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MEMORANDUM FOR: Roger J. Mattson, Director
Division of Systems Integration

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: SCHEDULE FOR RESOLVING AND COMPLETING GENERIC ISSUE NO. 82 - BEYOND DESIGN BASES ACCIDENTS IN SPENT FUEL POOLS

This memorandum approves of a priority ranking of "MEDIUM" for Generic Issue 82, "Beyond Design Bases Accidents in Spent Fuel Pools." The evaluation of the subject issue is provided in Enclosure 1.

In accordance with NRR Office Letter No. 40, "Management of Proposed Generic Issues," the resolution of this issue will be monitored by the Generic Issue Management Control System (GIMCS). The information needed for this system is indicated on the enclosed GIMCS information sheet. Your schedule for resolving and completing this generic issue should be commensurate with the FY 1984-1986 NRR budget request and the guidelines in the NRR Operating Plan for completing medium priority issues. Normally, as stated in the Office Letter, the information needed should be provided within six weeks.

The attached prioritization evaluation will be incorporated into NUREG-0933, "Prioritization of Generic Safety Issues," and is being sent to other NRC offices, the ACRS, and the PDR for comments on the technical accuracy and completeness of the prioritization evaluation. Any changes as a result of comments will be coordinated with you. However, the schedule for the resolution of this issue should not be delayed to wait for these comments.

The information requested should be sent to the Safety Program Evaluation Branch, DST. Should you have any questions pertaining to the contents of this memorandum, please contact Louis Riani (24563).

Original Signed by
H R. Denton

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

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Enclosures:
1. Prioritization Evaluation
2. Generic Issue Management Control System

cc: See next page

AD/T:DST
MFarm
11/30/83

*SEE PREVIOUS SHEET FOR CONCURRENCE

OFFICE	DST:SPEB	DST:SPEB	DST:AD/T	DST:D	PPAS:D	NRR:DD	NRR:D
NAME	*LRiani/LLM	*WMinners	FRowsome	TSpeis	JFunches	ECase	HDenton
DATE	11/18/83	11/29/83	11/27/83	11/29/83	12/1/83	12/1/83	12/7/83

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Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Enclosures:
1. Prioritization Evaluation
2. Generic Issue Management Control System

cc: See next page

AD/T:DST
MFarr
11/ /83

OFFICE	DST:SPEB	DST:SPEB	DST:AD/T	DST:D	PPAS:D	NRR:DD	NRR:D
SURNAME	LRiani/LLM	WMinners	FRowsome	TSpeis	JFunches	ECase	HDenton
DATE	11/18 /83	11/29/83	11/ /83	11/ /83	11/ /83	11/ /83	11/ /83

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ENCLOSURE 1

ITEM 82--BEYOND DESIGN BASIS ACCIDENTS IN SPENT FUEL POOLS

DESCRIPTION

Historical Background

The risks of beyond design basis accidents in the spent fuel storage pool were examined in WASH-1400 (Ref. 16, App. I, pp. I-96ff). It was concluded that these risks were orders of magnitude below those involving the reactor core. The basic reason for this is the simplicity of the spent fuel storage pool--the coolant is at atmospheric pressure, the spent fuel is always subcritical and the heat source is low, there is no piping which can drain the pool, and there are no anticipated operational transients that could interrupt cooling or cause criticality.

The reasons for re-examination of spent fuel storage pool accidents are two-fold. First, spent fuel is being stored instead of reprocessed. This has led to the expansion of onsite fuel storage by means of high density storage racks, which results in a larger inventory of fission products in the pool, a greater heat load on the pool cooling system, and less distance between adjacent fuel assemblies. Second, some laboratory studies have provided evidence of the possibility of fire propagation between assemblies in an air-cooled environment.[a,b] These two reasons, put together, provide the basis for an accident scenario which was not previously considered.

Safety Significance

A typical spent fuel storage pool with high density storage racks can hold roughly five times the fuel in the core. However, since reloads typically discharge one third of a core, much of the spent fuel stored in the pool will have had considerable decay time. This reduces the radioactive inventory somewhat. More importantly, after roughly three years of storage, spent fuel can be air-cooled. That is, such fuel need not be submerged to prevent melting. (Submersion is still desirable for shielding and to reduce airborne activity, however.)

