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EMERGENCY COOLING AND AIR FILTRATION
SYSTEMS FOR HAPO REACTORS

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EMERGENCY COOLING AND AIR FILTRATION SYSTEMS

FOR HAP0 REACTORS

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EMERGENCY COOLING AND AIR FILTRATION SYSTEMS FOR HAPD REACTORS

I. INTRODUCTION

This report represents a critical review of existing reactor cooling systems and discusses suggested supplementary cooling system which might be employed in emergencies resulting from such natural hazards as earthquake, equipment failure, or personnel error. In addition the subject of building filtration is discussed.

Maintenance of an uninterrupted flow of cooling water is of major concern to the safety of any HAPD reactor. For some time supplementary cooling systems which would be capable of removing heat output in the event of failure in the existing emergency backup systems have been under scrutiny. Loss of coolant may cause a damaging power excursion (should this occur during operation) or will inevitably result in fuel melting and a subsequent release of fission products to the atmosphere, even if the reactor is shut down prior to the loss of coolant.

II. SUMMARY AND CONCLUSIONS

The present backup water supply systems are able to furnish water for any desired period in the event that the supply from a reactor's river pumphouse is cut off. However, it is assumed that the present backup systems have not been damaged. Occurrence of an earthquake of sufficient intensity to render ineffective the present backup systems would necessitate a damage resistant supplementary cooling system if disaster is to be prevented. The proposed system that appears to have the most merit consists of a rock filled, concrete lined tunnel to conduct water from the river to a point near the reactor where the water would then be pumped into the reactor. A water-tight, reinforced concrete enclosure located below ground would be used to house the pumps and diesel engines together with fuel tanks.

With regard to justification of this system one can only say that it is not impossible to experience an earthquake of sufficient intensity to destroy components of the existing piping.

The filtration system currently receiving the most favorable reception provides for a fog spray at the rear face of the reactor, along with a filter building and either a scrubber building or dry halogen removal equipment. This system would be designed to remove approximately 99.95 percent of the particulates and at least 50 percent of the halogens from the air passed through it, but only minor amounts of the noble gases.

III. DISCUSSION

3.1 Coolant Supply System (F Reactor, K Reactor)

3.1.1 Description of Facilities

At present the principle of continuity of water supply is supported by multiple pumping units with electrical primary power, and steam standby power; by multiple storage tanks, some of which are capable of supplying cooling water to the reactors by gravity flow; by

multiple pipe-lines within each reactor area; and by pipelines interconnecting the reactor areas. A schematic diagram of a representative Hanford reactor cooling system is shown in Figure 1. In addition, the water flow from the river to the reactor for a typical single reactor area (such as F reactor) is shown in Figure 2 while the corresponding representation of flow for K reactor is shown in Figure 3. The reactor area water flow pattern is also shown schematically in Figures 4 and 5.

3.1.2 Operation of Backups

In the event that the water supply from the river pumphouse is lost the reactor would be shut down immediately. For at least four days after shutdown filtered water is available (B, C, D, F, and DR reactors). Water for at least another three days cooling is available from the raw water reservoirs. If pumping power is available this water may be filtered and used in the normal fashion. When this supply of water is exhausted, raw import water will be used to cool the reactor. This supply will be continuous as long as export pumps continue to function at other areas.

In the case of the K reactors which have no raw water reservoirs, filtered water may be supplied for at least two days. A few hours after shutdown adequate flow may be furnished by the companion reactor.

3.1.3 Failure Experience

A brief history of failures and fission release incidents experienced in the Hanford reactors to date are summarized in Table 1.

3.1.4 Consequences of Inadequate Cooling

A general qualitative estimate of fission product release associated with inadequate cooling of the fuel elements is presented in Table 2.

