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MEMORANDUM FOR: Karl V. Seyfrit, Chief
Reactor Operations Analysis Branch
Office for Analysis and Evaluation
of Operational Data

AEOD/E315

FROM: Earl J. Brown, Lead Engineer
Engineering Systems
Reactor Operations Analysis Branch

SUBJECT: MISUSE OF VALVE RESULTING IN VIBRATION AND DAMAGE TO THE VALVE ASSEMBLY AND PIPE SUPPORTS

The enclosed Engineering Evaluation Report is forwarded for your information and further consideration. The evaluation indicates that:

(1) The valve assembly damage resulting from misuse was severe enough to warrant wide dissemination such as an IE Information Report.

(2) The current intermittent operation of the RHR system in the shutdown cooling mode has the potential for cumulative damage to valve assemblies. It appears appropriate that system operation should be reviewed for compatibility with valve assembly design and qualification which should include frequency of operation and vibration. It may also be prudent to review the adequacy of flow control in the shutdown cooling mode.

A previous AEOD engineering evaluation, E305 (Ref. 5), also cited valve damage that resulted from misuse. Therefore, the subject warrants prompt action.

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for
Earl J. Brown, Lead Engineer
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AEOD ENGINEERING EVALUATION REPORT*

UNIT: Susquehanna 1
DOCKET NO.: 50-387
LICENSEE: Pennsylvania Power & Light Company
NSSS/AE: GE/Bechtel

EE REPORT NO.: AEOD/E315
DATE: July 7, 1983
EVALUATOR/CONTACTS: Earl J. Brown

SUBJECT: MISUSE OF VALVE RESULTING IN VIBRATION AND DAMAGE TO THE VALVE ASSEMBLY AND PIPE SUPPORTS

EVENT DATES: February 18, 1983 (LER 83-034) and April 7, 1983 (LER 83-056)

SUMMARY

This report represents an evaluation of two licensee event reports (LERs) involving operation of the residual heat removal system (RHR) in the shutdown cooling mode at the Susquehanna Unit 1 plant. The first event identifies damage to the LPCI system injection throttle valve and pipe supports that was caused by severe vibration of the system from throttling the valve outside the optimum flow rate range. The second event identifies a situation in which a test to determine the capability of the RHR heat exchanger led to excessive vessel and primary coolant cooldown rates, and provides insight about RHR system operation relative to the injection throttle valve vibration in the first event.

Based on a review of the information, there is substantial evidence that throttling the valve outside the optimum range (misuse) resulted in excessive vibration and subsequent damage to the valve assembly and pipe supports. However, it appears that a relatively low level decay heat cooling requirement, in combination with some limitations in the RHR system design, configuration, and flow control system, was an important factor in the decision to throttle the valve. Approximately four months after the vibration event, the valve disc was found separated from the stem with the cause suspected to be cracking of weld locking tabs on the disc retaining nut as a result of vibration. Failure of this valve before or during LPCI system injection during a postulated loss of coolant accident has potentially serious safety consequences.

It appears appropriate to disseminate information about the type of damage that resulted from apparent misuse of the valve. In addition, current intermittent operation of the RHR system in the shutdown cooling mode appears to have the potential for cumulative damage to valve operator motors. Therefore, it may also be prudent to review the adequacy of flow control in the shutdown cooling mode.

*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

DISCUSSION

This engineering evaluation reviews two reports of events at Susquehanna Unit 1 (Docket 50-387). The events are described in LERs 83-034 and 83-056 and involve operation of the residual heat removal (RHR) system in the shutdown cooling mode. Although the specific events are independent, they are related in that one event (LER 83-056) illustrates system operational conditions that apparently influenced a decision to operate the low pressure coolant injection (LPCI) throttle valve outside the optimum throttling range (LER 83-034).

The initial item of interest was vibration and damage to the LPCI system injection throttle valve F017B. To understand the operational aspects, Figure 1 (from Ref. 1) illustrates the "B" loop flow path from the reactor recirculation loop through the RHR heat exchanger and return to the reactor recirculation loop. Valve F017B is just upstream of the recirculation loop isolation check valve, F050B, and the normally closed injection valve, F015B. The RHR system design is sized for 10,000 gpm flow through valve F017B. The other valves involved in RHR flow control or pathway are the heat exchanger bypass valve, F048B, the heat exchanger inlet valve, F047B, and heat exchanger outlet valve, F003B. Valves F017B and F048B are globe valves and F047B and F003B are gate valves.