If the pool were to be drained of water, the discharged fuel from the last two refuelings would still be "fresh" enough to melt under decay heat. However, the Zircaloy cladding of this fuel could be ignited during the heatup.[a] The resulting fire, in a pool equipped with high density storage racks, would probably spread to most or all of the fuel in the pool. The heat of combustion, in combination with decay heat, would certainly release considerable gap activity from the fuel, and would probably drive "borderline aged" fuel into a molten condition. Moreover, if the fire becomes oxygen-starved (quite probable for a fire located in the bottom of a pit, such as this), the hot zirconium would rob oxygen from the uranium dioxide fuel, forming a liquid mixture of metallic uranium, zirconium, oxidized zirconium and dissolved uranium dioxide. This would cause a release of fission products from the fuel matrix quite comparable to that of molten fuel.[a]

In addition, although confined, spent fuel pools are almost always located outside of the primary containment. Thus, release to the atmosphere is more likely than for comparable accidents involving the reactor core.

Possible Solutions

No generic solution to this potential problem has yet been identified. Several possibilities exist, however. The first possibility is to reprocess the spent fuel, and thus reduce the inventory in the pool. Second, the pool could be compartmentalized by installing partitions (and individual coolant supply diffusers for each compartment), thus limiting the extent of an accident. Third, spray headers could be installed to provide cooling even when the pool is drained and not refloodable.

Priority Determination

LWR spent fuel storage pools do not differ greatly. None are equipped with drains; a portable pump must be brought in when it is desired to empty the pool. The cooling systems are provided with antisiphoning devices (check valves and/or antisiphoning holes) so that pipe breaks in the cooling system will not drain the pool. All are seismic Category I. One difference does exist: PWR pools are generally below grade (often on bedrock), while BWR pools are considerably above grade. Thus, even a hole in the bottom of the pool will not rapidly drain a PWR pool. This priority determination therefore is concentrated on a BWR pool, because of its (somewhat) greater vulnerability.

Frequency

BWR spent fuel can be uncovered either by extended loss of pool cooling, which results in boiloff, or by an accident which drains the pool. We shall consider both mechanisms.

Typically, a BWR spent fuel storage pool has no drains. Instead, coolant is withdrawn at the surface by skimmers, which conduct the water into two surge tanks. The cooling system consists of two pumps and two heat exchangers, which reject heat to the Reactor Building Closed Cooling Water (RBCCW) system. These are not independent trains. The suction on the surge tanks is common, and flow from the heat exchangers is combined to go through one filter/demineralizer before it is returned to the spent fuel pool. Return is by means of a set of diffusers located near the bottom of the pool. The piping connected to the diffusers contains check valves or some other antisiphoning device.

Immediately after a refueling, both pumps and heat exchangers are usually needed. After a few months of decay, the heat load will diminish to the point where only one pump and heat exchanger are needed. Water makeup is normally via the Condensate Transfer System, which is connected to one of the surge tanks.

The spent fuel pool cooling system is cross connected to one train of the Residual Heat Removal (RHR) system at both inlet and outlet. The primary reason for this is to allow use of RHR for supplementary fuel pool cooling during periods when an entire reactor core is off-loaded. However, this also provides a back-up means of pool cooling. In addition, since the RHR suction can be lined up to the condensate storage tank or even to river water, RHR also provides a backup means of maintaining pool water inventory.

Control and operation of the spent fuel pool cooling system and RHR crossties is not performed from the control room; most of the valves involved are manually operated. However, if pool cooling is lost, it will take over two days for the pool temperature to rise to boiling, and at least two days more for the level to drop to the top of the fuel assemblies, even under design heat load conditions. Moreover, there are level alarms on the surge tanks and the pool itself in the control room. Thus, even though the systems are not automatic, the long time intervals involved should be sufficient to prevent problems with human confusion, etc.

WASH-1400 estimated the frequency of loss of one spent fuel pool cooling "train" to be 0.1 per reactor-year. We will assume, based on experience with other systems, that the conditional probabilities of the second "train" also failing due to a common-mode problem is 5%, and due to a random failure, 1.5%. In addition to this, the second pump and heat exchanger are in use (i.e. are not a redundant backup) about 30% of the time. Thus, the combined frequency of a pool heatup event is 3.7 E-2 per reactor-year.