3.2 Emergency Cooling

3.2.1 Perspective

The following disaster initiation events have been considered in previous studies⁽²⁾⁽⁵⁾⁽⁶⁾ as those situations which could result in loss of coolant to a reactor and the possible need for supplementary cooling:

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- a. Faulty operation procedures whereby coolant loss results from some unintentionally incorrect act or practice.
- b. Failure of equipment to operate as required.
- c. Natural phenomena such as earthquakes and meteors.
- d. Events resulting from enemy action (bombing, commando raid, flood and sabotage).

The existing coolant systems are not particularly blast and flood resistant, but according to previous studies, it appeared possible to provide a supplementary cooling system which could remain operable as long as the reactor structure itself remained intact.

3.2.2 Proposed Emergency Cooling System and Costs

No attempt is made in this document to recommend a supplementary cooling system for preventing a reactor disaster resulting from enemy action owing to the lack of necessary information for an evaluation of economic incentives. It is believed that cooling emergencies arising from faulty operation procedures and equipment failure can be best circumvented by means of: stringent process standards, thorough training of operating personnel, and by providing control and cooling system equipment capable of automatic action. Operating procedures and equipment failures have been a subject of continuing effort at HAPO, but the problem of earthquake damage may require further mention. In this light it may be desirable to provide a supplementary cooling system of high damage resistance composed of a system as nearly independent as possible from the existing one.

As a result of previous studies of supplementary cooling systems⁽²⁾⁽³⁾⁽⁵⁾ designed to provide protection against enemy caused coolant system loss various systems have been scoped. One suggested system⁽⁶⁾ in particular appears to have merit for preventing coolant loss due to earthquakes. This system provides for the flow of raw river water through a rock filled, concrete lined tunnel under gravity head to a point near each reactor building where a deep well turbine type pump would deliver it via well protected pipes to each reactor.

The process tubes could be supplied by either of two paths depending on the extent of damage to reactor front and rear face piping.

The first path would be via separate front face risers which connect to each crossheader at a point between the existing check valves while the alternate path would be via of the existing rear face risers. This alternate path would be employed in the event of front face piping destruction.

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The system capacity would provide about 15 percent of operating flow when the water is supplied to the front face and about 6 to 8 percent of operating flow if the water is supplied to the rear face. Water flow to the front face would be adequate to prevent boiling in the process tubes if about 50 seconds elapsed after reactor scram before water was lost from the existing system while water supplied from the rear face would be adequate to prevent boiling at about 10 to 15 minutes after scrambling the reactor.

With regard to damage resistance of the proposed system, the rock filled supply tunnel would be well suited to resist earthquake, flood, and bomb damage. The engines and pumps, together with the necessary fuel storage tanks and other auxiliaries would be installed in a water-tight, reinforced concrete enclosure (monolithic construction) located below ground with air intake and exhaust lines routed to a point above grade. The pipelines to the reactor and auxiliary front face risers would be designed so as to have the maximum isolation from earthquake or blast induced motion. There are additional assurances of system survival due to the fact that the heavy concrete walls which surround the rear face work area protect the rear face piping to a greater degree than is possible for the front face.

It has been estimated that the above system would cost in the neighborhood of \$14,000,000 for all reactors and that an outage of about 10 days per reactor would be necessary to modify existing piping and to tie in the proposed system. There is the possibility that this work could be timed so as to coincide with other outages.

3.2.3 Status of Proposal

The proposal itself has not progressed beyond the scoping stage but tentative construction schedules and drawings of the proposed plot plan and front face piping modifications have been made.

3.2.4 Justification for Facility

As in all studies of this type the assessment of the probability of occurrence of any incident remains the most obscure point. Thus far the incentive for providing a supplementary cooling water system arises primarily from the necessity of preventing nuclear incidents resulting from earthquakes.

It is virtually impossible to predict the probability of the occurrence of earthquakes since this would have necessitated the availability of records of earthquake activity for several hundred years. However, according to previous documents, (11)(6) the HAP0 plant facilities fall within the classification of Zone 2 of the U.S. Coast and Geodetic Survey Seismic Probability Map.

