ORG-NREA-900507

Research
PDR

Advance Copy

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

'90 MAY -8 P12:31

MAY 7 1990

MEMORANDUM FOR: Bill M. Morris, Director, Division of Regulatory Applications, RES

FROM: Eric S. Beckjord, Director, Office of Nuclear Regulatory Research

SUBJECT: GENERIC ISSUE 137, "REFUELING CAVITY SEAL FAILURE"

The prioritization of Generic Issue 137, "Refueling Cavity Seal Failure," shows that the estimated public risk posed by refueling cavity seal failures is small. Therefore, the issue will be DROPPED from further consideration. Prior to the evaluation, IE Bulletin 84-03 was issued to address the concern.

The enclosed prioritization evaluation will be incorporated into NUREG-0933, "A Prioritization of Generic Safety Issues," and is being sent to the regions, other offices, the ACRS, and the PDR, by copy of this memorandum and its enclosure, to allow others the opportunity to comment on the evaluation. All comments should be sent to the Advanced Reactors and Generic Issues Branch, DRA, RES (Mail Stop NL/S-169). Should you have questions pertaining to the contents of this memorandum, please contact Ronald Emrit (492-3731).

Eric S. Beckjord

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Enclosure:
Prioritization Evaluation

cc: T. Murley, NRR
E. Jordan, AEOD
T. Martin, Reg. I
S. Ebneter, Reg. II
A. Davis, Reg. III
R. Martin, Reg. IV
J. Martin, Reg. V
PDR
ACRS

080082

DF02
1/1

9610080285 900507
PDR ORG NREA
PDR

ENCLOSURE

PRIORITIZATION EVALUATION

Generic Issue 137: Refueling Cavity Seal Failure

ISSUE 137: REFUELING CAVITY SEAL FAILURE

DESCRIPTION

Historical Background

On August 21, 1984, the Haddam Neck plant experienced failure of a refueling cavity seal during preparations for refueling. The failure of the seal caused 200,000 gallons of water to drain from the refueling cavity into the lower levels of the containment building in 20 minutes. No fuel was being transferred at the time. If a similar seal failure were to occur at a plant during fuel transfer, fuel elements could be uncovered and could result in high radiation exposure to plant personnel, possible fuel cladding failure, and release of radioactive material. Also, because the refueling cavity is connected to the spent fuel storage pool, the potential exists for this seal failure to initiate drainage of the spent fuel pool, if the fuel transfer canal were open at the time.

Refueling cavity seal failure could lead to an event sequence not previously considered by the NRC, i.e., uncovering spent fuel being transferred and spent fuel in storage in the spent fuel pool. These sequences are not considered explicitly in the SRP[11] nor in the NRC guidance pertaining to acceptability of facility designs, technical specifications, operating procedures, and emergency procedures. The SRP[11] Sections that may be affected by this issue are 9.1.2 "Spent Fuel Storage," 9.1.3, "Spent Fuel Pool Cooling and Cleanup System," and 15.7.4, "Radiological Consequences of Fuel Handling Accidents." Regulatory Guide 1.25[1154] may also be affected.

Following the event at Haddam Neck, IE Bulletin N. 84-03[1158] was issued requiring licensees to investigate the potential for refueling cavity seal failures at their plants. Of the total responses received from OLs (72 plants with 112 units), 26 plants (40 units) use an inflatable reactor cavity seal. Most of the plants use a pressurized bladder of similar configuration to that used at Haddam Neck. Some significant differences between the Haddam Neck seal bladder design and those used at other plants were noted as well as other plant design features which might provide some capability to cope with the consequences of reactor cavity seal failure.

This issue is related to Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools," but was determined not to be encompassed within the scope of Issue 82.[1155] In Issue 82, a refueling cavity seal failure was not included as an initiating event for accidental draining of a spent fuel pool. Therefore, Issue 137 was established as a new generic issue rather than expand the scope of Issue 82 to include reactor cavity seal failures as an additional initiator of possible spent fuel pool accidents.[1156,1160]

Safety Significance

A refueling cavity seal failure is itself considered to be an initiating event for an accident sequence. The immediate result of a refueling cavity seal failure during fuel transfer is the loss of water from the refueling cavity.

The possible safety consequences are as follows: (1) high radiation levels in the containment due to uncovering of spent fuel in transfer; (2) radioactive material release in the containment building due to rupture of fuel pins (by self-heating after uncovering); (3) high radiation levels in the spent fuel building due to uncovering of stored spent fuel; and (4) radioactive material release outside the containment building due to rupture of fuel pins in the storage pool. The consequences involving the spent fuel pool are based on the assumption that the fuel transfer canal connecting the refueling cavity to the spent fuel pool is open at the time of the initiating seal failure and that the canal cannot be closed.

