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ANSWERS TO QUESTIONS OF THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS RELATIVE TO THE NEED FOR RETENTION OF GOVERNMENT LAND

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ANSWERS TO QUESTIONS OF THE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
RELATIVE TO THE NEED FOR
RETENTION OF GOVERNMENT LAND

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ANSWERS TO QUESTIONS OF THE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
RELATIVE TO THE NEED FOR
RETENTION OF GOVERNMENT LAND

Compiled by:
R. L. Junkins

INTRODUCTION

A meeting has been scheduled with a Subcommittee of the Advisory Committee on Reactor Safeguards to review the future need for retention of government land on the Wahluke Slope. A number of questions have been asked by the Washington AEC Division of Production as a basis for the discussions. This interim report provides answers to several of the questions received from AEC-RL00 as modified by E. F. Miller, Technical Assistant Director, Division of Production, during his recent visit.

DISCUSSION

A tabulation was requested of the fission product inventory at equilibrium operation, reactor loading, assumed melting in the maximum credible accident, the fraction of fission products released to the building and to the atmosphere, including the assumed filter removal, fog spray and plate-out efficiencies. These data were requested for N, K, and B-type reactors with the fission products grouped by noble gases, halogens, iodine-131 specifically, volatile solids and nonvolatile solids.

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The answers to these questions are summarized in Tables I through IV. No credit is taken for removal of fission products by the fog spray systems in B and K types of reactors since the coverage of these systems is for the rear face only. The maximum design accident in these types of reactors is assumed to be the loss of a front face cross header.^{1,2} The postulated maximum design accident in the N Reactor assumes a longitudinal failure of the inlet manifold pipe. This postulated accident was described previously³ and reviewed recently⁴ in terms of 10 CFR 100 Reactor Siting Criteria.

Graphical presentation of the total body dose at distances of 2.5, 5.5, and 16 miles was requested as a function of time after the assumed accident; for melting of 1, 10, and 50% of the fuel loading; for invariant wind speed and direction; for variation in wind speed and direction; assuming fission product removal efficiencies as in Tables II and IV and assuming all fission products released from the molten fuel escape to the atmosphere. These data were requested for each type of reactor.

Results of these calculations are illustrated in graphs as follows: for N Reactor, Figures N-1 through N-6 illustrate the whole body dose at the requested distances, assuming a stable atmosphere and invariant wind speed and direction. Figures N-7 through N-12 illustrate the effect of variability in wind speed and direction. Figures N-1 through N-3 and N-7 through N-9 assume release to the atmosphere as in

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Table III. The remaining graphs treat the same variables, but assume that all of the fission products which are released from the molten fuel are also released to the atmosphere, i.e., no credit is taken for any removal mechanism. In all of these calculations, the release is assumed to be from the stack at a volumetric rate of 1000 cfm.⁴ The maximum design accident for N Reactor^{3,4} involves fission product release assumed to be equivalent to the melting of 100 tons of fuel. Other assumptions are the same as in Table II and the dose at various distances is illustrated in Figures N-7 through N-9.

For the K and B types of reactors, it is necessary for clarity, to illustrate the results in a different manner because of the differences in confinement systems. For these reactors the exhaust fans are designed to continue to operate after the postulated accident to provide for filtration and release from the stack. In essence, this means that release of fission products would be rapid after fuel melting begins. The volumetric discharge rate is about 100,000 cfm from an effective building volume of about 350,000 cubic feet. These confinement systems were designed to withstand an accident involving loss of coolant to a few process tubes but not more than the tubes served by a single cross-header; the assumed maximum credible accident. Thus in assumed accidents involving melting of more than one to two percent of the K or B-type reactor cores, at least a portion of the fission product release would be unfiltered at or near ground level.

