce contamination of casks and lower the quantity of recoverable fissile isotopes lost to future power generation by application of throwaway approach to failed fuel. An economic study to compare costs of direct disposal or nonreuse storage of breached fuel assemblies or leakers could evaluate costs of shipping, decontamination and energy recovery, concern for canning.

Radioactivity Released by Failed Fuel

The amounts of radioactivity released in storage and transport is the most significant issue. Although data may exist it is not well documented. Alternative sources apparently will have to be investigated to derive tangible values. The occasional cases reported in the survey are handicapped by sampling of the large masses of water in the storage pools, and the diminished motivation to identify problems that do not directly affect power production of the commercial reactor.

Radioactive Cleanup

The magnitude of cleanup operations is naturally dependent on the quantities of radioactivity released. Since this basic data has not yet been identified in the literature survey no comments can be made at this time. Solution of the problem is limited to reiteration of verbal procedures that have been and will be discussed by phone and visits to utilities and fuel vendors.

Plant Design Assumptions

The validity of current assumptions can be partially addressed. The assumption that 1% of the fuel assemblies will be failed would be deficient by a factor of 20 on an overall basis. However, the trend in 1975 suggests that only 11% of fuel assemblies will fail. It would be important to apply 1976 data to extend this trend.

The assumption that 1% of the failure assemblies have breached cladding will require segregation of breached cladding data from fission gas type leaker data. The segregation of failure data has not been accomplished.

The assumption that 1% of the contents of a ruptured rod will be discharged has not yet been verified for want of specific data. No data has been found that records the amount of solids released from fuel with ruptured cladding.

Identification of Failed Fuel Types

The rate of fuel failure peaks in 1973. This corresponds with the occurrences of fuel-cladding interaction causing hydriding and cladding penetration. The largest single failure cause resulting in release of radioactivity was the hydriding mechanisms caused by water content in the sintered UO_2 pellets. Design changes such as lower water allowable content in the fuel, pressuring the gas plenum of the fuel rod, gettering and rounding the corners of the pellets have reduced this failure mechanism to a very few occasions.

Location of Failure Occurrence

As would be expected, the occurrence of fuel failures is almost completely in reactors. The more severe radiation and temperature environments and more sophisticated monitoring and instrumentation contribute to the more frequent detection of fuel failures in the reactor core. Two cases have been reported as occurring upon removal from a storage basin. These Zircaloy clad assemblies were suspected to be leakers upon placement in the pool and may have suffered from fuel swelling.

Survey of Actual Utility Practices - L. D. Jacobson, E. M. Greene, J. C. Sonnichsen

Telephone contacts with fuel vendors and utilities at this time have not been extensive. However, indications are that the data required is available although there is reluctance to disclose the data.

A survey questionnaire has been formulated to send to all utilities that have operating nuclear power plants. Meeting dates have been established

with selected utility representatives to review the form of the questionnaire in order to insure that it receives a favorable reception. Personal contacts are planned with certain utilities that have had nuclear plants operating for a number of years.

Future Work

During the next quarter contacts are planned with utilities, storage facilities and fuel vendors in order to: 1) verify published fuel failure data, 2) determine the type of failure, 3) determine the resultant release of radioactivity and 4) determine the behavior of failed fuel assembly during storage. Further, an outline of the report is expected to be completed and work begun on the draft report.

References

1. Westinghouse Nuclear Fuel Operating Experience, W. J. Dollard and F. W. Kramer, Proceedings of American Power Conference, p. 87, 1972.
2. NEDO-10505, Experience with BWR Fuel through September 1971. H. G. Williamson and D. C. Ditmore, p. 28, May 1972.
3. Review of the Effects of Storage and Transportation Environment on the Integrity of LWR Spent Fuel Assemblies, M. N. Menon, C. W. Funk and D. C. O'Keefe. HEDL-TME-77-22

FUEL MATERIALS PREPARATION - Category 7

R. B. McCord/E. W. Gerber

Objective

Provide technical information for incorporation of the reference LWR MOX fuel fabrication process into conceptual fuel recycle plant designs.

Introduction

The fuel fabrication technology program has undergone a major change in program scope. Activities beyond first quarter FY-1977 have been re-directed to provide analysis and advisory services necessary to incorporate the reference fuel fabrication process into the Technical Data Summary and conceptual plant designs. The program will also provide technical evaluation of advance equipment designs and product specifications.

Accomplishments and Status

A review of the Preliminary Technical Data Summary has been completed and comments were forwarded to Savannah River Laboratory.