From discussions with the licensee staff, the RHR shutdown mode flow path is established with bypass valve F048B full open, flow control valve F017B at a position for 10,000 gpm, and either of the heat exchanger inlet or outlet valve, F047B or F003B, closed such that all flow bypasses the heat exchanger. To establish heat exchanger flow, gate valves F047B and F003B are positioned in the full open position (either one or both would have to be opened depending upon whether one or both had been closed). With valves F048B, F047B, and F003B full open, the RHR flow is approximately 3/4 bypass flow and 1/4 heat exchanger flow. Therefore, the <u>minimum</u> heat exchanger flow is about 1/4 of full flow and can only be decreased by throttling valve F017B. It appears that this flow distribution in combination with a very low level of decay heat created a situation in which it was desirable to reduce flow through the RHR heat exchanger but this could only be accomplished by throttling valve F017B.

LER 83-034, dated March 18, 1983, provides information about an event at Susquehanna Unit 1 on February 18, 1983. The event involved severe vibration of the LPCI system injection valve F017B. With the RHR system in the shutdown cooling mode, an operator making rounds discovered that the valve was vibrating severely. Further inspection revealed that the valve had lost its packing, the position indicator had vibrated off, the adjacent saddle-type pipe hanger had two broken welds and weld cracks were observed on another pipe hanger. In addition, two snubbers attached to the saddle-type pipe hanger were replaced, although no observable damage was evident. The B loop was declared inoperable and the A loop was placed in service. Inspection of the A loop while in service revealed that several pipe hanger welds had cracks, but it was determined that operability was not affected. This appears to indicate the A loop had been operated in a manner similar to the B loop. All damaged components were repaired.*

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*Recent reports (Ref. 2 and 3) indicate other damage to the RHR F017B valve. The resident inspector indicated that recent investigations concerning RHR venting problems revealed that the valve disc had separated from the stem. It was found that weld tabs which hold the disc nut locked had cracked and permitted the nut to back off. It is suspected that the previously reported vibration caused these weld tabs to crack.

The vibration was apparently caused by operation of the RHR shutdown cooling loop with flow rates outside the optimum throttling range of F017B. System operation outside the optimum throttle range of valve F017B was procedurally allowed by a temporary change notice which was implemented to provide a finer control of reactor coolant temperature. The operating procedure was reviewed and revised to impose operating restrictions that will prevent a recurrence of this event.

LER 83-056, dated May 6, 1983, provides information about another event at Susquehanna Unit 1 on April 17, 1983. This event involved operation of the RHR system in the shutdown cooling mode. The original intent was to conduct a startup test to determine the capability of the RHR heat exchanger. As a result of an unexpected series of interactions, the test led to excessive vessel and primary coolant cooldown rates. An engineering analysis by the licensee concluded that the cooldown rates did not impair structural integrity of the reactor coolant system.

This sequence of events involved the same system and components described for LER 83-034 and shown in Figure 1. It could involve either the A loop (not shown, but with the same configuration as the B loop with valve numbers followed by A rather than B) or the B loop of RHR. Prior to the test, reactor temperature/pressure was maintained with the shutdown cooling by using the RHR heat exchanger for approximately five minutes out of each hour. As previously described, this means that valve F017 was set for 10,000 gpm flow, valve F048 was full open, and either the heat exchanger inlet or discharge valve (F047 or F003) was closed to provide complete bypass flow (no cooling from the heat exchanger). The level of decay heat was such that heat exchanger flow was only needed for 5 minutes out of every hour (recall that this flow was approximately 3/4 bypass and 1/4 heat exchanger). Use of the heat exchanger was controlled by alternate opening and closing of valves F047 and F003 (i.e., if F047 was closed, it would be opened to use the heat exchanger; F003 then would be closed after five minutes to stop cooling; after 55 minutes, F003 would be opened to start cooling; F047 then would be closed to stop cooling).

The test procedure to determine the capability of the shutdown heat exchanger apparently specified full 10,000 gpm flow through the heat exchanger (about four times the normal amount that was needed for five minutes each hour). Prior to the test, the heat exchanger had been isolated for approximately one hour. The test was started by diverting all flow in RHR loop A through the heat exchanger by closing bypass valve F048. This heat exchanger bypass valve was fully closed approximately three minutes after the start of the test. When a 60°F temperature drop in the suction line of the A recirculation loop was approached, the startup test was aborted by opening the heat exchanger bypass valve and isolating the heat exchanger. By that time, the temperature drop was approximately 80°-90°F and reactor level was dropping due to shrinkage. The low level scram trip was subsequently actuated (this was a reactor protection system actuation only, the reactor was not critical) and shutdown cooling was isolated on an RHR pump A trip. This sequence together with subsequent action to restore reactor level resulted in excessive vessel and primary coolant cooldown rates. Later in the sequence to return the RHR B loop to shutdown cooling, the heat exchanger discharge valve would not open due to an open motor winding (burnout).

