AEOD TECHNICAL REVIEW REPORT

UNIT: LaSalle County 1
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LICENSEE: Commonwealth Edison
NSSS/AE: General Electric/S & L

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SUBJECT: LEAK IN RWCU "B" REGENERATIVE HEAT EXCHANGER RELIEF LINE

EVENT DATE: November 18, 1982

SUMMARY

On November 18, 1982 with plant in normal operation mode 1, operators attempted to shift the reactor water cleanup system from the "A" train to the standby "B" train which was idle at that time. As the standby "B" pump was brought up to speed, the "B" regenerative heat exchanger shell side relief valve cycled with a loud banging noise and steam leaking occurred as a result of a pressure relief line crack at the socket weld junction to the shell side of heat exchanger.

The exact mode of failure could not be determined. The licensee has proposed the following possible causes: inadequate preheating on the line during initial welding, induced thermal shock on heat exchanger during fast heatup, and/or plant personnel stepping on the line during surveillance or inspection. However, based on this review, a more likely cause is water hammer. This is evidenced by the lifting of the relief valve due to pressure surges similar to those associated with water hammer.

Damaging water hammer could have occurred in the voided section of the relief line when the pump was rapidly started. The piping of the pressure relief line has a U-shape configuration, where voids could form at the high points during a long idle period as a result of water shrinkage caused by reduced water temperature or inadvertent draining. During the shifting operation, some time is required for valve lineup and complete line filling to eliminate the voids in the pipe line.

It appears that water hammer effects were not considered in the original piping design due to lack of specificity in the design codes and the regulatory guidance. The recurrence of a similar event could be precluded by proper administration of operating procedures.

DISCUSSION

LER 82-155/03X-1 reported that on November 18, 1982 the plant was in normal operational mode 1 at approximately 300 MWE power level, when operators attempted to run standby "B" pump of the reactor water cleanup (RWCU) system. As the pump was brought up to the speed, the "B" regenerative heat exchanger shell side pressure relief valve 1G33-F340B cycled, creating a loud banging noise. The RWCU "B" pump was shutdown immediately. In the meantime a control alarm indicated a high differential temperature existed in the "B" heat exchanger room. An entry to the "B" heat exchanger room was made to investigate the cause of the banging noise and the high differential temperature. A steam leak was observed to be coming from the top regenerative heat exchanger shell side pressure relief line (1 1/4" size). The leakage was from a crack at the socket weld junction between the pressure relief line and the regenerative heat exchanger. The RWCU system was promptly isolated with both "A" and "B" regenerative heat exchanger trains valved out of service. All of the steam and water leakage was controlled and contained within the "B" heat exchanger room. The defective pipe section was replaced and repair work was completed on November 25, 1982. The "B" train of the RWCU system was put back into operation following the filling of the line and gradual pump startup. There was no indication of recurrence of pipe cracks. Since a faulty weld was suspected as a possible cause of cracking in the "B" train, a dye penetrant test was conducted on the socket weld junction of the pressure relief line to the shell side of "A" regenerative heat exchanger. The results revealed that no detectable defects exist in this line. The exact mode of failure could not be determined in the subsequent licensee investigation. The pipe failure was postulated at the time of LER report to have occurred due to one or a combination of the following possible causes;

A. Inadequate preheating on the line during initial welding.
B. Induced thermal shock on heat exchanger during fast heatup.
C. Plant personnel stepping on the line during surveillance or inspection.

The RWCU system removes impurities from the reactor water and provides a means for water removal from the primary system during startup, shutdown or refueling. Therefore this system can be operated at anytime during planned operation, or it may be shutdown when not required to clean up the reactor coolant.

