ENCLOSURE 1

PRIORITIZATION EVALUATION

GENERIC ISSUE ISSUE NO. 94

"ADDITIONAL LOW-TEMPERATURE-OVERPRESSURE PROTECTION FOR LIGHT WATER REACTORS"

ISSUE 94: Additional Low-Temperature-Overpressure Protection for Light-Water Reactors

DESCRIPTION:

Historical Background

Low temperature overpressurization was designated generic issue A-26 (Ref 2) and resolved in 1979 by MPA B-04 (Ref. A) which required PWR licensees to implement procedures to reduce the potential for overpressure events and install equipment modifications to mitigate such events. Current staff requirements are in Standard Review Plan 5.2.2, "Overpressure Protection," and its attached BTP-RSB 5-2, "Overpressure Protection of Pressurized Water Reactors While Operating at Low Temperatures."

From 1979 to July 1983, twelve pressure transients have been reported. Of these, two events at Turkey Point Unit 4 on November 28 and 29, 1981 exceeded the Technical Specification limit (415 psig below 355°F) by about 700 and 351 psi, respectively (Refs. F and G). The overpressurization transients at Turkey Point were the first events to occur at an operating pressurized water reactor that exceeded the Technical Specification limits since the NRC staff resolved generic issue A-26. The events were identified to Congress as Abnormal Occurrences which indicate that the events involved a major reduction in the degree of protection to the public health or safety.

The continuation of overpressure transient events and the two instances at Turkey Point may indicate potential weaknesses in the present overpressure protection criteria or its implementation that warrant further consideration. The two overpressure transient occurrences at Turkey Point resulted from one overpressure mitigation system (OMS) channel being out for maintenance and the other (redundant) channel being disabled by undetected errors during the first event and from undetected equipment malfunctions during the second event (Reference d).

Safety Significance

Major overpressurization of the Reactor Coolant System if combined with a critical size crack could result in a brittle failure of the reactor vessel. Failure of the reactor vessel could make it impossible to provide adequate coolant to the reactor and result in a major core damage or core melt accident.

This issue applies to the design and operation of all PWRs.

Possible Solution

Resolution of this generic issue was suggested by RSB (Ref. B), MEB (Ref. C) and AEOD (Refs. D and E) to include all or some of the following proposed new requirements:

a. Amend the STS and the SRP to require each licensee to identify the criteria used to determine if and when the LTOP system setpoints need to be adjusted to account for the irradiation induced embrittlement of the reactor vessel.

b. Make more use of the relief valves in the residual heat removal systems (RHRS) for low-temperature-overpressure protection by raising the setpoint for the auto-closure of the isolation valves.

c. Amend the STS to allow no plant operation in the "water solid" condition with either train of the Low Temperature Overpressurization System (LTOPS) out of service.

d. Amend the STS to allow no plant to operate in the "water solid" condition with an SI pump in service.

e. Require the LTOP system to be fully safety grade.

f. Require all operating reactors to upgrade their Technical Specifications to the STS for LTOPs.

PRIORITY DETERMINATION

Frequency/Consequence Estimate

Before 1979, there were 30 reported events in PWRs where the pressure/temperature of the reactor coolant system violated Technical Specifications. After 1979, following changes to operating procedures and the implementation of overpressure mitigation systems (OMS), there have been two reported events of overpressure excursions at low temperature. Since 1979 PWRs have accumulated approximately 250 plant years of operating time. Therefore the currently expected frequency of overpressure excursion events is 0.01 per plant year. There was expressed concern for including 1979 experience since increased operator awareness of overpressure problems may have biased the results, however, the small number of OMS installed systems would have also permitted more overpressure events and it was concluded that the 1979 data should be included.

The reactor vessel and weld materials have toughness properties which are defined by the nil ductility transition reference temperature, RT(ndt). The higher the copper and nickel content the higher the RT(ndt). The RT(ndt) also increases with fluence or the cumulative exposure of the vessel to neutron irradiation. The probability of vessel failure due to a pressure spike is a function of the initial temperature T in relation

to the RT(ndt) or the T-RT(ndt). It is also a function of the initial pressure and the change in pressure.

The probability of vessel failure was estimated using the Vessel Integrity Simulation Analysis (VISA) code (Ref. H) based on the assumed values of pressure, temperature, and RT(ndt). The code was a Monte Carlo technique which results in no probability of failure based on a reasonable number of runs if the expected flaw size distribution (which predicts small probabilities for a large 1/4 thickness flaw) is used. Therefore, to get an estimate, the probability of a 1/4 thickness flaw was assumed to be 1.0. The vessel failure probability calculated with this probability of a 1/4 thickness flaw was then reduced by a factor of 2250 to adjust the results to the expected flaw size distribution. This factor was obtained by ratioing the results given by two VISA runs. The first assuming the expected flaw size distribution, but a very high cooper and nickel content in order to force calculated failures. The second assuming the probability of a 1/4 thickness flaw to be 1.0 and the same very high copper and nickel contents. The adjusted estimate was then multiplied by six to account for the assumed six welds on the reactor vessel beltline.