Future Work

Further review of the process portion of the TDS will be accomplished during the next quarter. An evaluation of safeguards criteria and their impact on the fabrication process will be initiated, as will a survey of RDT Standards for LMFBR fuels and existing ASTM Standards for UO_2 LWR fuels. Further requirements for technical assistance will be defined by SRL in the near future.

TECHNOLOGY TO REDUCE THE GENERATION OF TRU WASTES WITHIN THE NUCLEAR
FUEL CYCLE - Category 8

R. E. Lerch

Objective

To develop and demonstrate procedures and technologies to minimize the generation of transuranic (TRU) wastes within the commercial LWR fuel cycle.

Introduction

The TRU waste reduction program will identify the impact of various design, operational, or administrative changes on reducing the volume of TRU wastes being generated in the LWR fuel cycle. The program will in turn provide direct data (e.g., ranges of TRU waste composition, treatment techniques for HEPA filters, etc.) for conceptual design of TRU waste treatment facilities in the LWR fuel cycle. The program will also identify the cost-benefits of employing TRU waste reduction technologies in industry.

Accomplishments and Status

Responses to a Request for Quotation (RFQ) on fabrication and delivery of a low energy gamma assay system were received and evaluated. The system was ordered and is in fabrication. Delivery of the completed system is expected during September 1977 for planned demonstration testing in an industrial facility.

Discussions were continued with personnel at the Nuclear Materials Division of Babcock and Wilcox (NMD), Appolo, PA, regarding a cooperative program on reducing transuranic waste generation. Specific areas of discussion and expected follow-on work included the following:

- Historical data on waste generation related to completion of FFTF cores 1 and 2 fabrication and related scrap recovery operations are being assembled.
- NMD is selecting a location and obtaining pertinent background radiation level measurements, at the selected location, for planned low energy gamma assay system installation.

- HEPA filter service life extension by the use of prefilters, not previously used by NMD, is to be implemented under test conditions pending completion of detailed arrangements between sites.
- Long term interest in application of HEDL-developed, combustible α -waste processing by Acid Digestion is currently receiving more specific attention at NMD due to current local objections to the use of conventional incineration processes.

Laboratory studies were started on recovery of Special Nuclear Materials (SNM) from HEPA filters. Two techniques were initially considered: 1) backflushing of the filter media using detergents or surfactants and appropriate criticality safety considerations, and 2) separation of the filter media and frame followed by acid leaching of the filter media. Data on backflushing of the filter media indicate that finely divided uranium oxide particulate can be flushed from the media; however, the criticality restrictions for a plutonium oxide system are very restrictive, limiting the practical use of such a system. Further testing will emphasize development of the second technique.

Laboratory studies employing surfactants or detergents to flush UO_2 from HEPA filter media test disks indicated that up to 70% of the particulate loading could be dislodged by a backflushing operation. These UO_2 particulates, in the range from $0.3\mu m$ to $4\mu m$, could not be dislodged by simple shaking or vibration nor by nitric acid flushing since the hydrophobic nature of the filter media prevented wetting by the acid. While these initial results look promising, the normal nuclear criticality limits and restrictions must be applied to such a system. Since historical data on SNM loadings of HEPA filters indicate that in some cases the criticality limits of practical systems would be exceeded, no further work on development of a backflushing technique will be performed.

A conceptual design, for removal of SNM-burdened media by a hydraulically actuated punch in the absence of any moderating materials, to be

followed by SNM recovery from these media in a critically safe aqueous system, has been prepared. In addition to SNM recovery, ultimate immobilization of volume reduced residues is an inherent process consideration.

Future Work

Historical data on transuranic waste generation during fabrication of MOX fuel will be obtained from NMD and analyzed. A program to evaluate use of pre-filters to prolong the life of HEPA filters will be initiated. Laboratory experiments will continue on removal of HEPA filter media from the frame and on recovery of SNM values from the filter media by acid leach techniques.

ENVIRONMENTAL EFFECTS - Category 9

J. F. Fletcher/D. E. Peterson

Objective

Provide evaluations of environmental effects resulting from nuclear fuel cycle operations.

Regional evaluations of radiological effects which may result from operation of nuclear fuel cycle facilities will be made using the WTRAN and DOSE codes in coordination with other national laboratories.

Introduction

The present effort focuses on the evaluation of concentrations of radio-nuclides in the natural water systems at SRL and vicinity and on the radiological dose to regional population which may result from normal emission occurring during operation of typical fuel cycle facilities. Modifications to both the WTRAN and DOSE codes are necessary for this purpose.

