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

June 8, 1988

NRC INFORMATION NOTICE NO. 88-36: POSSIBLE SUDDEN LOSS OF RCS INVENTORY DURING LOW COOLANT LEVEL OPERATION

Addressees:

All holders of operating licenses or construction permits for pressurized water reactors (PWRs).

Purpose:

This information notice is being provided to alert addressees to the potential for a sudden loss of reactor coolant system inventory while conducting steam generator tube inspections and modifications with hot leg nozzle dams in place. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

During the second refueling of Diablo Canyon Unit 1, in the spring of 1988, deficiencies in the procedures to be used during the steam generator tube inspections were identified that could significantly increase the probability of a sudden ejection of reactor coolant followed by core uncovery.

In order for the steam generator tubes to be inspected at Diablo Canyon, they were drained, by drawing air through reactor and pressurizer vents, until the reactor coolant inventory was drained down to the mid-level of the hot leg piping (see Figure 1). Lowering the reactor coolant to this level also uncovers the steam generator primary side manways so that they can be removed to gain access to the steam generator hot and cold leg plenums and their respective hot and cold leg nozzles. Nozzle dams are then placed in these steam generator plenum nozzles so that the reactor coolant level can be raised to increase the net positive suction head to the decay heat removal pumps without refilling the steam generators.

If the hot leg nozzle dams were all installed before all of the cold leg nozzle dams were in place, a small increase in reactor vessel pressure would cause reactor coolant to be rapidly expelled from the open cold leg manways. This would occur because the increased pressure, unable to vent through the dammed-up hot legs, would force the coolant down in the vessel, through the cold legs, and out of the manways. A pressure increase of only 2-1/2 psig in the vessel

would lower the coolant level to the point where the top of the fuel would begin to be uncovered, with the level of the remaining coolant in the open steam generator located at the bottom of the cold leg plenum manway.

Similar mechanisms have been identified at San Onofre Units 2 and 3 in their response to Generic Letter 87-12 (Reference 1), and by the Westinghouse Owners Group in an ongoing analysis of reactor behavior during the shutdown condition.

The possibility of ejecting coolant by this mechanism can be eliminated by ensuring that a steam generator hot leg plenum manway and its associated hot leg pipe are kept open to provide an adequate vent path whenever any cold leg openings are made. This can be accomplished by ensuring that a hot leg manway is the first manway to be opened, and a hot leg nozzle dam is the last dam to be installed. In addition, not installing the last hot leg nozzle dam until a sufficient vent path is established in the reactor vessel or pressurizer will reduce the possibility of developing a pressure differential which could eject a dam.

Discussion:

On April 10, 1987, the Diablo Canyon Unit 2 reactor vessel became pressurized to approximately 7 to 10 psig when the residual heat removal flow was lost for a period of 1-1/2 hours (Reference 2). Fortunately, during this event the manways, although loosened, were still in place and the nozzle dams had not yet been installed. Operating a reactor coolant system that has been drained to a low level often involves unusual problems that have a significant probability of causing a loss of residual heat removal unless special care is taken. NUREG-1269 (Reference 3), the report of the NRC investigation into the Diablo Canyon event, discusses a number of these problems. These include the following:

> The level which is established for draining the steam generator tubes is frequently only slightly above the level which will provide an adequate suction head for the residual heat removal pumps. This marginal suction head can lead to air entrainment due to vortexing at the suction point, which may cause a loss of pump suction.
>
> The temporary reactor vessel level measurement system necessary for this type of operation tends to be inaccurate because of the long lengths of tubing normally used. The possible air entrainment and the surface level variations due to fluid flow at this low level provide additional mechanisms that cause error in the level measurement.

The NRC has documented many instances where residual heat removal has been lost, because of loss of pump suction, while the plant was being operated at reduced reactor coolant water levels. Generic Letter 87-12 (Reference 1) lists 37 loss-of-decay-heat-removal events, occurring from 1977 to 1987, that were attributed to inadequate reactor coolant system level. In four cases, including the 1987 Diablo Canyon event, boiling is known to have occurred before residual heat removal could be reestablished.

Although small vents are normally established in the reactor vessel head and in the pressurizer before the coolant level is drained down, these are far too

small to prevent pressurization of the reactor coolant system after the boiling point is reached. For the recent steam generator inspection at Diablo Canyon, which was initiated 10 days after shutdown, the reactor was producing 5 MW of decay heat. This is sufficient to produce 5 lb of steam per second, which would require a vent area greater than 12 square inches in order to hold the pressure rise to less than 25 psi. During the 1987 Diablo Canyon event, the reactor, which had been shut down for seven days, reached the boiling point about 1/2 hour after decay heat removal capability was lost. The pressure increased to the 7-to-10-psig maximum value a short time later even though small vents were available in the vessel head and pressurizer.

