UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

May 27, 1987

NRC INFORMATION NOTICE NO. 87-23: LOSS OF DECAY HEAT REMOVAL DURING LOW REACTOR COOLANT LEVEL OPERATION

Addressees:

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

Purpose:

This notice provides information regarding the loss of decay heat removal capability at pressurized water reactors resulting from the loss of RHR pump suction during plant operations with low reactor coolant levels. It is expected that recipients will review this information for applicability to their reactor facilities and consider actions, if appropriate, to prevent similar problems. Suggestions contained in this notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On April 10, 1987 the Diablo Canyon Unit 2 reactor experienced a loss of decay heat removal capability in both trains. The reactor coolant system had been drained down to the mid-height of the hot-leg piping in preparation for the removal of the steam generator manways. During the 85 minute period that the heat-removal capability was lost, the reactor coolant heated from 87° F to boiling, steam was vented from an opening in the head, water was spilled from the partially unsealed manways, and the airborne radioactivity levels in the containment rose above the maximum permissible concentration of noble gases allowed by 10 CFR 20. The reactor, which was undergoing its first refueling, had been shut down for seven days at the time and the containment equipment hatch had been opened.

Erroneous level instrumentation, inadequate knowledge of pump suction head/flow requirements, incomplete assessment of the behavior of the air/water mixture in the system and poor coordination between control room operations and containment activities all contributed to the event. Under the conditions that existed, the system that indicated the level of coolant in the reactor vessel read "high" and responded poorly to changes in the coolant level. In addition, the intended coolant level, established for this operation, was later determined to be below the level at which air entrainment due to vortexing was predicted to commence. At the time of the event, the plant staff believed that the coolant level was six inches or more above the level that would allow vortexing.

The event began at about 8:43 pm, when a test engineer in preparation for a planned containment penetration local leak rate test, began draining a section of the reactor coolant pump leakoff return line, which he believed to be isolated. However, because of a leaking boundary valve, this action caused the volume control tank fluid to be drained through the interded test section to the reactor coolant drain tank. The control room operators, who were not aware that the engineer had begun conducting the test procedure, increased flow to stop the fluid reduction from the volume control tank. A few minutes later the operators were informed that the reactor coolant drain tank level was increasing but they could not determine the source of the leakage. Although the actual level of coolant in the reactor vessel was apparently dropping below the minimum intended level, the indication of level in the vessel remained within the desired control band. At 9:25 p.m. the electrical current of the active RHR pump (No. 2-2) was observed to be fluctuating. The 2-1 pump was started and the 2-2 pump was shut down. However, the current on the 2-1 pump also fluctuated, so it was immediately shut down as well.

The operators did not immediately raise the water level in the reactor because they still did not know either the source of the leakage, the true vessel level, or the status of the work on the steam generator manways. Operators were sent to vent the RHR pumps. One pump was reported to be vented at 10:03 p.m. At 10:21 p.m. an attempt was made to start this RHR pump, but the current fluctuated and it was shut down again. During this period the operators did not know the temperature of the coolant in the reactor vessel because the core exit thermocouples had been disconnected in preparation for the planned refueling. By 10:30 p.m. airborne activity levels in the containment were increasing and personnel began to evacuate from the containment building.

At 10:38 p.m. when the operators learned that the steam generator manways had not been removed, action was initiated to raise the reactor vessel water level by adding water from the refueling water storage tank. About 10 minutes later the test engineer identified the source of the leakage and stopped it. By 10:51 p.m., the vessel level had been raised sufficiently to restart one of the RHR pumps. The indicated RHR pump discharge temperature immediately rose to 220° F. At this time the reactor vessel was slightly above atmospheric pressure and steam was venting from an opening in the reactor vessel head.

Discussion:

The NRC has documented numerous instances in the past where decay heat removal systems have been disabled because pump suction was lost while the plant was being operated at low reactor coolant water levels. IE Information Notice 86-101 describes four such events that occurred in 1985 and 1986. NRC Case Study Report AEOD/C503 describes six such events that occurred in 1984, five that occurred in 1983, and seven that occurred in 1982. IE Information Notice 81-09 described an event at Beaver Valley in March 1981. The case study report further indicates that a total of 32 such events occurred from 1976 through 1984. The documentation includes descriptions of a total of 23 events that have occurred since 1981 involving loss of decay heat removal capability resulting from a loss of pump suction while operating at reduced water levels.