To go from a pool heatup event to an event that threatens the fuel, several other failures must occur. First, the RHR system must fail, both as a cooling system and as a supply of makeup water. For this, we assume a conditional probability of 1.5%, based on RHR's reliability in the LPCI mode.[16] Second, the condensate transfer system could be used as a makeup system, either by supply to the fuel pool cooling system suction or (if the pool cooling system is isolated) by overfilling the surge tanks and causing backflow into the fuel pool. Since the condensate system is not powered by emergency power busses, it may well be put out of service by any common mode failure of the spent fuel pool cooling system. Thus, we will assume a conditional failure probability of 5% for the condensate transfer system.

Ultimately, makeup to the pool could be supplied by bringing in a fire hose (60 gpm would suffice). Although one would expect that the failure probability associated with bringing in a hose (over a period of four or more days) would be very low, it must also be remembered that working next to 385,000 gallons of potentially contaminated boiling water on top of a 10-story building is not a trivial problem. We will assume, based purely on judgment, that the conditional failure probability for this method of makeup is on the order of 5%.

When these probabilities are combined, the result is a frequency of 1.4 E-6 per reactor-year for an accident initiated by loss of spent fuel pool cooling.

Several events could cause an accident by draining the pool. We will first examine those events which are not likely to cause gross failure of the confinement system. First, there is the possiblity of a break in the cooling system (beyond the condensate transfer makeup capacity) which we estimate to happen no more often than once per thousand reactor years (the "S2" frequency). To drain the pool, the antisiphoning check valves must fail (conditional probability of 8%, based on a German component failure study) and there must be a failure of the pool cooling system to isolate (conditional failure probability of 1%, based purely on judgment). RHR should provide sufficient makeup, since each RHR pump can supply 10,000 gpm and normal maximum fuel pool flow is 1200 gpm. However, RHR may be inoperable, for which we assume a conditional probability of 1.5% (based on WASH-1400). When these figures are combined, the siphoning scenario is estimated to occur with a frequency of 1.2 E-8 per reactor-year.

In addition, the pool could be drained by a cask drop accident (frequency 2.5 E-7/RY, from WASH-1400) or a turbine missile (4.1 E-7/RY, also from WASH-1400). Here, the RHR might not have sufficient capacity, and the time frame is not as long as the previous scenarios. We will assume, based again on judgment, that the combined RHR conditional failure probability is 10%. This gives an accident frequency of 6.6 E-8/RY. If we add the 1.2 E-8/RY from the siphoning scenario, the total frequency for this class of accidents is 7.8 E-8 per reactor-year.

Finally, we come to two scenarios which will could open up the pool to the atmosphere as well as drain it. First, there is the tornado missile (& 5 E-6/RY, from WASH-1400). This should not simultaneously cause failure of RHR. However, RHR may be otherwise inoperable (in this shorter time frame) or have insufficient capacity. We will assume that the combined RHR conditional failure probability is 5%. This gives an accident frequency of 2.5 E-7 per reactor-year.

Second, a seismic event could breach the pool. The WASH-1400 estimate for this is 10-5 to 10-7 per reactor-year, depending on the site. We will use the higher figure, recognizing that this will limit the number of sites to which the analysis will apply.

After a seismic event severe enough to breach a seismic Category I spent fuel pool, the probability of RHR failure is higher than that of our previous scenarios. Moreover, the RHR might not be able to supply enough makeup. Finally, the time frame is very short, considering that manual valves must be opened and other earthquake-induced problems may be distracting plant personnel. We will assume that 90% of the time, the draining rate will be low enough to both be within the capacity of RHR makeup and also be slow enough to allow operator diagnosis and the necessary manual lineup of RHR to the pool. We will further assume a 90% probability of RHR remaining operable after the earthquake. This gives a total failure conditional probability of 19%.

Thus, for a site with a high seismic probability, the frequency of earthquake-induced accidents is estimated to be 1.9 E-6 per reactor-year. Adding the tornado-induced accident frequency to this, we get a frequency for this class of accidents of 2.2 E-6.