FINDINGS

These two events illustrate several issues concerning interaction aspects between system design and operation. One issue concerns valve assembly operation in a manner for which it was not intended. Two previous AEOD reports (Refs. 4 and 5) specifically address motor burnout and valve vibration which were similar to those observed in these events at Susquehanna. Reference 4 identifies several possible causes of motor burnout. One item was motor duty cycle which concerns the number of times a valve is operated within a given time frame. Based on the manner in which the shutdown cooling mode is currently operated, the motor operator burnout cited in LER 83-056 may be related to the frequent open and closing of the valve. Similarly, reference 5, identifies several events in which vibration of the valve assembly, apparently caused by inappropriate throttling, had resulted in loosening of the limit switches and subsequent excessive closing torque was applied. Thus, the recent events at Susquehanna appear to be similar to previously observed phenomena.

Based on the preceding discussion and related followup activities for these licensee event reports, the following findings are provided:

(1) Valve misuse with throttling outside the optimum range resulted in excessive vibration and damage to the LPCI injection throttle valve assembly and the system piping supports. Current procedures rely on administrative controls to prevent operation outside the optimum throttling range.

(2) Vibration damage was detected because an operator making rounds observed excessive motion. Previous operation had apparently already resulted in weld cracks in piping supports in the A loop, but these cracks were not detected until after the valve vibration in loop B had been observed.

(3) The disc separation from the stem in the LPCI system injection valve, F017B, found subsequent to the vibration, has potentially severe consequences relative to LPCI operation. The separation could remain undetected because position indicators would show full open and inservice pump tests would normally not have flow through this valve. Also, it would be possible for a degraded disc-stem connection to fail under conditions of full LPCI system injection flow.

(4) The combination of system design, configuration, flow control system, and low level of decay heat resulted in intermittent but frequent cycling of the RHR heat exchanger inlet and outlet valves during the shutdown cooling mode of operation. It appears that efforts to provide either continuous or longer periods of heat exchanger flow led to a conclusion that the only viable short term action was to throttle the LPCI system injection throttle valve outside the optimum range.

(5) The current operational sequence for the RHR system in the shutdown cooling mode with intermittent use (five minutes out of every hour) of the heat exchanger may have contributed to valve operator motor damage because of increased duty cycle. However, higher levels of decay heat which would require more frequent valve cycling (something other than continuous flow) could result in more rapid motor operator failure due to increased duty cycle requirements.

(6) Shutdown cooling flow distribution has little if any control flexibility at the low end of heat exchanger flow.

(7) The heat exchanger test procedure that led to the event reported in LER 83-056 appears to be inappropriate in general because it could result in severe thermal shock loads for the reactor vessel.

(8) It would seem appropriate to develop an improved method of flow control to permit continuous heat exchanger flow during the shutdown cooling mode of RHR operation. This method should consider possible control of the service water flow as well as the primary reactor water flow through the heat exchanger.

(9) The extent of valve assembly damage due to vibration indicates that such effects were not adequately accommodated in design and qualification programs. A similar finding was cited in reference 5.

CONCLUSIONS

Based on this review and followup activities, the damage to the LPCI injection throttle valve assembly and support system appears to be among the most severe that has been attributed to vibration resulting from valve misuse. If the damage had gone undetected, failure at a later time could have adversely affected operation of the low pressure injection system. It is important to note that misuse of the valve appears to have been directly related to system flow limitations which in turn resulted from a combination of system design, configuration, flow control system, and the low level of decay heat. The extent of valve assembly and pipe support damage, together with the interactive aspects between design and operation, appear to be appropriate material for an IE information notice. In addition, current intermittent operation of the RHR system in the shutdown cooling mode appears to have the potential for cumulative damage to valve operator otors. Therefore, it appears appropriate to review the adequacy of the shutdown cooling mode system and flow control because such operation could have adverse effects on equipment that is essential under some accident conditions.

REFERENCES

1. NRC, FSAR, Susquehanna Steam Electric Station, Figure 5.4 - 14b, "RHR Process Diagram."

2. BRC, PNO-I-83-60, Reactor Trip on Main Steam Line High Radiation Signal, June 14, 1983.

3. NRC, Morning Report - Region I, June 15, 1983, Susquehanna Unit 1.

4. NRC, E. J. Brown and F. S. Ashe, "Survey of Valve Operator-Related Events Occurring During 1978, 1979 and 1980," AEOD/C203, dated May 1982.