Accomplishments and Status - J. F. Fletcher, D. E. Peterson

Checkout of the original version of the WTRAN code was completed early in the report period. A modified version of the code was subsequently developed and successfully tested which provides an analysis capability of 1600 grid areas or 1600 irregular areas.

A complete listing of all municipal water facilities in South Carolina and Georgia was made. This information will be used to define the source of water supply and method of treatment for the grid areas of the Savannah River study area. Table 10 shows listings of the water supply for two community service areas in Aiken, S. C.; Shaws Creek, Shiloh Springs, plus 13 wells provide community water supplies for 31,800 people in Aiken. In addition, 23 wells provide supplies to mobile home parks and other facilities.

A screening process is underway to eliminate typographical and other errors in the water supply data, so that meaningful statistical summaries can be developed for the individual states and the United States as a whole.

Table 10 provides examples of some errors encountered in the data. Under City, Aiken is listed as KEN and under source No. 3, the source is listed as SURFACE even though the water comes from wells.

Future Work

- During the next quarter the DOSE code will be modified to calculate the dose associated with only the water pathway. The program will be expanded to 1600 grid areas.
- A test run of WTRAN and DOSE with Savannah River data is scheduled near the end of the report period.

TABLE 10

SAMPLE LISTINGS OF DRINKING WATER SUPPLY DATA

STATE SC CITY KEN
 KEY CODE 45 012 000001000
 USER AIKEN - ADDRESS P.O. BOX 1177 KEN , SC 29801
 PHONE 803-648-4623 COUNTY AIKEN

TYPE OWNER CITY, DISTR POPULATION SERVED 28000 NO. SERVICES 7500 NO. METERS 8000

TYPE SERVICE AREA COMMUNITY

NO. WHOLESALE CUSTOMERS 1

PRODUCTION CAPACITY NORMAL 580000 GPD; EMERGENCY : GPD; STORAGE CAPACITY 2600000 GAL
 DAILY PRODUCTION AVERAGE 400000 GPD; MAXIMUM 580000 GPD

SOURCE NO. 1
 DESCRIPTION SHAW'S CREEK LAT 33 DEG 36 MIN 23 SEC SOURCE SURFACE TREATMENT PRECHLO CONTROL
 LONG 91 DEG 41 MIN 15 SEC COAG
 SEDIM
 FILTR
 TST, 000R
 FLJORD
 DISINF

SOURCE NO. 2
 DESCRIPTION SHILOH SPRINGS LAT 33 DEG 39 MIN 39 SEC SOURCE SURFACE TREATMENT PRECHLO CONTROL
 LONG 91 DEG 40 MIN 50 SEC COAG
 SEDIM
 FILTR
 TST, 000R
 FLJORD
 DISINF

SOURCE NO. 3
 DESCRIPTION TWO WELLS (STAN LAT 33 DEG 33 MIN 37 SEC SOURCE SURFACE TREATMENT PRECHLO CONTROL
 LONG 91 DEG 43 MIN 26 SEC COAG
 SEDIM
 FILTR
 TST, 000R
 FLJORD
 DISINF

SURVEY YEAR 19 0 LAST UPDATE 092275

STATE SC CITY AIKEN
 KEY CODE 45 012 J00005000

USER TALATHA DIST ADDRESS RT 1 BOX J90 AIKEN , SC 29801
 PHONE 803-652-2774 COUNTY AIKEN

TYPE OWNER CITY, DISTR POPULATION SERVED 1000 NO. SERVICES 282 NO. METERS 330

TYPE SERVICE AREA COMMUNITY

NO. WHOLESALE CUSTOMERS 0

PRODUCTION CAPACITY NORMAL 172000 GPD; EMERGENCY : GPD; STORAGE CAPACITY 325000 GAL
 DAILY PRODUCTION AVERAGE 40000 GPD; MAXIMUM 172000 GPD

SOURCE NO. 1
 DESCRIPTION WELL 1 LAT 33 DEG 23 MIN 42 SEC SOURCE GROUND TREATMENT FILTR CONTROL
 LONG 91 DEG 42 MIN 55 SEC

SOURCE NO. 2
 DESCRIPTION WELL 2 LAT 33 DEG 24 MIN 30 SEC SOURCE GROUND TREATMENT FILTR CONTROL
 LONG 91 DEG 45 MIN 10 SEC