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In all of the cases assumed for K and B types of reactors the time of fission product emission are assumed to be during an interval of less than ten minutes after fuel melting has begun. The time of exposure is correspondingly short. The available time for providing warning consists of the time after the initiating event to the beginning of fuel melting plus the time of transport from the point of release. For accidents involving loss of coolant to a cross-header or an entire reactor the minimum time before melting is estimated to be two hours.^{1,2}

The results of the calculations for these types of reactors are illustrated in Figures K-1 through K-3 and Figures B-1 through B-3. Allowance for variability in wind speed and direction has a negligible effect because the period of emission is assumed to be short. The lower line on each of these graphs is based on an elevated release with assumed removal efficiencies as in Table IV. For accidents involving melting of more than one or two percent of the fuel, this is not believed to be a realistic model for reasons previously described and is included only by request. The upper line on each graph assumes a ground level release of all fission products which escape the molten fuel, i.e., no credit is taken for any removal mechanism.

Comparison of the releases of fission products to the building with the assumed values in TID-14844⁵ was requested and if the values used in these calculations differ, recalculations based on TID-14844 assumptions were requested.

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The assumed releases from molten fuel to the building in TID-14844 were: 100% of the noble gases, 50% of the halogens, and 1% of the solid fission products. The assumed releases of fission products from molten fuel in this report, Tables II and IV, and in previous work¹⁻⁴ are identical except that 50% release of volatile solids (selenium, cesium, and tellurium) was assumed rather than 1% as in TID-14844. Since these assumptions are somewhat more pessimistic, recalculation of the assumed accidents was agreed to be unnecessary.⁵

A summary of incidents involving nuclear safety for Hanford production reactors was requested. The Hanford production reactors have experienced no accident which has released more than a minor amount of radioactive material to the reactor environs in the approximately 120 reactor-years of accumulated experience. However, lapses in safety control have occurred which either resulted in the release of minor amounts of radioactive material or increased the risk for such release beyond established standards. This report summarizes some of the more significant of these incidents involving nuclear safety.

The types of incidents which have occurred are separated into the following categories:

1. Reactivity insertion and excessive power
2. Reactor cooling
3. Radiation control

The more significant incidents of each of the types listed above are included. Emphasis has been placed on choosing events which have occurred most recently.

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REACTIVITY INSERTION AND EXCESSIVE POWER

Accidental reactivity insertion has resulted from safety and control rod withdrawal, inadvertent discharge of poison material, and mischarging of fuel and poison material. Backup safety systems (high level flux monitors and tube pressure monitors) and procedures specifically designed to protect against such events precluded serious safety consequences from any of these incidents.

1. Erroneous Power Level Indication

a. KW Reactor - May 20, 1959

The reactor was started up with the power meter unknowingly reading low by a factor of two. The reactor was manually shut down following a high process channel outlet temperature alarm at an indicated power level of about one-third full power, or a real power of about two-thirds full power. Prior to this temperature alarm none of the operating crew was aware that the actual power level was higher than that indicated on the power meter. The maximum individual tube outlet temperature at the time of the shutdown was estimated to be 110 C which was within normal limits.

The power level meter error was improperly diagnosed partially because the formal startup procedures did not require determination of power from more than one instrument nor instrument verification. Subsequently, thorough cross checking of critical instrumentation has been included in the reactor startup procedures.

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b. DR Reactor - November 7, 1959

During nearly full power operation, a sample line plugged at the temperature sensing pot for the bulk effluent temperature and power level recorders. Over a six-hour period, the power level was gradually increased a total of about 15% in an attempt to maintain the indicated power level. At this time, the fault was found and the power level corrected. The bulk effluent temperature exceeded the standard limit of 94.0 C by 0.5 C.

2. Inadvertent Rapid Reactivity Insertion

- a. Sudden power increases of one to three percent have infrequently occurred from unverifiable causes. The frequency of reported cases is no more than one to two per year. In such cases the initiating event is almost certainly the inadvertent withdrawal by the operator of a small increment of control rod. This requires only that the control rod drive handle be turned in the direction to withdraw rather than insert rod. To prevent a more substantial power increase from this cause, a rod travel interrupter circuit is in the control rod drive circuit at each reactor, which requires that after a short movement the control handle must be turned off before a second increment of rod withdrawal can be performed.