Pneumatic rubber seals similar to the one at Haddam Neck (used mainly at PWRs) are most vulnerable to failure. They are susceptible to misalignment, improper inflation, puncture, and rupture. Other types of seals, such as the permanent steel bellows on most BWRs, have been more reliable than pneumatic seals.[1157] At least 45 plants are equipped with pneumatic seals: 38 operating PWRs, 4 operating BWRs, and 3 PWRs under construction. Thirty-six of the affected plants use a seal with a single inflatable gland. Nine plants (including Haddam Neck at the time of the seal failure there) use a seal with two inflatable glands separated by a metal spacer ring. Only five plants indicated in their response to IE Bulletin No. 84-03[1158] that their spent fuel pools could possibly drain through a failed refueling cavity seal.

Possible Solution

The proposed resolution to this issue is actually made up of several resolutions which apply to different plants according to each individual plant's refueling cavity configuration, seal design, and operating procedures. The various aspects of the proposed resolution are based on assessments by the Haddam Neck staff[1159] and the NRC.[1156] All of the proposed actions are aimed at bringing the affected plants into conformance with the features employed at the nuclear plants that are least vulnerable to a refueling cavity seal failure and its consequences. Several of the proposed actions have already been implemented at Haddam Neck.

The overall proposed resolution includes both mitigative and preventive measures. Proposed mitigative measures include: (1) temporary reinforcement of existing seals until permanent corrective measures are implemented; and (2) implementation of procedures to assure prompt operator response to a leak and to gross seal failure (completed at Haddam Neck). Preventive measures include: (1) installation of improved-design seals at plants with single inflatable seals; (2) replacement of double inflatable seals with permanent steel seals (completed at Haddam Neck); and (3) installation of a coffer dam to prevent spent fuel pool draining through the refueling cavity at plants where this is possible (completed at Haddam Neck).

PRIORITY DETERMINATION

Frequency Estimate

Two accident sequences were considered: (1) refueling cavity seal failure resulting in serious transfer canal drainage; and (2) seal failure resulting in spent fuel pool drainage. The probabilities of these accidents were developed

from the frequencies of the steps in the accident sequences. The frequency of the initiating event, an inflatable refueling cavity seal failure, was estimated to be 10^{-2}/RY based on historical information compiled in NUREG/CR-4982[1157] and corroborated by PNL calculations.[64] In addition, in NUREG/CR-4982, it was estimated that the seal failure rate decreased by a factor of 10 to 10^{-3}/RY, due to improvements in design and increased awareness of the problem following the Haddam Neck incident.

The frequency of transfer canal drainage accidents (Y) was estimated by taking the product of the following: (a) the frequency of refueling cavity seal failure; (b) the probability that spent fuel is being transferred at the time of seal failure; and (c) the probability that reactor operators do not recover from the seal failure incident in time to prevent drainage of the refueling cavity. The probability that fuel is being transferred is estimated based on the assumption that, during a refueling outage at an average plant (i.e., with seal in place and canal flooded), fuel is actually in transit through the canal only a portion of the time. We have, therefore, assumed that the frequency of spent fuel being in transit concurrent with seal failure to be 0.5/RY. The frequency of non-recovery is taken from NUREG/CR-4982[1157] in which it is estimated to be 5×10^{-2}/demand. Thus, the frequency of refueling cavity seal failure resulting in serious transfer canal drainage (Y) is estimated to be:

$$Y = (10^{-3}/RY)(0.5)(5 \times 10^{-2}) = 2.5 \times 10^{-5}/RY$$

The parameter Z, the frequency of refueling cavity seal failure resulting in serious spent fuel pool drainage, is estimated to be the product of the frequency of spent fuel pool drainage and the probability of no recovery. The frequency of spent fuel pool drainage resulting from inflatable seal failure has been estimated at 10^{-5}/RY.[1157] This value incorporates the estimated seal failure rate of 10^{-3}/RY. The frequency of nonrecovery from this accident is assumed to be the same value (5×10^{-2}/demand) as that used above to estimate the value for parameter Y. The resulting frequency for parameter Z is:

