Item C-9: RHR Heat Exchanger Tube Failures

DESCRIPTION

Historical Background

A BWR RHR system is designed for: (1) containment spray/suppression pool cooling, (2) fuel pool cooling augmentation, (3) low pressure coolant injection, and (4) bringing the reactor down to a cold shutdown condition. Major components of the RHR system are the RHR heat exchangers which are of the tube and shell design.

In the recent past, there have been some RHR heat exchanger tube failures. This item is documented in NUREG-0471.[1]

Safety Significance

An RHR heat exchanger tube failure will result in leakage of service water through the failed tube into water that will be pumped into the reactor coolant system. This leakage is caused by the designed inter-system pressure differentials. It can be postulated that a failure of the pressure control system, along with a tube failure, can cause a leakage of reactor coolant water into the service water system and then into the environment. The release of reactor coolant water to the environment could have serious consequences if, for example, during a major accident a significant amount of activity is deposited in the reactor coolant water.

Possible Solution

The task would investigate the cause of the tube failures and the design of the pressure control system to assure that long-term core cooling capability is available. A proposed fix is to hydrotest each RHR heat exchanger once a year.

PRIORITY DETERMINATION

Assumptions

The limiting condition for the amount of activity in the reactor coolant water would be a core-melt accident. It shall be assumed that this accident has taken place, the RHR system is put into the reactor shutdown mode by the operator, the pressure control system fails, and that tube failures are present.

Frequency Estimate

The total event frequency (F) is the product of frequency of a core-melt accident, the probability of the pressure control system to fail on demand, and the probability of tube failures.

From WASH-1400,[2] the frequency of a core-melt accident is 10^{-5}/RY. The probability of control system failure is 10^{-2}/demand from a PAS Risk Study of Generic Issues.[3] The probability of tube failure in a BWR is conservatively estimated to be 1. Analysis of LER data has shown that there have been about 4 tube failure events in about 175 years. However, it would be expected that, after any significant event that contaminates the primary system, operators would test the RHR system for leaks, etc., prior to its initiation. Therefore, this assumption is a very conservative high estimate of the probability of a tube

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[1] NUREG-0471, "Generic Task Problem Descriptions (Categories B, C, and D)," U.S. Nuclear Regulatory Commission, June 1978.
[2] WASH-1400 (NUREG-75/014), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," U.S. Atomic Energy Commission, October 1975.
[3] Memorandum for R. Frahm from R. Emrit, "Summary Report on a Risk Based Categorization of NRC Technical and Generic Issues," June 30, 1989. [9507280169]

failure. Therefore, F = $(10^{-5}/RY) \times (10^{-2}/demand) \times (1) = 1 \times 10^{-7}/RY$.

Consequence Estimate

Assume that the major accident, which is the initiating event, has deposited 103 Ci in the reactor coolant water. This is about equal to the release to the environment due to a BWR-3 or BWR-4 event (WASH-1400[4]).

Flow through a typical RHR heat exchanger is 10,000 gpm on the service water side. Then, assume conservatively that 10 tubes have failed and that, therefore, the full flow rate of primary water could be discharged to the secondary side by the failed tubes. Therefore, the flow rate in this scenario[5] is

$$10{,}000 \text{ gpm} \times \frac{1 \text{ RHR HX}}{1000 \text{ tubes}} \times 10 \text{ failed tubes} = 100 \text{ gpm}$$

This amount would be conservative because the pressure differential (even with a failed control system) wou1d inhibit full flow.

If there are 106 Ci in the primary water, this means there are about 102 Ci/ gal[6] (assuming even dispersion in the entire primary water inventory). Then, 100 gpm x 102 Ci/gal = 104 Ci/min released to the environment.

There are radiation monitors on the service water exhaust piping. Assume the operator ignores the alarm, or it otherwise does not function, such that the affected heat exchanger is not isolated for 2 hours. This is very conservative because any post-LOCA service water discharge would be monitored closely.

$$\frac{10^4 \text{ Ci}}{\text{Min}} \times \frac{60 \text{Min}}{\text{Hr}} \times 2 \text{ Hrs} = 1.2 \times 10^6 \text{ Ci}$$

Total Consequence =

This was assumed equal to the release to the environment due to a PWR-7 event. Therefore, this is equal to 2.3×10^3 man-rem in public dose.

Cost Estimate

The proposed fix is to manually hydrotest each RHR heat exchanger once a year. There are 24 affected BWRs (Humboldt Bay is shut down and Oyster Creek 1 has a different system configuration) and the industry cost to hydrotest is $25,000/year/plant for licensing, initial procedure design, initial system modification, testing, and reporting. Assuming 5 staff-years of NRC effort to review tests and prepare SERs, the NRC cost is $500,000. Assuming the average remaining plant life for each plant is 30 years, the total industry cost is $18M.

Value/Impact Assessment

Based on a total risk reduction of 0.2 man-rem for 24 BWRs, the value/impact score is

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[4] WASH-1400 (NUREG-75/014), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," U.S. Atomic Energy Commission, October 1975.
[5] Memorandum for H. Denton from S. Hanauer, "Preliminary Ranking of NRR Generic Safety Issues," March 26, 1982. [8204280036]
[6] Memorandum for H. Denton from S. Hanauer, "Preliminary Ranking of NRR Generic Safety Issues," March 26, 1982. [8204280036]

$$S = \frac{0.2\ \text{man} - \text{rem}}{\$(0.5 + 18)\text{M}}$$

$$= 0.01\ \text{man} - \text{rem} / \$\text{M}$$

Other Considerations

(1) Occupational dose for proposed technical fix is minimal.

(2) The RHR system (including the heat exchanger and the service water pressure control) is a redundant system, long-term cooling should not be prevented by a tube failure event but can be provided by the steam and feedwater system and the RHR is not always necessary.

(3) Under postaccident shutdown, it would be expected that the service water would be monitored closely and that operator action could prevent large releases.

(4) Routine RHR use for shutdown should periodically demonstrate tube integrity and pressure control system performance. Furthermore, it would be expected that for post-LOCA shutdown, all RHR functions would be checked prior to use and any problem detected and repaired, if possible, prior to initiation of the system.

(5) No NRC resources have been expended on issue resolution.

(6) The issue as presently stated is not clear, that is, long-term core cooling, although stated as part of the issue, has little bearing on the central issue of RHR tube failure. Long-term core cooling capability is addressed in USI A-45.

(7) The issue could be reworked for non-accident conditions (higher probability events) but the consequences would then be extremely low and the overall value/impact score would remain low.

(8) RHR tube leakage from service water to primary system could result in overfilling the suppression pool. However, other systems are more likely to result in overfilling and RHR tube failure is a negligible contributor

to this risk. Furthermore, current requirements for emergency operating guidelines address this issue and are considered adequate to resolve it.

CONCLUSION

Based on the value/impact score and the additional considerations, this item should be DROPPED from further consideration.