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b. There are two instances of accidental flushing of a full column of poison from a poison column control process channel at appreciable power levels; both events occurred prior to 1962 and as a result of equipment failure. At full power level the poison column flush can cause a rapid power level increase of up to 10%. While efforts are made to avoid inadvertent discharge of poison columns, such accidents are assumed in safety analyses leading to process limits.

c. H Reactor - May 5, 1958

During full power operation, an attempt was made to charge an empty Poison Column Control Facility tube with poison pieces. Due to malfunction of the charge machine, flow was momentarily removed from the tube causing the water to boil out, thus introducing a minor reactivity gain. Flow was immediately restored. About four hours later, a second attempt was made to charge the tube with the same results; this time the localized power rise was sufficient to cause an immediately adjacent flux monitor trip which scrambled the reactor.

The power rise did not cause temperature limits to be exceeded. Had the tube flow been left off for a sufficient time at full power, melting of the empty tube could have occurred.

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3. Failure to Control Power Rise

KE Reactor - August 5, 1960

A startup following a scram from subequilibrium power levels was being attempted. The power level increase to a high level was more rapid than normally allowed. The reactor was shut down by a pressure (flow) monitor low trip. A temporary rate-of-rise meter had shown the power level to be increasing at normal rates. However, this instrument was later found to be reading low. Further, a calibration switch was found in the wrong position, causing the instrument to indicate low by about a factor of two. The pressure monitor trip was believed to be a low-pressure trip. This could have been caused by an increase in tube flow rates that result from reduced viscosities as the temperature increases. Such pressure transients with increasing temperature are normal.

4. Loading Error

H Reactor - April, 1964

An error was made in the charging sequence in which the three poison pieces (lithium) in each E-N column were placed in the rear portion of the charge rather than being uniformly spaced along the length of the column. The fuel and poison pieces had been properly placed in the charge make-up pallets; the error resulted when the charging crew removed the elements in the wrong order. This improper sequencing persisted for an eight-hour shift resulting in the mischarging of about 170 tubes. An excessive amount of reactivity

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(about 0.8%) was observed at startup, the reactor becoming super-critical during removal of the last few vertical safety rods. This reactivity error and the observed flux distortion during the ensuing operation indicated that a loading error had occurred; it was confirmed at the ensuing outage by spot checking the charge order of the suspect tubes. This charging error did not result in operation outside the control criteria and standard safety precautions are designed to prevent unknown excesses in reactivity from resulting in uncontrolled rises in power.

5. Flux Distortion

Occasionally (about once every year or two) the flux distribution in an operating reactor has become sufficiently distorted that standard tube temperature limits have been exceeded a few percent. Failure to monitor the flux distribution properly and provide adequate distributional control have been the causes of these incidents. While solid fuel elements were being used in the reactors, the localized higher fuel temperatures infrequently caused fuel element ruptures. Such localized power increases have never resulted in flow instability (which would initiate a pressure monitor trip) or evidences of fuel damage since the reactor has been using the I&E element.

REACTOR COOLING

Melting of fuel or fuel cladding has occurred only once as a result of inadequate cooling (see item 1 below). Other instances of coolant interruption and loss of one of the three independent sources of coolant supply have occurred but have not resulted in significant nuclear safety consequences.

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1. Partial Melting of Fuel Charge

KW Reactor - January 5, 1955

This incident occurred during the first 24 hours of operation of the reactor. The reactor power level was well below the design rating and was being gradually increased on a preplanned schedule. During the power increase, evidence was obtained of a sizeable process tube water leak. An attempt was made to map the coolant outlet temperature of all process tubes so that the location of the leak might be determined. During this time, the reactor was scrammed by a flow monitor trip, and fuel rupture indications were received. The offending tube was identified by the flow monitor and rupture detection indications. Later, it was determined that a portion of the fuel charge and process tube had partially melted. A rubber blank, used to isolate some of the process tubes from the coolant system during pre-startup zero-power lattice physics tests, had been accidentally left in the rear fittings of the incident tube. The location of the blank not only blocked the cooling water flow of the tube, but also isolated the tube from its temperature sensor, causing the sensor to monitor the temperature of the water from adjacent tubes in the outlet crossheader. The gauge monitoring tube flow had been improperly adjusted, causing the blanked-off tube to appear to be receiving a normal supply of coolant.

