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IN 86-101

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, DC 20555

December 12, 1986

IE INFORMATION NOTICE NO. 86-101: LOSS OF DECAY HEAT REMOVAL DUE TO LOSS OF FLUID LEVELS IN REACTOR COOLANT SYSTEM

Addressees:

All holders of an operating license or a construction permit for pressurized-water reactor (PWR) facilities.

Purpose:

This notice is intended to advise licensees of continuing problems during PWR outages with procedures and instrumentation for control of water level in reactor vessels when reactor coolant systems (RCSs) are partially drained for maintenance. These problems have resulted in temporary loss of decay heat removal.

It is expected that recipients will review this information for applicability to their reactor facilities and consider actions, if appropriate, to preclude occurrence of similar problems. Suggestions contained in this notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

A typical PWR has a decay heat removal system with two redundant trains. Generally, both trains take suction from the same RCS hot leg, and the connecting piping is attached to either the bottom or a lower quadrant of the hot leg. During certain maintenance activities, the water level in the reactor vessel must be lowered below the tops of the nozzles which connect the hot legs to the reactor vessel. Lowering the level too far can cause vortexing in the hot leg at the suction nozzle for the decay heat removal system, air entrainment in the water flowing to the operating decay heat removal pump, and air binding of the pump. If the other pump is started, it too is likely to become air bound. Consequently, all decay heat removal is lost until the water level in the reactor vessel and hence in the hot leg piping is raised and the decay heat removal pumps are vented and restarted.

During outages in the last year and half, decay heat removal pumps at several PWRs lost suction because of vortexing. Four of these events are described in Attachment 1 to this information notice. Deficiencies which contributed to the events include:

(1) lack of operator knowledge about the correlation between water level and pump speed at the onset of vortexing and air entrainment

(2) operating procedures that did not adequately consider vortexing and air entrainment

(3) reactor vessel water level instrumentation which was erratic or inaccurate, did not have adequate range, was not checked adequately before use, or was not monitored as frequently as necessary during use

During one of these events, local boiling of reactor coolant and some release of radioactive contamination to containment did occur.

Discussion:

In the aggregate, licensees involved in the events described in Attachment 1 have taken certain actions. These actions include additional operator training, improvement of instrumentation for monitoring water level in the reactor when the level has been lowered for maintenance, addressing in operating procedures the relationship between water level and flow rate for the onset of vortexing and air entrainment, and requiring in operating procedures that the performance of water level instrumentation be checked before water level is lowered.

The nuclear industry has been previously made aware of this problem. IE Information Notice 81-09 described an event that occurred at Beaver Valley Unit in March 1981. Further, the Nuclear Safety Analysis Center operated by the Electric Power Research Institute published NSAC-52 in January 1983. This report provides information on 12 PWR events which occurred from 1977 through 1981 and which resulted in the loss of capability to remove decay heat because of reduction of water inventory in the RCS. Case Study Report AEOD/C503 issued in December 1985 by NRC's Office of Analysis and Evaluation of Operating Data presents similar information from 1976 through 1984. That case study indicates that there were 32 events during that period including 6 in 1984. Although these reports are available to the industry, significant events continue to occur.

This notice requires no specific action or written response. If you have any questions regarding this matter, please contact the Regional Administrator of the appropriate regional office or this office.

Ed Jordan

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Attachments:
1. Loss of RHR events at PWRs
2. List of Recently Issued IE Information Notices

LOSS OF RHR EVENTS AT PWRs

San Onofre 2

On March 19, 1986, San Onofre 2, a Combustion Engineering designed reactor, was in cold shutdown and preparations were made to partially drain the RCS and perform maintenance in a steam generator channel head. Before initially draining the reactor vessel to the midpoint of the RCS hot and cold legs, wide- and narrow-range RCS level instruments were put in service by installing their temporary connections and calibrating them. Because their readings oscillated when a portable RCS eductor for control of airborne radioactive contamination was operated, tygon tubing was installed temporarily to provide a sight gauge for monitoring RCS water level. Thus, three devices were available for monitoring water level in the system.

On March 26, the water level in the reactor vessel was below the vessel flange, the RCS was vented to the containment atmosphere via incore detecter nozzles in the vessel head, a low-pressure safety injection (LPSI) pump was running to provide decay heat removal via the shutdown cooling system (SDCS), and a temporary dam was installed in the cold leg nozzle of the steam generator to facilitate maintenance which was to be performed on it. To permit repair of the nozzle dam which had been leaking, the water level in the reactor vessel was being lowered to 17.5 inches above the bottom of the 42-inch diameter hot legs.