With the hot leg nozzle dams in place the pressure rise would be quite rapid. Generation of a small amount of steam would be sufficient to produce the partial pressure of 2-1/2 psi necessary to uncover the core by ejecting the coolant through the open cold leg plenum manway. This amount of steam could be produced in less than a minute. However, the actual time to produce this pressure would depend on the time to heat the reactor coolant to the higher boiling point and on the rate of energy deposition in the cold materials in the upper part of the reactor vessel and, to a lesser extent, in the pressurizer. The time required for this to occur would likely be only a few minutes.

Loss of residual heat removal capability after the nozzle dams are installed and before the vessel level is raised would still result in a hazardous situation, however, more time would be available for operator action before loss of coolant occurred. The nozzle dams used at Diablo Canyon are designed to withstand about 50 psi of differential pressure. Approximately 1/2 hour of additional time would be available before the reactor coolant heated up to the approximately 300° F necessary to boil at this higher pressure. However, if a cold leg dam were to be expelled at this point, coolant ejection through the affected steam generator manway followed by core uncovery would be very rapid. For this reason, it is prudent to provide a means of venting the vessel with the dams installed. At Diablo Canyon, the schedule for detensioning the reactor vessel head was advanced so that this would be done before the reactor was drained for the steam generator inspection. Although the pressure necessary to lift the detensioned vessel head, in order to vent the vessel, is less than the pressure required to eject the nozzle dams, this pressure is greater than that which would be required to uncover the top of the fuel by expelling coolant through an undammed steam generator cold leg nozzle and the associated manway. Therefore, even with the head detensioned, the hot leg nozzles should be left open until all cold leg openings are closed.

Generic Letter 87-12 also identified a comparable mechanism for uncovering the core by pressurization during low coolant level operation. An opening in a cold leg, such as one caused by the opening of a reactor coolant system pump or a loop isolation valve (in some plants), would vent the space of the affected cold leg, maintaining this space at atmospheric pressure. Any pressure increase, such as would be caused by boiling in the reactor vessel, would be propagated throughout the remainder of the reactor coolant system, including both hot and cold sides of steam generator primary spaces. This differential pressure would force the coolant levels in the vessel down while the displaced coolant would be forced up and out of the affected cold leg opening. As with the mechanism already discussed, only about 2 1/2 psi would be required to

expel the water down to the top of the core with the coolant in the affected cold leg at the level of a pump opening. Although in this case some steam condensation may occur in the steam generators, as the 1987 Diablo Canyon event showed, this will not prevent pressurization. Note that this mechanism, involving coolant expulsion through a cold leg opening, does not require plugging the steam generator nozzles. As with the previous mechanism, this hazard might be eliminated by venting the reactor vessel through a large opening, such as a hot leg steam generator plenum manway or pressurizer opening, before opening the cold leg.

The loss of residual heat removal capability during low reactor coolant level operation has proven to be a frequent occurrence; leading in several cases to boiling in the reactor vessel. If this should occur, pressurization of the reactor vessel can lead to sudden core uncovery by the expulsion of coolant through any opening in the cold leg side of the reactor coolant system. This hazard can be eliminated by providing a large vent for the reactor vessel space before opening the cold leg.

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Charles E. Rossi

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Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical Contacts: Paul P. Narbut, RV
(805) 595-2354

Donald C. Kirkpatrick, NRR
(301) 492-1152

Warren Lyon, NRR
(301) 492-0891

Attachments:
1. Figure 1 - Reactor Coolant System
2. List of Recently Issued NRC Information Notices