Consequences

A BWR spent fuel storage pool with high density racks may contain almost 3500 fuel bundles, which is about 4½ times the inventory of the reactor core. Thus, an accident in the spent fuel pool can threaten much more fuel than a reactor accident. Compensating for this is the fact that much of the stored spent fuel has had considerable time for decay of hazardous radioactive fission products. To estimate the hazard to the public from melting of the spent fuel pool inventory, special CRAC2 runs were performed,[e] using the usual "prioritization assumptions" of a uniform population density of 340 persons per square mile, a central Midwest plains meteorology, and no ingestion pathways.[c] The calculations were performed for a spent fuel pool with a series of 1/3-core reload modules. The first module had one week decay time. The second, 18 months, the third, 3 years, and so on for a total of 13 modules. Cases were run using release fractions from the BWR-2, BWR-3 and BWR-4 release categories. This corresponds to release direct to atmosphere, release through a hole in the secondary containment, and release with the containment at design leakage and SBGT operable. The results of the calculations, and their corresponding frequencies from the previous section, are:

Analagous Release Category	Frequency (RY)-1	Consequences (man-rem)	Product (man-rem/RY)
BWR-2	2.2 E-6	7.4 E+6	16.3
BWR-3	7.8 E-8	6.5 E+6	0.5
BWR-4	1.4 E-6	1.1 E+6	1.5
		Total	18.3

It should be noted that this analysis is predicated on the assumption that the exposed elements will burn; and that the fire will propagate throughout the pool. Additional research is necessary to substantiate this hypothesis.

Costs

As was discussed previously, no specific solution to this potential problem has yet been settled upon. However, any hardware addition would probably have to be seismic Category I, and thus costs are unlikely to be less than one million dollars. NRC costs will be negligible compared to licensee costs.

Assuming a 40 year plant life, priority parameters are estimated as follows:

Man-rem/reactor = 700
Priority Score S & 700 man-rem/million dollars.

It should be noted that a low seismic probability will drop these figures to about 200 man-rem and 200 man-rem per million dollars. This will not change our final conclusion. In any case, this analysis has been based on a specific pool design, which was picked in an attempt to be both generic and worst-case. Thus, the number of plants actually at risk may be limited.

Conclusion

Based on the available information and the figures calculated above, this item should be given MEDIUM priority.

REFERENCES

16. WASH-1400 (NUREG-75/014), "Reactor Safety Study, an Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," U.S. Nuclear Regulatory Commission, October 1975.

a. Memorandum for T. Speis from R. J. Mattson, "Proposed Generic Issue on Beyond Design Basis Accidents in Spent Fuel Pools," August 10, 1983.

b. NUREG/CR-0649 (SAND 77-1371), "Spent Fuel Heatup Following Loss of Water During Storage," A. S. Benjamin et al, March 1979.

c. NUREG-0933, "A Prioritization of Generic Safety Issues," U.S. Nuclear Regulatory Commission (in press).

d. Memorandum for Z. Rosztoczy from P. William, "Trip Report: International Meeting on Severe Fuel Damage and Visit to Power Burst Facility," April 25, 1983.

e. Letter to H. Vander Molen from D. Strenge (PNL), September 30, 1983.

ENCLOSURE 2

GENERIC ISSUE MANAGEMENT CONTROL SYSTEM

The Generic Issues Management Control System (GIMCS) provides appropriate information necessary to manage safety related and environmental generic issues through technical resolution. For the purpose of this information system technically resolved is defined as the point where the staff's technical resolution has been issued. Generally, speaking, this occurs when the technical resolution has been invorporated into one or more of the following:

(a) Commission policy statement/orders
(b) NRC Regulations
(c) Standard Review Plan
(d) Regulatory Guide
(e) Generic Letter

GIMCS will provide management information for both active and inactive issues. Accordingly, the control system consists of two parts: Active and Inactive.

GENERIC ISSUE MANAGEMENT CONTROL SYSTEM-ACTIVE (GIMCS-A)

The active section of GIMCS will provide information to manage and control High-priority generic issues, issues for which possible resolution has been identified for evaluation, issues for which a technical resolution is available (as documented by memorandum, analysis, NUREG, etc.), issues designated by the Director of NRR and previously inactive issues for which resources have become available.