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2. Reactor Coolant Stoppage

KE Reactor - March 26, 1963

An error in reactor crossheader valving during a shutdown resulted in complete coolant flow stoppage for a period believed to be between two and four minutes. The risers on one side of the reactor were to be isolated to permit maintenance work; the crossheaders were mistakenly valved off from the risers on the other side of the reactor so that complete flow stoppage occurred when the supply risers were valved off. Differential pressure crossheader gauge alarms and abnormal temperature fluctuation alerted the operating crew to the error so that flow was restored immediately.

Subsequent operation revealed no evidence of excessive fuel temperature. However, calculations indicated that the temperature rise in some fuel could have been up to half that required to reach the melting temperature of the fuel cladding.

3. Complete Failure of Front Face Nozzle

KE Reactor - January 12, 1963

During operation at about 60% full power the nozzle on a fuel tube was completely fractured. A spline inserter tool was mistakenly left connected to the nozzle and was struck by a pipe during a subsequent upward movement of the charge face platform. The reactor was scrammed immediately by a low trip on the affected tube pressure gauge. There was no appreciable rise in front face radiation level, and subsequent investigation revealed no fuel damage.

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A second contributing factor to the incident was that the protrusion of the nozzle handle failed to break the electric eye circuit which action would have stopped the platform movement. The principal concern from nozzle breakage is that steam formation could flush fuel onto the charge platform.

4. Crossheader Damage

DR Reactor - July 10, 1963

The front charge platform was being lowered to a new location during shutdown charging operation when a charging machine mounting rail struck a drain valve stem on a crossheader. Before the platform travel could be stopped, the drain valve and related piping was pushed down transmitting sufficient force to the crossheader to form a dimple in the header adjacent to the drain line header weld junction. The combination of the charging machine mounting rail extending beyond its normal position toward the reactor by about 2-1/2 inches (because of a failed holding mechanism), of the drain valve handle being in a non-normal position of maximum extension toward the platform, and of the charging machine being located in the vertical line of the drain valve stem resulted in the incident.

As a safety precaution in case the crossheader had been weakened, this portion of the crossheader was replaced before resuming operation. Crossheader fracture could result in complete loss of coolant to one or two rows of process tubes.

5. Electrical Power Failure

All Reactors - April 6, 1962

A total failure of the electric power supplied by BPA resulted from a fault on a Hanford line. The circuit breakers on the other two lines opened incorrectly at approximately the same time, interrupting BPA power for approximately 2-1/2 minutes.

At the time of power failure two reactors were shut down and six were operating. All operating reactors scrambled normally and cooling loads automatically and successfully transferred to the secondary cooling system at each reactor. The last ditch system was not required at any reactor.

The overall performance of personnel and equipment was satisfactory and no damage was sustained to any of the reactor facilities as a result of the power failure. There were some isolated malfunctions of process and auxiliary equipment design and maintenance; however, this failure provided an excellent shakedown of emergency systems which permitted correction of the observed deficiencies.

RADIATION CONTROL

1. Fuel Element Fire

KW Reactor - April 29, 1959

A fuel failure occurred in a process tube that also contained a thin metallic ribbon of nuclear poison, called a "spline." Rupture removal was attempted by pushing the tube, charge and spline out of the reactor together. Part of the tube was pushed and was broken off,

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but was held up by the spline. Sparks were then noted by observers at a remote viewing window, followed by a flame which persisted for about ten seconds. The remainder of the tube was later pushed out without further incident.

2. Discharge of Fuel onto the Rear Work Platform

H Reactor - January 10, 1961

Two charges of irradiated enriched fuel were inadvertently discharged onto the rear work platform about 22 hours after the reactor had been shut down. The fuel elements were cooled with the fog spray system and were ultimately disposed of without further incident.