Based upon a review of the previous overpressure events prior to 1978, it was found that 30% reached a peak pressure that was between 1,100 psia and 2,485 psia. In another 5% of these events the peak pressure was between 950 psi and 1200 psia. In the remaining 65%, pressure was prevented from exceeding 950 psia by operator actions. Thus, a series of VISA code runs were made at 2485 psia, 1200 psia and 950 psia to obtain the probability of reactor vessel failure as a function of T-RT(ndt).

Two types of reactor vessels were analyzed. The first is represented by the Oconee 3 vessel with 0.20% copper and 0.63% nickel content. The second is represented by a vessel with high copper (0.35%) and nickel (1.00%) contents.

Based on the information available on 38 PWR reactors, the copper and nickel content of fourteen of these reactors was higher than in the Oconee-3 vessel. Thus, 38% of the operating PWRs or 17 reactor vessels are assumed to be similar to the "High" plant and the remaining 30 vessels are assumed to be similar to Oconee-3.

At the midlife of the vessels the fluence is estimated to be 8.5E+18 neutrons per square centimeter. This fluence converts to a RT(ndt) of 267°F for the "High" vessel and 231°F for the Oconee type vessel using the methodology contained in Rev. 2 to Regulatory Guide 1.99. If it is assumed that the starting temperature is 110°F, the T-RT(ndt) value is about -150°F for the "High" vessel and -120°F for the Oconee-type vessel. These values of T-RT(ndt) result in the probabilities of failure of:

	PROBABILITY OF FAILURE, PER EVENT	
Peak Pressure	Oconee Vessel	"High" Vessel
2,485	1.5E-3	2.2E-03
1,200	7E-07	7E-06
950	<1E-09	<1E-09

The predicted probability of failure at 2485 psia peak surge at the end of life fluence (1.4E+19 neutrons/cm^2) for the Oconee vessel is 2.6E-03 and 2.7E-03 for the "High" type vessel.

The average failure frequency for the Oconee type vessels is calculated to be 4.5E-06 failures/PY and 6.6E-06 failures/PY for the "High" type vessel. It is assumed that a failure of the reactor vessel will result in a core-melt

accident with a probability of 1.0. The implementation of the possible solutions would reduce the frequency of an LTOP occurring but not the probability of a vessel failure given the occurrence of an LTOP event. The frequency of LTOP events is expected to reduce by a factor of 10 for the solutions proposed. This reduction in LTOP occurrence results in a core-melt frequency reduction of 4.05E-6/PY for the Oconee-type vessels and 5.9E-06/PY for the "High" vessels.

The core-melt accident resulting from a LTOP failure of the pressure vessel is expected to result in a S_1D accident sequence as defined in WASH-1400 (Ref. 16). The S_1D sequence is a small break LOCA with failure of the emergency coolant injection. The S_1D sequence results in releases with the associated probability for the following release categories given a core-melt.

PWR-1 = 0.01	PWR-5 = 0.0073
PWR-3 = 0.2	PWR-7 = 0.8

The whole body man-rem dose obtained by using the CRAC code (Ref. 64) assuming an average population density of 340 persons per square mile (which is the mean for U.S. domestic sites) from an exclusion area of a one half mile radius about the reactor out to a 50 mile radius about the reactor. A typical midwest meteorology is also assumed. Based upon these assumptions the following whole body man-rem doses result from the following categories.

PWR-1 = 5.4E+06 man-rem	PWR-5 = 1E+06 man-rem
PWR-3 = 5.4E+06 man-rem	PWR-1 = 2.3E+03 man-rem

Utilizing the reduction in core-melt frequency, the probability per release category and the whole body dose consequence factor the public risk reduction are calculated as:

PUBLIC RISK, Man-Rem/PY		
Release Category	Oconee 3	"High"
PWR-1	0.2	0.3
PWR-3	4.4	6.4
PWR-5	0.03	0.04
PWR-7	0.007	0.01
TOTAL:	4.6	6.7

For the average remaining plant life of 26 years, the averted public risk is 120 man-rem/reactor and 174 man-rem/reactor for the Oconee 3 and "High" type vessels, respectively.

Based upon a reactor vessel population of 47 of which 17 are in the "High" vessel classification the expected value of averted public risk is 6560 man-rem.