For all but four of these 23 events the primary cause of the loss of pump suction and loss of decay heat removal capability was attributed to incorrect, inaccurate, or inadequate level indication. Two events were attributed to loss of pump suction because of vortexing brought on by the simultaneous operation of both pumps. In many of these events procedural errors were also a contributing factor. In at least nine of the cases, the redundant pump was lost because air was entrained when the operators, not understanding the cause of the problem, switched to the second pump. There are repeated references to difficulties in getting the pumps vented quickly after air binding had occurred and to the operators' inability to take immediate action to raise reactor vessel levels until the safety of personnel working on the primary systems could be assured. The length of time that decay heat removal was completely lost varied from eight minutes to two hours and averaged almost an hour. In at least three previous cases, boiling is known to have occurred.

A number of actions have been recommended previously to prevent the loss of RHR pump suction during low vessel level operations. These include:

Providing accurate level instrumentation designed for reduced vessel water level operations.

Providing alarms in the control room for low decay heat removal flow and low water level.

Including in the procedures specific requirements for frequent monitoring and strict limits on level.

Considering in the procedures the possibility of vortex formation and air entrainment, including a precaution against starting a second RHR pump until the cause of the loss of the first pump is determined and corrective actions have been taken.

Training the operators on the correlation between water level and pump speed at the onset of vortexing and air entrainment.

Careful planning, coordination, and communication with control room personnel regarding all ongoing activities which could affect the primary system inventory.

The NRC review of the Diablo Canyon event indicated that vortexing and air entrainment may occur at higher water levels than anticipated. In addition, operation at mid-hot-leg levels can lead to unanticipated conditions which may not have been adequately considered in instrumentation design and procedure preparation.

The NRC staff's initial assessment of this event has identified the potential for a significant loss of decay heat removal capability both from a total loss of the RHR system and from a loss of the steam generator heat sink due to air blanketing of the steam generator tubes. Correct operator actions then become critical for plant recovery.

NRC communications in the past have expressed serious concern with failures to maintain adequate decay heat removal capability. IE Information Notice 81-09 pointed out that loss of shutdown cooling capability had been found to be a potentially significant contributor to the total risk. AEOD/C503 and other sources indicate that the time available to restore shutdown cooling before core uncovery can occur is not necessarily large. At four days after shutdown from long-term power operation, with the vessel drained down to the RHR suction loss level, the vessel water can heat to the boiling point in about 1/2 hour. Under such conditions boiloff to the core uncovery level can occur in less than two hours.

Following the loss of decay heat removal capability on April 10, 1987 at Diablo Canyon, PG&E took a number of actions to prevent loss of RHR suction during low level operation and to improve recovery should such a loss occur. These actions included the following:

Evaluation of the reactor vessel level indicating system to determine the level at which vortexing would occur and the effect of vortexing on the level measurement.

Enhancements of the instrumentation to include accurate level measurement, alarm capability and core exit temperature measurement during low level operation.

Enhancement of procedures to include requirements for verifying proper RHR pump suction before starting the second RHR pump. Also included are precautions specifying minimum vessel levels as a function of RHR flow.

Improvements in work planning, control and communication to include a restriction of the work scope to items that do not have the potential to reduce RCS inventory.

Improvement of operator training including a discussion of the potential causes of RHR flow loss, as well as recovery procedures.

The NRC is currently considering additional generic action on this issue.

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

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Attachment:
1. List of Recently Issued NRC Information Notices

LIST OF RECENTLY ISSUED INFORMATION NOTICES 1987

Information Notice No.	Subject	Date of Issuance	Issued to
87-22	Operator Licensing Requalification Examinations at Nonpower Reactors	5/22/87	All research and nonpower reactor facilities.
87-21	Shutdown Order Issued Because Licensed Operators Asleep While on Duty	5/11/87	All nuclear power facilities holding an OL or CP and all licensed operators.
87-20	Hydrogen Leak in Auxiliary Building	4/20/87	All nuclear power facilities holding an OL or CP
86-108 Sup. 1	Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion	4/20/87	All PWR facilities holding an OL or CP.
86-64 Sup. 1	Deficiencies in Upgrade Programs for Plant Emergency Operating Procedures.	4/20/87	All nuclear power facilities holding a CP or OL.
85-61 Sup. 1	Misadministrations to Patients Undergoing Thyroid Scans	4/15/87	All licensees authorized to use byproduct material
87-19	Perforation and Cracking of Rod Cluster Control Assemblies	4/9/87	All Westinghouse power PWR facilities holding an OL or CP
87-18	Unauthorized Service on Teletherapy Units by Non-licensed Maintenance Personnel	4/8/87	All NRC licensees authorized to use radioactive material in teletherapy units
87-17	Response Time of Scram Instrument Volume Level Detectors	4/7/87	All GE BWR facilities holding an OL or CP

OL = Operating License
CP = Construction Permit