It had been assumed by the charging crew that the rear work platform was in the full up position; however, following completion of the charge-discharge operation on these two tubes the continued high radiation level in the rear area indicated the fuel had not fallen into the discharge basin. It was subsequently found that the rear platform had descended to a point below these tubes and the fuel elements had been discharged onto the platform.

A charge machine interlock prevents charging unless the rear platform is in the full up position; in this instance the interlock had been temporarily bypassed to perform maintenance work and the platform had unknowingly descended to a point below the tubes being discharged.

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Statistical probabilities of a major reactor disaster, such as that resulting from complete loss of water to a K reactor, caused by earthquake and significant reactor incidents, such as a fracture of an inlet crossheader on a B-type reactor was requested.

The assignment of a statistical probability to accidents which have not occurred during the operating life of the Hanford production reactors is speculative at best. Since there is no incident experience upon which to base a statistical analysis, probabilities can only be assigned by making assumptions. Considerable effort has been expended over the past ten years in trying to develop a failure model which would make use of minor incident statistics which would, through appropriate combinations, culminate in a major type incident. These studies did not prove successful since it was found that the assessment of probabilities of acts, failures, or failures to act was extremely difficult, and one was forced to use an excessive number of assumptions despite the fact that more reactor operating experience has been accumulated at Hanford than anywhere else in the world.

A slightly different approach to the problem is to examine the probability of a complete coolant loss incident based upon accumulated reactor operating experience. No occurrences have been encountered during the 120 operating-reactor years of experience, and from these facts it is possible to establish probabilities of having incurred no failures for various assumed major accident frequencies. Figure A shows probability as a function of both the true rate of major accidents

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per reactor operating year and the mean years between accidents. It is noted that there is a 5% probability of a major accident if the true frequency of accidents is 2.5 per 100 operating years, or stated another way, with 95% confidence, the failure frequency is no greater than 2.5 per 100 operating years (40 operating years between accidents). With 50% confidence the incidence drops to 0.58 accidents per 100 operating reactor years. Careful judgment suggests the above statements of accident safety to be very conservative; however, how much conservatism actually exists does not yield to analysis.

In generating the aforementioned curve, the assumption is made that each reactor operating year is identical, and this is not necessarily the case. Over the past 20 years new reactors have been built which have incorporated advances in technology and the older units have had major improvements made in their control and cooling systems during this time period. Probably of equal significance is the accumulation of a large backlog of operating experience. However, during this same time period, the power levels have increased steadily to where they are several times the design level at some units. Also, the reactors are getting older and some deterioration due to aging must be taking place although a very aggressive maintenance program has been in continuous effect here at Hanford. It is concluded from these remarks that the assumption of a uniform susceptibility to a major accident throughout the lifetime of the reactors is reasonably valid.

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A complete water-loss accident has been judged not credible in the hazards analyses made of the single purpose Hanford production reactors. With the exception of intentional acts of war or sabotage, the total interruption of reactor cooling could only result from natural phenomena, with a major earthquake being the most likely. The Hanford vicinity is one of the more stable seismic areas of the Pacific Northwest, and in view of the low probability of damaging earthquakes, this type of accident has been judged not credible. However, this approach permits another method of examining the probability of a complete coolant interruption event. A study by Holmes and Narver of the reactors and their supporting systems indicates that an earthquake of a Modified Mercalli intensity of eight or greater (ground acceleration of 0.3 g) would be required to sever the major coolant supply lines. The question reduces to the probability of an earthquake of this intensity occurring in the Hanford area. During historic times (at least 100 years), no such events have occurred. The strongest shock on record to occur in western Washington was the 1949 earthquake originating in the Puget Sound channel, a distance of 150 miles from Hanford. The intensity at Prosser, which is 30 miles from the reactor areas, was MM-6. Prosser, however, is known to be unusually sensitive to seismic disturbances. Four other western Washington shocks between 1932 and 1946 had maximum intensities of MM-7. The eastern Washington earthquakes occurring in historic times have not been as intense as in western Washington, nor have they been as frequent. Shocks have seldom exceeded MM-6 which implies only superficial damage.