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This implies the possibility, over a period of decades, of damage of the general nature indicated by the M-M7 and 8 levels of the Modified Mercalli Intensity scale of 1931, the geology of this region being classified largely as unconsolidated sediments rather than basement rock. However, it is impossible to state with certainty that earthquakes of intensity higher than M-M8 will not be experienced at HAP0.

It is not known what maximum earthquake intensity could be successfully withstood by certain critical components such as the valve pit piping and risers or the inter-area export system pipeline. In the case of valve pit and riser piping, it can be estimated that intensities corresponding to about M-M9 or 10 would be required before these pipes were damaged. It has been observed that well designed pipe runs are not damaged by earthquakes in this intensity range. However, the inter-area export line appears more susceptible to damage owing to the length of the system and the fact that portions of it are constructed of steel reinforced concrete pipe.

3.3 Building Filtration

3.3.1 Perspective

Numerous methods⁽⁷⁾ have been studied which would control potential air borne contamination from existing Hanford reactors. There have been three schemes proposed. The first scheme provides for the filtration of all exhaust air to the ventilation stack with the provision for a fog spray system within the rear face enclosure and either a scrubber building or dry halogen removal system. The second scheme entails sealing certain parts of the 105 Building to resist an internal pressure buildup of 0.2 psig together with filters and fog sprays for contamination control. The third scheme allows for the erection of a domed structure, to cover the top of the 105 Building, which will resist an internal pressure of buildup of 2 psig. Fog-sprays and caustic scrubbers would be available inside the dome for reducing the amount of halogens released to the atmosphere.

3.3.2 Proposed Filtration System and Costs

According to previous studies the first scheme appears to be the most feasible approach to the problem of building filtration for the existing reactors. This proposed system consists of a filter building in the air exhaust tunnel containing two stage filter banks. Both the first and second stages consist of banks of 8 filters wide by 9 filters high with the first stage bank acting as a roughing filter and the second stage bank as a fine or "absolute" filter. Provision is made for routine contact maintenance to clean and/or replace filter elements and for remote

removal of filter banks if necessary. In addition, it is possible to abandon the entire filter building through the inclusion of proper isolation seals and a connection to a new filter building.

After leaving the filter building the air passes through a scrubber building in which a series of nozzles spray filtered water into the air stream. The spray will condense around and settle out most of the remaining fission product particulate matter and will absorb some of the halogen gases in the air stream. Upon leaving the scrubber building, the air passes out of the ventilation stack.

A further variation to this scheme that is strongly being considered is a dry halogen removal system⁽¹²⁾ instead of the scrubber building. This system would be installed in the filter building.

There is a provision for an additional spray system to be installed within the rear face enclosure of the reactor building area which would dispense a dense fog blanket over the discharge area in the event of a slug fire or other gross contamination within this enclosure. This spray system will perform the same primary functions that the scrubber system with the additional function of providing some degree of thermal cooling for any possible exposed slugs that may become lodged in the rear face piping or on the elevator.

It was estimated that the collection efficiency of the filter system would be 99.95 percent or greater for sub-micron particles present in low concentrations and that at least 50 percent of the radioactive iodine and bromine would be removed from the exhaust air.

As far as operation of this filtration system is concerned there are two proposals: (1) operate the filtration and scrubber buildings 100 percent of the time with the rear face spray actuated only by a continuous high reading of radioactivity at the rear face and (2) by-pass the filter and scrubber buildings with exhaust air being routed through the filters only upon an indication of radioactive contamination in the exhaust air stream. However, in the latter method of operation it would be possible to re-route the exhaust air through the proposed filter system during the charge-discharge function. It has been estimated⁽⁷⁾ that the total project cost for converting all eight of the existing reactors to method (1) would cost approximately \$3,600,000 while method (2) would cost \$3,900,000.