5. NRC, E. J. Brown and F. S. Ashe, "Inoperable Motor Operated Valve Assemblies Due to Premature Degradation of Motors and/or Improper Limit Switch/Torque Switch Adjustment," AEOD Engineering Evaluation Report E305, April 13, 1983.

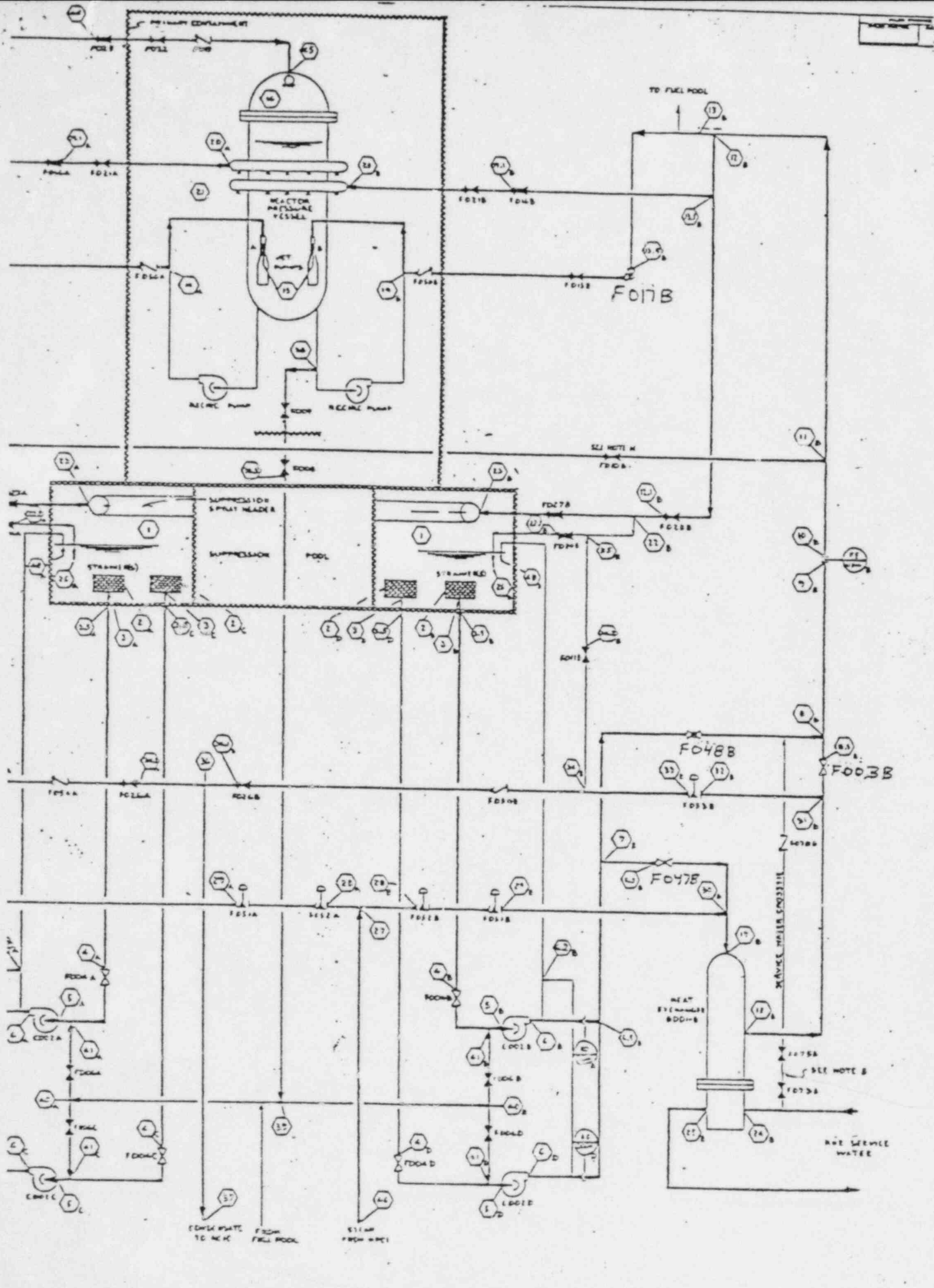

FIGURE 1. RHR PROCESS DIAGRAM