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Exploring the local terrain for evidences of severe earthquakes which resulted before historic times reveals the remnants of a number of land slides in the Rattlesnake Horseheaven Hills and the White Bluffs areas but generally nothing more. It is judged that these slides could have occurred following relatively moderate seismic events. One cannot draw too much comfort from the absence of other evidence of earthquakes since many of the Washington shocks are fairly deepseated and are not prone to show surface phenomena.

All of the above considerations have been based on an operating reactor. The much more likely case for complete coolant exclusion from the reactor would result from valving errors during reactor shut-down. The consequences of such an event are far less serious and it is expected that flow could be restored in time to prevent any fission product release. If the coolant were inadvertantly valved off and not detected, fuel melting would, however, eventually occur. For such an event to occur would require two valving errors and the failure of numerous pressure monitors to respond or for operators to act upon their response.

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The rupture of a crossheader on a B or K-type Hanford production reactor has been judged to have a finite probability of occurring during the operating life of these reactors and is classified as the maximum credible accident. During the 120 reactor years of operating experience no failures or near-failures have occurred, and the uncertainties of assigning a probability to a coolant loss accident applies equally well to the crossheader accident. Since there is no backup for a crossheader, a number of precautionary measures have been taken to avoid an accidental failure.

The crossheaders are well supported and their location between and behind rows of inlet nozzles makes them generally inaccessible and not subject to impact by tools and equipment in common use on the charge face work platforms. In this service, the use of schedule 40, stainless steel pipe easily satisfies the requirements of ASA pressure piping code B31.1. Very small steady-state thermal stresses and virtually no cyclic thermal stresses are applied to the inlet crossheaders because of the relatively low and constant temperature of the reactor cooling water passing through them. The low temperature and the chemical properties of the water effectively prevent stress corrosion cracking. Insulating flanges are installed between the carbon steel riser piping and the stainless steel crossheader piping to avoid galvanic coupling of the materials. While the fluid velocities in the inlet crossheaders are high (30 to 45 feet per second) compared to more conventional piping practice (5 to 15 feet per second), piping vibration is nominal. Nothing has been found that would indicate impaired

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serviceability of the crossheaders, and an established surveillance program provides for monitoring the integrity of the reactor front face piping.

The most likely cause of a crossheader failure is judged to result from a flying object (missile), a falling object or moving equipment catching a header and rupturing the pipe. To date two minor incidents have been experienced by crossheader piping. Both events occurred at shutdown reactors and both were the result of a charging machine protruding beyond the work platform. In one case no damage was done to the crossheader; in the other, the header was slightly bent and a section of pipe was replaced before the reactor started up (for details see incident summary).

Additional information which was requested is being prepared by members of the HAPO staff for oral presentation at the June 19, 1964, meeting with members of the Advisory Committee on Reactor Safeguards. These additional requests cover the following topics:

- (1) Summary of separations plants incidents, probability and magnitude of postulated accidents and effect of operations of these plants on the environment.
- (2) Review of meteorological evaluation methods and application of accident calculations.
- (3) Hazards associated with radioactive liquids discharged to the river in the event of accidents in view of possible access nearer the reactors than at present.

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Such additional information as we believe may be helpful will also be available at the June 19, 1964, meeting with ACRS.

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BIBLIOGRAPHY

- ¹HW-74095, "Hazards Summary Report, Safety Analysis and Hazards Evaluation, Hanford K Production Reactors," Volumes 1 through 3, Secret, June 28, 1963.
- ²HW-74094, "Hazards Summary Report, Safety Analysis and Hazards Evaluation, Six Oldest Hanford Production Reactors," Volumes 1 through 3, Secret, June 28, 1963.
- ³HW-76930, "N-Reactor Hazards Summary Report," Volumes 1 through 5, Secret, April 15, 1963.
- ⁴E. C. Watson, et al., "Estimated Distances for Exclusion Area and Low Population Zone Boundaries: N Reactor," Secret, February 3, 1964.
- ⁵J. J. DiNunno, et al., "Calculation of Distance Factors for Power and Test Reactor Sites," TID-14844, March 23, 1962.
- ⁶Discussions with E. F. Miller, Division of Production, U. S. Atomic Energy Commission, Washington, D. C.