One of the hot legs supplies water to the inlet side of the SDCS. The nozzle for the connecting pipe to the SDCS is located on the bottom of that hot leg. While the water level was being lowered, a vortex formed on the suction side of LPSI Pump 16. The vortex entrained air causing the pump to become air bound, loss of SDCS flow, and thus loss of decay heat removal. To avoid damage to the pump, it was secured. The redundant pump, LPSI Pump 15, was started, and it too became air bound and was secured. To again establish flow through the SDCS, the system was vented, and the water level in the reactor vessel was raised. Seventy minutes after the first indication of vortexing, decay heat removal was again established when LPSI Pump 16 was returned to service. During the time that decay heat removal was lost, the hot leg temperature increased from 114° F to 210° F, and local boiling occurred in the reactor core. Steam and 2 curies of radionuclides were released to containment.

The wide- and narrow-range level instruments are connected to taps on the RCS hot leg drain line and on the pressurizer. Instrument zero for the narrow-range instrument is at the level of the bottom of the hot leg, and its range is from zero to +42 inches, i.e., the top of the hot leg. Instrument zero for the wide-range instrument is at the reactor vessel flange, and its range is from -120 inches (or 19.5 inches below the bottom of the inside surface of the hot leg) to +300 inches. The operators distrust these two instruments because their readings oscillate when the RCS eductor is operating and because low points in flexible tubing at the upper pressure tap collect condensate.

The RCS eductor is a portable device which is temporarily installed by maintenance personnel when the RCS is opened for repair work. The eductor takes suction on the air space above the reactor coolant surface and discharges to the containment purge system. Its function is to minimize the exposure of maintenance personnel to airborne radioactive contamination.

While installing and filling the tygon tubing, an air bubble was inadvertently trapped in the tubing causing it to read high by 10.5 inches. Further, the reference scale for the tubing was displaced by 2.5 inches in the upward direction causing a total error of 13 inches on the high side. The operators were relying on this device while reactor water level was being lowered. The licensee intended to lower the level to 17.5 inches above the SDCS nozzle; however, the level was actually being lowered to 4.5 inches above the SDCS nozzle. After the level reached 9.5 inches, vortexing started. Although, the operator did not have confidence in the narrow range instrument, its reading was approximately correct at that time.

The operator did not have at hand a formal correlation of the potential for vortexing as a function of water level and SDCS flow rate. Lack of knowledge about the performance of the system at low water levels and unreliable instrumentation for monitoring water level were the principal causes of this event.

<u>Zion 2</u>

On December 10, 1985, Zion 2, a Westinghouse designed reactor, was in cold shutdown with the water level in the reactor vessel below the flange, the RCS vented to atmosphere, a residual heat removal (RHR) pump running to provide decay heat removal, and a charging pump running to provide makeup to the RCS. The water level in the reactor vessel had been lowered to facilitate repair of an RHR valve. A recorder in the control room was connected to the refueling water level transmitter and was being used to monitor the water level in the reactor vessel.

Between December 10 and 14, enough additional water was inadvertently removed or lost from the RCS to lower the water level in the vessel far enough to cause vortexing and air binding of RHR Pump B. Pump B was immediately secured. The redundant RHR pump was started, and it too became air bound and was secured. Because of anomalous performance of the refueling water level instrumentation, an operator entered containment to read the tygon standpipe that had been installed temporarily to monitor water level in the reactor vessel. The licensee concluded that suction to the RHR pumps had been lost and started to raise the water level in the reactor vessel. After level had increased 10 inches, an RHR pump was restarted, but had to be secured because it still had inadequate suction pressure. To provide pressure quickly and to increase level further, RHR suction was transferred from the RCS to the refueling water storage tank. The water level in the reactor vessel was raised an additional 2-1/2 feet. Approximately 75 minutes after loss of decay heat removal, RHR Pump B was vented and successfully returned to service. RHR Pump A was vented, demonstrated to be operable, and deenergized. The reactor had been shut down for approximately 100 days, and the increase in RCS temperature was 15° F.

For Zion 2, the suction lines to the RHR pumps connect to a horizontal run of RCS hot leg piping. The nozzles for the suction lines are located on the underside of the the hot leg piping and at a 45° angle from the bottom of the line. The internal diameter of the hot legs is 29 inches, and the internal diameter of the suction lines is 11 inches. When reactor water level falls approximately 5.5 inches below the centerline of the hot leg, uncovering of the RHR nozzle commences, and when the water level falls below approximately 13.5 inches below the centerline, the RHR nozzle is completely uncovered. During the event of December 14, 1985, vortexing started with water level at 6 inches above the centerline with RHR flow at 3000 gpm.

A 10-inch line returns water from the RHR system to the RCS and is connected to the top of one of the RCS cold legs. The water level sensing line for the refueling water level transmitter is connected to a 4-inch line which is connected to the same cold leg. Both nozzles are in the same vertical plane. The 4-inch nozzle is located at 90° with respect to the 10-inch nozzle. When the cold leg is partially filled as it was during this event, water from the RHR return line impinges with appreciable force on the water surface close to the nozzle for the 4-inch line. Because of possible dynamic effects of this impingement, the operators believe that water level readings from the refueling water level transmitter are inaccurate and erratic when the water level in the reactor vessel is low. Furthermore, when the water level in the reactor vessel is anywhere below the nominal midpoint of the cold leg, the refueling water level instrument will indicate erroneously that the water level is at the midpoint.