3.3.3 Status of Project

The proposals have been studied and a cost breakdown has been submitted. In addition, a tentative schedule has been outlined

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and scoping drawings have been issued for comment so that now construction funds are being sought.

3.3.3 Justification for Project

Several types of incidents giving rise to the omission of fission products that have been previously studied are tabulated in Table 2. According to this table and Table 1, which is a history of fission product release from HAPD reactors, the most probable incident is slug burning. It has been assumed⁽¹⁰⁾ that the maximum expected probability of fires involving a small fraction of a slug would be of the order of one per reactor year and that the probability of a whole slug being consumed might be of the order of about one per 10 to 100 reactor years.

The amount of fission products escaping from the reactor block for a number of incidents is listed in Table 3. These values are based on 100 days' operation at a 2000 MW reactor power level, and one minute decay time after shutdown. As in previous studies⁽⁹⁾⁽¹⁰⁾ the release is assumed to consist of 25 percent of the total available material, proportioned as 100 percent of the noble gases, 70 percent of the halogens, and 10 percent of the particulates.

In order to gain an idea of the usefulness of the filtration system proposed the following release coefficients may be assumed:

noble gases	1
halogen	0.5
particulate	0.001

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TABLE 1
HISTORY OF FISSION PRODUCT RELEASE INCIDENTS

<u>Type</u>	<u>No. of Occurrences</u>	<u>Circumstances</u>	<u>Fission Product Release</u>
1. Single Tube Melting	1	Initial start-up of New Reactor	No release beyond shielding.
2. Pigtail Failure	1	Inadequate Maintenance Procedure.	None
3. Reactor Stack Emissions	5	Discharge of ruptured fuel elements (partial slug burning)	a. Worst case -- Low level contamination to 5 mi. Radiation protection to 100 Area. b. Three cases - Contamination confined to 100 Area. c. One case -- No contamination detected outside 105 Building.
4. Miscellaneous	1	107 basin dried (wind spread active material)	Detectable about 5 mi.

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TABLE 2

REACTOR ACCIDENTS

<u>Type</u>	<u>Cause</u>	<u>Order of Magnitude Release Probable</u>	<u>Probability</u>
1. Inadequate shut-down cooling	Violation of Standards	None	Moderate
2. Slug burning	Discharge of Ruptured Fuel	Small	Low
3. Loss of cooling to single channel	Pigtail failure	A. Safety operates (small)	Very low
		B. Safety fails to operate (moderate)	
4. Loss of cooling to multiple channels	Several pig-tails or a crossheader fails.	A. Small	Extremely low verging on maximum credible.
		B. Moderate to Major.	
5. Full reactor meltdown	Gross loss of piping at reactors	Very large	Probably not credible.

TABLE 3

RELEASE TO BUILDING OF FISSION PRODUCT FRACTIONS

Incident	Power Level, MW	Total Inventory, Curies*	Release to Building, Curies*	Noble Gases, Curies*	Halogens, Curies*	Particulates, Curies*
0.1 Tube	0.1	4×10^5	1×10^5	4×10^4	3×10^4	3×10^4
1 Tube	1	4×10^6	1×10^6	4×10^5	3×10^5	3×10^5
4 Tubes	4	1.6×10^7	4×10^6	1.6×10^6	1.1×10^6	1.3×10^6
150 Tubes	150	6×10^8	1.5×10^8	6×10^7	4×10^7	5×10^7
Full Reactor	2000	6×10^9	1.5×10^9	6×10^8	4×10^8	5×10^8

*All activities are based on 100 days' operation and 1 minute after shutdown.

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FIGURE 1

Schematic Diagram of Representative Hanford Reactor Cooling System

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FIGURE 2
w Diagram River to Reactor

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RE 3
Water Plant

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FIGURE 4
Reactor Area - 100-F

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FIGURE 5
Reactor Area - 100-KE-KW

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