TABLE I
AMOUNT OF URANIUM AND INVENTORY OF RADIOACTIVE FISSION PRODUCTS
N-REACTOR

Quantity of Uranium (in tons)		Fission Product*	Fission Products in Core at Shutdown in curies	Quantity of Fission Products Released to the Atmosphere Following "Maximum Credible Accident" Expressed as curies at Selected Decay Times							
in Core	Equivalent Melt "MCA"			5 min	2 hours	4 hours	8 hours	1 day	2 days	5 days	10 days
370	100	NG	2.5 (9**	2.6 (8	1.4 (8	1.2 (8	1.1 (8	8.0 (7	6.2 (7	4.1 (7	2.1 (7
		H	1.9 (9	1.8 (6	1.4 (6	1.1 (6	9.2 (5	6.1 (5	4.3 (5	2.3 (5	1.1 (5
		I-131	1.1 (8	1.8 (5	1.8 (5	1.8 (5	1.8 (5	1.7 (5	1.5 (5	1.2 (5	8.0 (4
		VS	2.5 (9	1.2 (6	3.5 (5	2.5 (5	2.3 (5	2.0 (5	1.6 (5	1.0 (5	5.8 (4
		RFP	1.2 (10	1.6 (3	880	780	660	490	390	300	240
		Total	1.9 (10	2.6 (8	1.4 (8	1.3 (8	1.1 (8	8.1 (7	6.2 (7	4.1 (7	2.1 (7
		*based on 700 Mwd/t									

* NG - Noble Gases (Xe, Kr)

H - Halogens (Br, I)

VS - Volatile Solids (Se, Te, Cs)

RFP - All Remaining Fission Products

** 2.5 (9 = 2.5×10^9

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TABLE II

FISSION PRODUCT RELEASE FACTORS
N-REACTOR

<u>Fission Products</u>	<u>Percent of Inventory in Failed Fuel:</u>				
	<u>Escaping:</u>				<u>Released to Atmosphere</u>
	<u>Fuel</u>	<u>Plate- Out</u>	<u>Fog Spray</u>	<u>Filter System</u>	
Noble Gases	100	100	100	100	100
Halogens	50	50	50	5	0.6
Volatile Solids	50	30	50	0.05	0.004
All Remaining Fission Products	1	30	50	0.05	0.00008

TABLE III

AMOUNT OF URANIUM AND INVENTORY OF RADIOACTIVE FISSION PRODUCTS
K AND B REACTORS

Re-actor	Quantity of Uranium (in tons)		Fission Product*	Fission Products in Core at Shutdown in curies	Quantity of Fission Products Released to the Atmosphere Following "Maximum Credible Accident" Expressed as curies at Selected Decay Times						
	in Core	Equivalent Melt "MCA"			2 hours	4 hours	8 hours	1 day	2 days	5 days	10 days
K	432	4	NG	2.7 (9**	5.6 (6	4.9 (6	4.2 (6	3.2 (6	2.4 (6	1.6 (6	8.4 (5
			H	2.1 (9	1.1 (5	8.8 (4	7.3 (4	4.8 (4	3.4 (4	1.8 (4	9.0 (3
			I-131	1.2 (8	1.4 (4	1.4 (4	1.4 (4	1.4 (4	1.2 (4	9.8 (3	6.4 (3
			VS	2.8 (9	280	200	180	160	130	84	49
			RFP	1.4 (10	80	71	63	54	40	33	25
			Total	2.2 (10	5.7 (6	5.0 (6	4.3 (6	3.2 (6	2.5 (6	1.6 (6	8.5 (5
B	225	5	NG	1.2 (9	5.8 (6	5.1 (6	4.4 (6	3.3 (6	2.5 (6	1.7 (6	8.7 (5
			H	9.3 (8	1.1 (5	9.2 (4	7.6 (4	5.0 (4	3.5 (4	1.9 (4	9.4 (3
			I-131	5.3 (7	1.5 (4	1.5 (4	1.5 (4	1.4 (4	1.3 (4	1.0 (4	6.6 (3
			VS	1.2 (9	300	210	190	170	140	88	51
			RFP	6.1 (9	75	66	57	42	34	26	21
			Total	9.4 (9	5.9 (6	5.2 (6	4.5 (6	3.3 (6	2.6 (6	1.7 (6	8.8 (5