SURVEY YEAR 19 0 LAST UPDATE

RECORD NUMBER 47250

DISTRIBUTION

NO. OF COPIES

OFFSITE

- 1   ERDA Chicago Patent Group
9800 South Cass Avenue
Argonne, IL 60439
A. A. Churm
- 1   Aerojet, Energy Conversion Company
1120 Connecticut Avenue, N.W.
Suite 1050
Washington, DC 20036
Frank J. Kiernan, Eastern Regional Manager
- 1   Allied Chemical Corporation
550 Second Street
Idaho Falls, ID 83401
F. H. Anderson, General Manager
- 2   Allied-General Nuclear Services
P. O. Box 847
Barnwell, SC 29812
A. E. Schubert, President
A. K. Williams
- 1   Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
J. A. Kyger, Assoc. Director
- 1   Battelle-Columbus Laboratories
505 King Avenue
Columbus, OH 43201
J. M. Batch, Director
- 1   Battelle-Human Affairs Research Centers
4000 N.E. 41st Street
Seattle, WA 98105
J. E. Rasmussen, Director
- 2   Battelle-Pacific Northwest Laboratories
P. O. Box 999
Richland, WA 99352
T. W. Ambrose, Director
J. H. Jarrett

NO. OF
COPIES

- 1   Babcock and Wilcox
P. O. Box 1260
Lynchburg, VA 24505
R. H. Ihde, Manager, Contracts and Marketing
- 1   Boeing Engineering and Construction Division
P. O. Box 3707
Seattle, WA 98124
Richard L. Grant, Director, Nuclear Projects
- 1   Burns and Roe, Industrial Services Corporation
P. O. Box 663
Paramus, NJ 07652
M. I. Naparstek, Manager, Proposals
- 1   Combustion Engineering
Nuclear Power Division
1000 Prospect Hill Road
Windsor, CT 06095
C. K. Anderson
- 1   Commonwealth Edison Company
P. O. Box 767
Chicago, IL 60690
G. R. Corey, Vice Chairman
- 1   Carolina Power and Light Company
P. O. Box 1551
Raleigh, NC 27602
L. E. Smith, Manager, Fuel
- 1   Corning Glass Works
Corning, NY 14830
M. G. Britton, Manager, Technical Liaison

NO. OF
COPIES

1	<u>Edison Electric</u> 90 Park Avenue New York, NY 10016 J. Carp, Director, Energy Policy
10	<u>E. I. duPont de Nemours and Company</u> Aiken, SC 29801 C. H. Ice, Director, SRL
1	<u>ERDA Albuquerque Operations Office</u> P. O. Box 5400 Albuquerque, NM 87115
1	<u>ERDA Chicago Operations Office</u> 9800 South Cass Avenue Argonne, IL 60439
1	<u>ERDA Division of Biomedical and Environmental Research</u> Washington, DC 20545 J. L. Liverman, Director
1	<u>ERDA Division of International Affairs</u> Washington, DC 20545 N. F. Seivering, Assistant Administrator
1	<u>ERDA Nuclear Energy</u> Washington, DC 20545 R. W. Roberts, Assistant Administrator
6	<u>ERDA Division of Nuclear Fuel Cycle and Production</u> Washington, DC 20545 G. W. Cunningham, Director G. Bradley P. Hogroian C. Kuhlman G. Pleat D. Spurgeon
1	<u>ERDA Division of Reactor Development Concentration</u> Washington, DC 20545 W. H. McVey, Chief, Fuel Recycle Branch

NO. OF
COPIES

- 1   ERDA Division of Safeguards and Security
Washington, DC 20545
H. E. Lyon
- 1   ERDA Idaho Operations Office
550 2nd Street
Idaho Falls, ID 83401
- 1   ERDA Oak Ridge Operations Office
P. O. Box E
Oak Ridge, TN 37830
- 2   ERDA San Francisco Operations Office
1333 Broadway, Wells Fargo Building
Oakland, CA 94616
- 1   University of California
Lawrence Livermore Laboratory
P. O. Box 808
Livermore, CA 94550
- 3   ERDA Savannah River Operations Office
P. O. Box "A"
Aiken, SC 29801
T. B. Hindman, Jr., Director, Fuel Cycle Project Office
Norman Hook
N. Stetson, Manager
- 27   ERDA Technical Information Center
- 2   Exxon Nuclear Company, Inc.
777 - 106th Avenue, N. E.
Bellevue, WA 98009
S. J. Beard
R. L. Dickeman, President
- 1   Florida Power Corporation
P. O. Box 14042
St. Petersburg, FL 33733
A. H. Hines, Jr., President
- 1   Florida Power and Light Company
P. O. Box 013100
Miami, FL 33101
Doctor Uhrig