$$Z = (10^{-5}/RY)(5 \times 10^{-2}/demand) = 5 \times 10^{-7}/RY$$

The next step in calculating radiation release frequencies is to multiply the accident frequencies by their respective containment failure probabilities. The applicable containment failure mode for Case Y is assumed to be represented by containment penetration leakage. The containment failure probability used in this issue was taken from Appendix A of NUREG/CR-2800,[64] which is based on the Oconee 3 PWR. Typical Technical Specifications for PWRs require that containment doors be close[illegible]d that penetrations be either closed or capable of being closed by automatic containment purge and exhaust isolation valves. The containment failure probability associated with penetration leakage is 7.3 x 10^{-3}. However, spent fuel pool building integrity is not required during fuel transfer and we have, therefore, assumed a containment integrity failure probability of 1. The release frequencies for parameters Y and Z are calculated as follows:

Transfer Canal

$F_y = (Y)(7.3 \times 10^{-3})$

$= (2.5 \times 10^{-5}/RY)(7.3 \times 10^{-3})$
$= 1.8 \times 10^{-7}/RY$

Spent Fuel Pool

$F_z = Z \times 1$

$= (5 \times 10^{-7}/RY) \times 1$
$= 5 \times 10^{-7}/RY$

Consequence Estimate

For the fuel transfer canal drainage scenario (Case Y), it was assumed that the events resulted in the uncovery of one fuel assembly, which is assumed to be in the transfer process at the time. It was also assumed that the exposed assembly undergoes overheating and melting and thus the site release was based on the NUREG/CR-2800[64] consequence calculated for PWR Category 4 and BWR Category 4 events. However, since the damaged fuel is limited to a single fuel assembly, the PWR and BWR consequence factors were reduced by a factor of 300 and 600, respectively. (The typical PWR core has about 300 fuel assemblies and the older BWR-2s have nearly 600 fuel assemblies.) The dose consequences for the fuel transfer canal drainage scenario were thus estimated to be 9000 man-rem/event and 1100 man-rem/event for PWR and BWR plants, respectively.

For the spent fuel pool drainage scenario (Case Z), core-melt was not assumed. Radiation exposure to the public was assumed to occur only in the event of a coincident refueling cavity seal failure and an open fuel transfer canal i.e., a drainage path for the spent fuel pool. Radiation exposures to the public were calculated using non-core-melt accident Release Categories PWR 9 and BWR 5. The dose consequences for these release categories were estimated to be 120 man-rem/event and 20 man-rem/event, respectively.[64]

The public risk is obtained by multiplying release probabilities (F_y and F_z) by their corresponding public dose consequences. The per-plant public risk estimates are:

Spent Fuel Pool Drainage

PWR $(5 \times 10^{-7}/RY)(120 \text{ man-rem/event}) = 6 \times 10^{-5}$ man-rem/RY
BWR $(5 \times 10^{-7}/RY)(20 \text{ man-rem/event}) = 1 \times 10^{-5}$ man-rem/RY

Transfer Canal Drainage

PWR $(1.8 \times 10^{-7}/RY)(9.0 \times 10^{3} \text{ man-rem/event}) = 1.6 \times 10^{-3}$ man-rem/RY
BWR $(1.8 \times 10^{-7}/RY)(1.1 \times 10^{3} \text{ man-rem/event}) = 2.0 \times 10^{-4}$ man-rem/RY

Thus, the total public risk estimates are as follows:

PWR $(6 \times 10^{-5} + 1.6 \times 10^{-3})$ man-rem/RY $= 1.7 \times 10^{-3}$ man-rem/RY
BWR $(1 \times 10^{-5} + 2.0 \times 10^{-4})$ man-rem/RY $= 2.1 \times 10^{-4}$ man-rem/RY

The resolution (SIR) is conservatively assumed to eliminate the problem of refueling cavity seal failure completely. Thus, the accident sequence frequencies and public risk are effectively reduced to zero as a result of the implementation of the SIR.

There are 45 affected plants (41 PWRs and 4 BWRs) with an average remaining lifetime of 28.8 years. Thus, the total risk associated with this issue is $[(41)(28.8)(1.7 \times 10^{-3}) + (4)(28.8)(2.1 \times 10^{-4})]$ man-rem or 2.25 man-rem.