* NG - Noble Gases (Xe, Kr)

H - Halogens (Br, I)

VS - Volatile Solids (Se, Te, Cs)

RFP - All Remaining Fission Products

** 2.7 (9 = 2.7×10^9

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TABLE IV

FISSION PRODUCT RELEASE FACTORS
K AND B REACTORS

<u>Fission Products</u>	<u>Percent of Inventory in Failed Fuel:</u>			
	<u>Fuel</u>	<u>Escaping;</u>		<u>Released to Atmosphere</u>
		<u>Plate- Out</u>	<u>Filter System</u>	
Noble Gases	100	100	100	100
Halogens	50	50	5	1
Volatile Solids	50	30	0.05	0.008
All Remaining Fission Products	1	30	0.05	0.0002

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FIGURE N-1

N-Reactor
Total Body Dose at 2.5 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
Fission Product Release as in Table II

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FIGURE N-2

N-Reactor
Total Body Dose at 5.5 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
Fission Product Release as in Table II

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FIGURE N-3

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N-Reactor
Total Body Dose at 16 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
Fission Product Release as in Table II

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FIGURE N-4

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N-Reactor
Total Body Dose at 2.5 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
All Fission Products Released From Fuel are
Released to Atmosphere

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FIGURE N-5

N-Reactor
Total Body Dose at 5.5 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
All Fission Products Released From Fuel are
Released to Atmosphere

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FIGURE N-6

N-Reactor
Total Body Dose at 16 Miles

Assumptions: Stable Atmosphere
Invariant Wind Velocity
All Fission Products Released from Fuel are
Released to Atmosphere

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FIGURE N-7

N-Reactor
Total Body Dose at 2.5 Miles

Assumptions: Stable Atmosphere
Variable Wind Velocity
Fission Product Release as in Table II

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FIGURE N-8

N-Reactor
Total Body Dose at 5.5 Miles

Assumptions: Stable Atmosphere
Variable Wind Velocity
Fission Product Release as in Table II

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N-Reactor
Total Body Dose at 16 Miles

Assumptions: Stable Atmosphere
Variable Wind Velocity
Fission Product Release as in Table II

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N-Reactor

Total Body Dose at 2.5 Miles

Assumptions: Stable Atmosphere
Variable Wind Velocity
All Fission Products Released From Fuel are
Released to Atmosphere

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Released to Atmosphere

50% Melts

10% Melts

1% Melts

Time After Shutdown in Hours

Time After Shutdown (Hours)	50% Melts (%)	10% Melts (%)	1% Melts (%)
2	~80	~15	~1.5
3	~150	~30	~2.5
4	~200	~40	~3.5
5	~230	~45	~4.0
6	~240	~47	~4.2
7	~245	~48	~4.3

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N-Reactor
Total Body Dose at 16 Miles

Assumptions: Stable Atmosphere
Variable Wind Velocity
All Fission Products Released from Fuel are
Released to Atmosphere

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K-Reactor
Total Body Dose at 2.5 Miles

Exposure Begins About 3 Hours
After Shutdown

FIGURE K-2

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K-Reactor
Total Body Dose at 5.5 Miles

Exposure Begins About 4 Hours
After Shutdown

FIGURE K-3

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K-Reactor
Total Body Dose at 16 Miles
Exposure Begins About 9 Hours
After Shutdown

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B-Reactor
Total Body Dose at 2.5 Miles

FIGURE B-2

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B-Reactor
Total Body Dose at 5.5 Miles

Exposure Begins About 4 Hours
After Shutdown

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FIGURE B-3

B-Reactor
Total Body Dose at 16 Miles

FIGURE A

Probability of Reactor Accidents

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