GENERIC ISSUE MANAGEMENT CONTROL SYSTEM-INACTIVE (GIMCS-I)

The inactive section of GIMCS will provide management information for issues awaiting assignment of resources. These are generally Medium priority issues that have no safety deficiency demanding high-priority attention, but there is a potential for safety improvements or reduction in uncertainty of analysis that may be substantial and worthwhile. Efforts for resolution of these issues should be planned, over the next several years, but on a basis that will not interfere with the resolution of High-priority generic issue work or other high priority work. Thus, medium generic issues will be inactive until such time as resources become available to resolve the various issues. As resource allocations are directed at medium issue resolution, they will become active. The detailed schedule for resolving and completing the generic issue will be developed and the issue will be transferred from the GIMCS-inactive section to the GIMCS-Active section for management and control.

Management and control indicators used in GIMCS are defined as follows:

1. Item No. - Generic Issue Number.

2. Issue Type - Safety, Environmental or Regulatory Impact High, Note 1 or Note 2 (From NUREG-0933), Medium.

3. Schedule -
   - Green - Technical Resolution is on schedule.
   - Orange - Technical Resolution schedule has slipped 4 to 6 months.
   - Red - Technical Resolution schedule has slipped 6 to 12 months.
   - White - Technical Resolution is not scheduled during present fiscal year.

4. Office/Div/Br - 1st listed has lead responsibility for resolving issue, others listed have input to resolution.

5. Task Manager - Name of assigned individual responsible for schedule updating.

6. Tac Number - Each issue should be assigned a TAC #

7. Title - Generic Issue Title.

8. Work Authorization - Who or what authorized work to be done on generic issue.

9. Contract Title - Provide Contract Title (if contract issued).

10. Contractor Name/ FIN No. - Identify Contractor Name and FIN Number (as appropriate). If contract is not yet issued, indicate whether the contract is included in the FIN plan.

11. Work Scope - Describes briefly the work necessary to technically resolve and complete the generic issue.

12. Affected Documents - Identifies documents that the technical resolution will be incorporated into to identify new criteria.

13. Status - Describes current status of work.

14. Problem/Resolution - Identifies potential problem areas and describes what actions are necessary to resolve them.

15. Technical Resolution - Identifies detailed schedule of milestone dates that are required for completing the issue through the issuance of the SRP revision or other change that documents requirements.

16. Milestones - Selected significant milestones. The "original" schedule remains unchanged. Changes in schedule are listed under "Current". Actual completion are listed under "Actual".

TYPICAL MILESTONES

Other Division Involvement	Original	Current	Actual
o Date information requested from Division			
o Date received from Division			
Contractor Information			
o Proposal Solicited			
o Proposal Evaluated and Accepted			
o Contract Schedule, if applicable			
o Testing Schedule, if applicable			
o Draft NUREG/CR report from contractor/consultant			
Staff review of draft NUREG/CR report			
Value Impact Statement prepared (coordinated with SPEB and RRAB as applicable)			
Final report prepared by Division (include SPEB preliminary comments and SRP revision)			
---------- 2 wks			
Final report forwarded to DST for processing			
---------- 2 wks			
CRGR Package to NRR Director for Review			
---------- 1 mo			
OMB Clearance obtained concurrently if applicable			

Review Package to CRGR

---------- 1 mo

CRGR review and EDO approval completed

---------- 1 mo

Federal Register Notice of Issuance of SRP for Public Comment

---------- 3 mo

Division review of public comments completed

---------- 2 wks

Comments incorporated and transmitted to DST for processing

---------- 2 wks

Final CRGR package to NRR Director for review

---------- 1 mo

Review Package to CRGR

---------- 1 mo

CRGR review and EDO approval completed

---------- 1 mo

Federal Register Notice of Issuance of SRP

GENERIC ISSUE MANAGEMENT CONTROL SYSTEM-INACTIVE

Issue Number	Issue Type	Schedule	Office/Div/Br	Task Manager	Tac No

Title ----------

Work Authorization ---

Contract Title -------

Contractor Name/
FIN No. ----------

Work Scope ----------

Affected Documents ---

Status ----------

Problem/Resolution ---

Technical Resolution -

Milestones	Original	Current	Actual