Cost Estimate

Industry cost related to implementation of the proposed resolution, and to operation and maintenance after implementation, are estimated to be at least \$4.1M. NRC costs in support of the industry's efforts are expected to be, at a minimum, \$2.4M.[64]

Value/Impact Assessment

Based on an estimated risk reduction of 2.25 man-rem and a minimum total cost of \$6.5M for the proposed solution, the value/impact score is given by:

$$S = \frac{2.25 \text{ man-rem}}{\$6.5M}$$

$$= 0.35 \text{ man-rem/\$M}$$

Other Considerations

ORE for post-accident cleanup and repair were considered both for drainage of the fuel transfer canal and for drainage of the spent fuel pool. For the spent fuel pool event, an ORE estimate of 1880 man-rem/event was taken from Appendix D of NUREG/CR-2800.[64] It was based on a small LOCA in which the ECCS functions as intended and no fuel melting occurs, but some fuel cladding ruptures. For the refueling canal event, melting of the fuel assembly in transit was assumed. Therefore, assuming an event that results in a portion of the core melting, an ORE of 7640 man-rem/event was estimated.[64] The per-plant occupational dose reduction due to accident avoidance was estimated as follows:

Spent Fuel Pool Drainage

$$(5.0 \times 10^{-7}/\text{RY})(1880 \text{ man-rem/event}) = 9.4 \times 10^{-4} \text{ man-rem/RY}$$

Transfer Canal Drainage

$$(2.5 \times 10^{-5}/\text{RY})(7640 \text{ man-rem/event}) = 1.9 \times 10^{-1} \text{ man-rem/RY}$$

For the 45 affected plants over the 28.8 years average remaining lifetime, the maximum expected reduction in ORE for cleanup and repair efforts necessitated by reactor cavity seal failure is $(9.4 \times 10^{-4} + 1.9 \times 10^{-1})$ man-rem/RY x 45 plants x 28.8 yrs = 247 man-rem.

Normally, ORE is incurred in making physical modifications or inspections in a high radiation field to implement the resolution of an issue and to clean up a facility during recovery or decommissioning efforts following an event; these aspects are covered above. However, for this issue, the scenario associated with a rapid drainage of the refueling canal with the transfer of a spent fuel assembly in process could subject plant personnel in the containment building to radiation exposure prior to their evacuation of the building. Analysis performed by PNL[64] indicates that, for the case of a single PWR fuel assembly lying in the bottom of a dry refueling canal, exposure levels on the order of 10,000 R/hr on the operating deck at the extreme edge of the canal are possible. Extrapolation of the PNL analysis[64] indicates a potential general radiation level on the order of 100 to 500 R/hr on the operating deck due to reflection from the containment dome. Considering the possible canal drainage time, alarm levels, and evacuation times, it appears unlikely that any operator would receive a lethal dose prior to evacuation; however, it is likely that a few people could receive a whole-body dose on the order of 50 to 100 man-rem. In terms of offsite public exposure, this dose is about comparable to some of the higher probability/lower consequence core-melt scenarios. Since the frequency of this event is estimated to be 2.5×10^{-5}/RY, we believe the likelihood of the event is sufficiently low and, therefore, do not perceive a need to alter the priority of this issue on the basis of potential accidental exposure of utility staff.

CONCLUSION

Based on the low estimated public risk posed by refueling cavity seal failures, the low value/impact ratio of the suggested resolution, and the fact that IE Bulletin No. 84-03 [1158] was issued to address the concern, it is recommended that this issue be placed in the DROP category.

REFERENCES

11. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, (1st Edition) November 1975, (2nd Edition) March 1980, (3rd Edition) July 1981.

64. NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985.

1154. Regulatory Guide 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors," U.S. Nuclear Regulatory Commission, March 1972.

1155. Memorandum for R. Bernero from T. Speis, "Relationship of TIA 84-72 (Haddam Neck Refueling Cavity Seal Failure) to Generic Issue No. 82 (Beyond Design Basis Accidents in Spent Fuel Pools)," April 11, 1985.

1156. Memorandum for K. Kniel from W. Minners, "Refueling Cavity Seal Failure," April 1, 1986.

1157. NUREG/CR-4982, "Severe Accidents in Spent Fuel Pools in Support of Generic Safety Issue 82," U.S. Nuclear Regulatory Commission, July 1987.

1158. IE Bulletin No. 84-03, "Refueling Cavity Seal Failure," U.S. Nuclear Regulatory Commission, August 24, 1984.

1159. Letter to D. Crutchfield (NRC) from W. Counsil (Connecticut Yankee Atomic Power Company), "Haddam Neck Plant Reactor Cavity Seal Ring Failure," September 12, 1984.

1160. Memorandum for K. Kniel from W. Minners, "Refueling Cavity Seal Failure," May 8, 1986.