Cost Estimate

The industry costs are dominated by the costs associated with upgrading the overpressure mitigation system principally the PORVs to safety grade. PNL estimated that valve backfit labor costs are $27,200/plant based on 12-wk/plant and $2,270/man-wk. This includes management review, QA control, licensing review, and engineering for the backfit. Material requirements are two safety grade PORVs and two instrumented (for automatic actuation) block valves, each costing $25,000. Incremental material costs such as piping, supports, hardware, etc., beyond those associated with initial installation of the safety grade PORVs and instrumented block valves at a plant are estimated at $50,000. The cost for the safety analysis is estimated at $50,000/plant. A Class III License Amendment for the valve upgrade is placed at $4,000. The implementation cost is therefore estimated to be 2.37E+05/plant. Other industry costs for analysis, technical specification changes and test procedure changes is expected to be $19E+04 per plant.

Total industry costs are \$2.6E+05 per plant or \$12E+06 for all 47 plants. The operation/maintenance costs are not expected to significantly increase over the existing plant costs for operation and maintenance.

The NRC costs are estimated to be \$3.8E+04 for development of a resolution and \$1.0E+04 per plant for review of the overpressure mitigation provisions. The total NRC costs are expected to be \$5.0E+5.

Value/Impact Assessment

The value/impact assessment (S) for all PWRs, using the expected value for risk reduction is

$$S = \frac{6560 \text{ man-rem}}{\$12M + \$0.5M} = 524 \text{ man-rem/\$M}$$

The upgrading of the OMS or LTOP system to safety grade (safety related or important to safety) does not of itself assure improved system reliability. Hence, the benefit of making the OMS safety grade to assure a higher probability of successful mitigation of overpressure challenges may not be realized. A greater benefit may result from more stringent procedures and technical specifications, e.g., not permitting water solid operation without both channels of the OMS in operation. Thus, it may be possible to decrease the number of overpressure incidents and better assure OMS operation without hardware changes; in which case the major cost contributor for the plant owner would be eliminated.

With the elimination of hardware changes it is estimated that procedural and technical specification changes can be developed for \$1.9E+04 per plant or \$9E+05 for all 47 plants. NRC costs are estimated to 60% of the hardware related NRC costs. Thus, without the hardware changes, for the expected value of risk reduction the value/impact score is

$$S = \frac{6560 \text{ man-rem}}{\$0.9M + \$0.3M} = 5470 \text{ man-rem/\$M}$$

Other Considerations

The frequency of overpressure events may be higher than the estimate used which was based soley on the number of events that have occurred. Other failure modes are possible with failure of the PORV a prime example. The frequency of events that initiate overpressure transients and would now challenge the OMS is probably unchanged from the pre-1979 level (about 0.13/PY). However, the OMS prevents these events from becoming overpressure events. Even if the unavailability of the OMS were 0.01/demand, the frequency of overpressure excursions would be increased by only 10% from the estimate that was used.

The analysis assumed that a brittle failure of the reactor vessel will always result in a core-melt accident. However, depending upon the break type and size, the amount of decay heat generated by the fuel, and the location of the vessel failure, the ECCS may be capable of keeping the core covered and thereby prevent fuel melt. The assumption that a vessel failure produces a core-melt lead to some overestimation in this analysis.

There is no additional occupational radiation exposure associated with the implementation of this issue, except the 20,000 man-rem per accident averted to clean-up after an LTOP-induced core melt. This amounts to 3.0 man-rem per "High" plant and 2.1 man-rem for the Oconee-3 type plant for a total of 114 man-rem.

Averted accident costs based upon the present worth of $1,650 million for cleanup and power replacement costs over a ten-year period amounts to $0.25M per plant for each "High" plant. For the Oconee-3 type plants, the averted accident costs are approximately $0.17M per plant. The total averted cost is $10.4M.

LTOP events which do not result in reactor vessel damage would still require an engineering analysis and inspection to assure the vessels integrity. Assuming such an analysis to cost $25,000 per event and an average outage of 5 days for which replacement power must be purchased at $300,000 per day the LTOP frequency reduction would result in cost saving of approximately $0.4M per plant or total averted cost of $18.6M.

CONCLUSIONS

This issue based upon the risk reduction and value/impact score is classified as a HIGH priority issue if a non-hardware, procedural or technical specification change can fulfill the risk reduction predicted.

REFERENCES

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D. AEOD/C401, "Low Temperature-Overpressure Events at Turkey Point Unit 4," March 1984.

E. AEOD/E426, "Single Failure Vulnerability of Power Operated Relief Valve (PORV) Actuation Circuitry for Low-Temperature-Overpressure Protection (LTOP)

F. IE Information Notice 82-17, "Overpressurization of Reactor Coolant System," U.S. Nuclear Regulatory Commission, June 11, 1982.

G. IE Information Notice 82-45, "PWR Low-Temperature Overpressure Protection," U.S. Nuclear Regulatory Commission, November 19, 1982.

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2. NUREG-0371, "Task Action Plans for Generic Activities (Category A)," U.S. Nuclear Regulatory Commission, November 1978.

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.

64. NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983.