NO. OF
COPIES

- 3   ERDA Richland Operations Office
P. O. Box 550
Richland, WA 99352
P. A. Craig
D. J. Melton
N. Karajianes
- 3   ERDA/FFTF-PO
P. O. Box 550
Richland, WA 99352
Director (2)
Assistant Director for Engineering Technology and Fuels
- 1   General Atomic Company
P. O. Box 81608
San Diego, CA 92138
John Shefcik
- 2   General Electric Company
175 Curtner Avenue
San Jose, CA 95125
R. G. Barnes
K. Bowlman
- 1   GPU Services Corporation
260 Cherry Hill Road
Parsippany, NJ 07054
B. H. Cherry, Manager, Fuel Resources
- 1   Kerr-McGee Nuclear Corporation
Kerr-McGee Building
Oklahoma City, OK 73102
Martin Binstock
- 1   Livermore Radiation Laboratories
P. O. Box 808
Livermore, CA 94550
Kenneth Street, Assoc. Director
- 1   Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, NM 87545
H. M. Agnew, Director

NO. OF
COPIES

- 1   Middle South Utilities, Inc.
P. O. Box 61005
New Orleans, LA 70161
F. W. Lewis, President
- 1   Monsanto Research Corporation
Mound Laboratory
P. O. Box 32
Miamisburg, OH 45332
W. T. Cave, Director
- 1   NL Industries
P. O. Box 928
Barnwell, SC 29812
George Stukenbroeker
- 1   Niagara Mohawk Power Corporation
300 Erie Boulevard, West
Syracuse, NY 13202
G. K. Rhode, VP, Engineering
- 1   NRC Nuclear Materials Safety and Safeguards
Washington, D. C 20545
R. Cunningham
- 1   NRC Research
Washington, DC 20545
Saul Levine, Deputy Director
- 1   Holmes and Narver, Inc.
400 E. Orangethorpe Avenue
Anaheim, CA 92801
W. A. Kalk, Manager, Nu Power Systems
- 1   Atlantic Richfield Company
Box 2679 - TA
Los Angeles, CA 90071
L. M. Richards, Coordinator, Nuclear Comm. Dev.
- 1   Nuclear Fuel Services, Inc.
6000 Executive Blvd.
Rockville, MD 20952
R. W. Deuster, President

NO. OF
COPIES

- 1   Oak Ridge Gaseous Diffusion Plant
Oak Ridge, TN 27820
W. J. Wilcox, Technical Director
- 2   Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830
Herman Postma, Director
- 1   Westinghouse Electric Corporation
Plutonium Recycle Fuel Programs
P. O. Box 355
Pittsburg, PA 15230
J. F. Bader, Manager
- 1   Proposal Management, Inc.
121 N. Orionna Street
Philadelphia, PA 19106
C. A. Hirenda, Director, Marketing
- 1   Research and Technical Division
P. O. Box 1600
Galveston, TX 77550
Louis W. Nelms, Chief, Research Branch
- 1   Rockwell International
Atomics International Division
8900 De Soto Avenue
Canoga Park, CA 91304
R. D. Oldenkamp
- 1   Rockwell International
Rocky Flats Plant
P. O. Box 464
Golden, CO 80401
R. O. Williams, VP
- 1   Science Applications, Inc.
1680 Hanover Street
Palo Alto, CA 94303

NO. OF
COPIES

- 1   NUSAC
777 Leesburg Pike
Falls Church, VA 22043
R. C. Adkins, Technical Representative
- 1   Phraeger Tech.
110 S. Euclid Avenue
Pasadena, CA 91101
K. Vickers
- 1   Tennessee Valley Authority
217 Electric Power Board Bldg.
Chattanooga, TN 37401
Ray Hoskins
- 1   The BDM Corporation
7915 Jones Branch Drive
McLean, Virginia 22101
R. G. Cross, Jr.
- 1   The S. M. Stoller Corporation
Western Reprocessors
1250 Broadway
New York, NY 10001
S. M. Stoller
- 1   Virginia Electric Power Co.
Nuclear Fuel Service Dept.
512 Franklin Building
P. O. Box 2666
Richmond, VA 32361
Claude Stephens
- 1   Yankee Atomic Electric Company
20 Turnpike Road
Westboro, MA 01581
Wendell Johnson, VP