Notwithstanding these problems with the refueling water level instrumentation, the tygon standpipe was not being continuously monitored while the water level was low. Further, the operator did not know the correlation of RHR flow rate and the water level for the onset of vortexing at the suction of the RHR pumps.

<u>Sequoyah 1</u>

On October 9, 1985, Sequoyah 1, a Westinghouse designed reactor, was in cold shutdown with the water level in the reactor vessel 4 inches below the centers of the hot leg nozzles, RHR Train B in service for removal of decay heat, and normal letdown and makeup out of service. The water level in the reactor vessel had been lowered to facilitate plugging and eddy current testing of tubes in a steam generator. During an evolution to put Train A in service, RHR Pump A was started and then Pump B was secured. Running both pumps simultaneously with low reactor vessel water level caused initiation of vortexing and air binding in Pump A. The pump was secured immediately, Pump B was restarted, and it operated normally. The alignment of Train A was verified and the pump was vented. Pump B was secured, and Pump A was restarted, became air bound, and was again secured. Pump B was restarted, but this time it became air bound and was secured immediately. After verifying that personnel were out of the steam generator, the water level in the vessel was raised to the centerline of the hot legs by adding water to the RCS from the RWST. Approximately 43 minutes after loss of decay heat removal, Pump A was vented and returned to service. Pump B was vented, demonstrated to be operable, and deenergized.

At Sequoyah 1, both RHR pumps take suction from the same hot leg (as they do at San Onofre 2, Zion 2, and Catawba 1). The water level in the hot leg was such that initially it would support operation of one RHR pump, but not both pumps. Starting the second pump without first securing the operating pump caused vortexing, air entrainment, and air binding of Pump A, which is apparently more sensitive to this problem than Pump B. The procedure for operating the RHR system with low water level in the reactor vessel did not adequately reflect the relationship between RHR flow rate and water level for the onset of vortexing in the suction line for the RHR pumps.

Catawba 1

On April 22, 1985, Catawba 1, a Westinghouse designed reactor, was in cold shutdown with RHR Train A inoperable because of maintenance, and RHR Train B in service to remove decay heat. Although one RHR train was inoperable, the licensee started to lower the water level in the reactor vessel to facilitate RCS pump seal maintenance. While draining was in progress, erratic performance of RHR Pump B indicated that vortexing, air entrainment, and air binding were occurring. The pump was secured; a charging pump was aligned to take suction from the RWST; and the water level in the reactor vessel was raised. Approximately 81 minutes after the first indication of vortexing, RHR Pump B was vented and returned to service. Temperature of the RCS peaked at 177° F.

For Catawba 1, the operating procedure for lowering water level in the reactor vessel does limit RHR flow as a function of level, apparently to preclude the onset of vortexing. However, the licensee believes that water level information obtained from inaccurate instrumentation contributed to complete loss of RHR flow. Further, the licensee incurred an increased risk of loss of RHR flow by lowering water level with one train of RHR cooling out of service. With the reactor in cold shutdown and the vessel partially drained, a limiting condition for operation in the Technical Specifications for Catawba 1 requires that one RHR train be operating and that the other be operable. Nevertheless, the operators concluded incorrectly that water level could be lowered if corrective action had been initiated to comply with the action statement for that limiting condition for operation.

Attachment 2
IN 86-101
December 12, 1986

LIST OF RECENTLY ISSUED IE INFORMATION NOTICES

Information Notice No.	Subject	Date of Issue	Issued to
86-100	Loss Of Offsite Power To Vital Buses At Salem 2	12/12/86	All PWRs or BWRs holding an OL or CP
86-99	Degradation Of Steel Containments	12/8/86	All power reactor facilities holding an OL or CP
86-21 Sup. 1	Recognition Of American Society Of Mechanical Engineers Accreditation Program For N Stamp Holders	12/4/86	All power reactor facilities holding an OL or CP
86-98	Offsite Medical Services	12/2/86	All power reactor facilities holding an OL or CP
86-97	Emergency Communications System	11/28/86	All power reactor facilities holding an OL or CP and fuel facilities
86-96	Heat Exchanger Fouling Can Cause Inadequate Operability Of Service Water Systems	11/20/86	All power reactor facilities holding an OL or CP
86-95	Leak Testing Iodine-125 Sealed Sources In Lixi, Inc. Imaging Devices and Bone Mineral Analyzers	11/14/86	All NRC licensees authorized to use Lixi, Inc. imaging devices
86-94	Hilti Contrete Expansion Anchor Bolts	11/6/86	All power reactor facilities holding an OL or CP
86-93	IEB 85-03 Evaluation Of Motor-Operators Identifies Improper Torque Switch Settings	11/3/86	All power reactor facilities holding an OL or CP
86-82 Rev. 1	Failures Of Scram Discharge Volume Vent And Drain Valves	11/4/86	All power reactor facilities holding an OL or CP

OL = Operating License
CP = Construction Permit