FINDINGS

Most cracks and leaks in small bore pipe lines of operating plant have been located in socket welds in vent, drain and instrument lines (Ref. 1&2). The crack mechanism, as concluded in the reference study, has been identified as fatigue due to plant induced vibration resulting from operation of pumps, valves or flow induced phenomena. In the review of this event, a search was conducted to identify whether there was a source of vibration in the area and to review the as-built piping configuration as well as piping design condition. Discussions with the licensee revealed that the pressure relief line from the regenerative heat exchanger shell side was not subject to any noticeable vibration. Also, the plant started commercial operation only a couple of months before the occurrence of this event. Therefore, vibration induced fatigue is unlikely as the cause of this pipe failure. Based on the information provided by the architect engineer, thermal growth at room temperature and dead weight are the only design conditions for the piping system of this pressure relief line.

Since relief valve cycling with a loud banging noise accompanied the steam leak in this event, it appears indicative that a dynamic transient pressure wave had occurred in the pipe line. Hence, the cracks in the pipe may be related to water hammer in the relief line as a result of rapid pump startup with line voiding. During the standby period, reduced water temperature or inadvertent draining can cause shrinkage of water in the pressure relief line between regenerative heat exchanger and pressure relief valve. Since this section of pipe has a U shaped profile, voids could be formed at the high points. The resulting voids may be at or near vacuum conditions, containing water vapor and small amount of gas evolved from solution. This will provide essentially no cushioning, and large water hammer pulses following pump startup can be generated when the accelerating water front hits the water column resulting in collapse of the vapor cavities (Ref. 3) This pressure fluctuation could cause the pressure relief valve to cycle open and closed.

The RWCU is an auxiliary system and the system has no safety function even though a small portion of the system is part of the reactor coolant pressure boundary. Isolation valves in the system will automatically isolate to limit blowdown in the event of a failure of the system line. Failure of piping in the RWCU system will not impair the integrity of the reactor coolant pressure boundary but will cause the release of radioactivity into the reactor building, creating a hazardous environment to plant personnel. Furthermore, since the RWCU is a high energy piping system, rupture of pipe in the system could result in disabling a safety-related system, and constitute a potential threat to the plant safety operation.

Although the current design codes and rules require that designs of piping systems consider impact forces caused by dynamic fluid transients, none of these codes provide guidance as to load type, magnitude, pulse shape or the conditions leading to formation of water hammer. Additionally, NRC regulatory guidance does not provide specific conditions that will cause water hammer in fluid piping systems, other than some safety-related systems. Due to lack of specificity in the design codes and the regulatory review guidance, dynamic fluid transient impacts such as water hammer appear to have been underestimated or overlooked by the design engineer.

Generally, voiding occurs in standby systems that are normally idle. Certain good practices that aid in preventing water hammer during startup operation of standby system or subsystem, such as line filling, valve lineup, venting and gradual pump startup, are usually covered in operating procedures. However, the potential for water hammer is generally not stated in the operating procedure, and sufficient information of system condition is often unavailable to the operators. Therefore most voided line water hammer events occur during plant startup and in the early months following commercial operation (Ref. 4). This indicates there is a learning and adjusting period during which plant personnel become familiar with operation and take appropriate steps to prevent or reduce the water hammer occurrence.

CONCLUSION

Based on the preceeding discussion, water hammer damage appears to be a more plausible explanation of the leak in the pressure relief line of the regenerative heat exchanger. The RWCU system is a high pressure system (more than 1100 psig fluid pressure), and cracks in the system piping could lead to release of a relatively large amount of radioactive material before the leaking could be controlled. This could create a hazardous environment to plant personnel. The RWCU system is a high energy piping system and rupture of pipe in the system could adversely affect operation of safety related equipment.

Although the water hammer was not considered in the original piping design, the effects of water hammer in the voided line could be prevented by appropriate implementation of operating procedures. Since the event can be controlled and prevented by operator-related actions, additional NRC staff action does not appear to be needed.

REFERENCES:

1. NUREG-0691 Investigation and Evaluation of Cracking Incidents in Piping in Pressurized Water Reactor.

2. AEOD/308 Engineering Evaluation Report "Cracks and Leaks in Small Diameter Piping."

3. Streeter, V. L. & Wylie, E. B.; "Hydraulic Transients", McGraw-Hill

4. NUREG/CR-2781 Evaluation of Water Hammer Event in Light Water Reactor Plant.