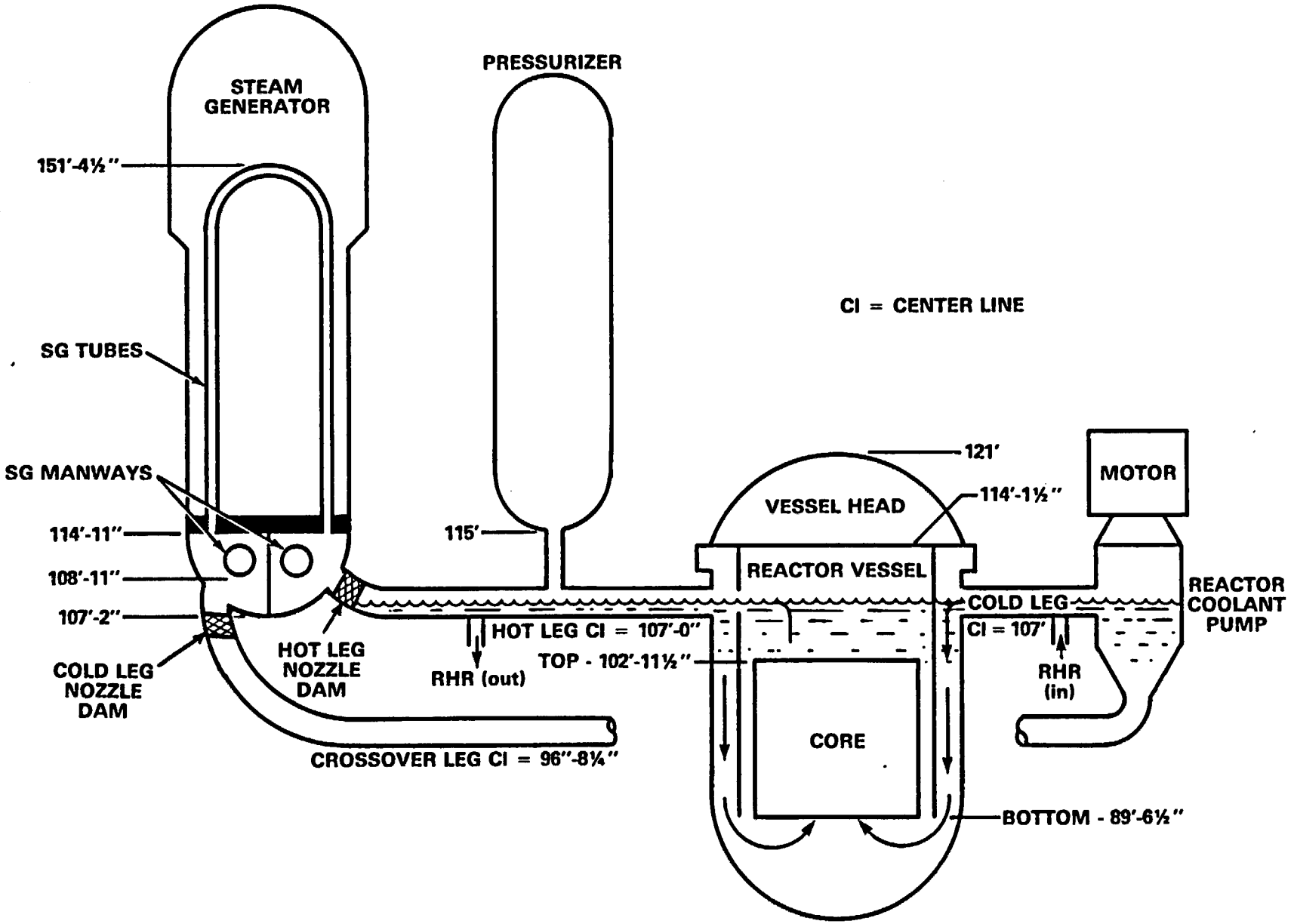
References:

1. Generic Letter 87-12, "Loss of Residual Heat Removal While the Reactor Coolant System is Partially Filled," July 9, 1987.

2. IN 87-23, "Loss of Decay Heat Removal During Low Reactor Coolant Level Operation."

3. NUREG-1269, "Loss of Residual Heat Removal System, Diablo Canyon, Unit 2," April 10, 1987.

Figure 1 REACTOR COOLANT SYSTEM



Attachment 1

LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
88-35	Inadequate Licensee Performed Vendor Audits	6/3/88	All holders of OLs or CPs for nuclear power reactors.
88-34	Nuclear Material Control and Accountability of Non-Fuel Special Nuclear Material at Power Reactors	5/31/88	All holders of OLs or CPs for nuclear power reactors.
87-61, Supplement 1	Failure of Westinghouse W-2-Type Circuit Breaker Cell Switches	5/31/88	All holders of OLs or CPs for nuclear power reactors.
88-33	Recent Problems Involving the Model Spec 2-T Radiographic Exposure Device	5/27/88	All Agreement States and NRC licensees authorized to manufacture, distribute or operate radiographic exposure devices and source changers.
88-32	Promptly Reporting to NRC of Significant Incidents Involving Radioactive Material	5/25/88	All NRC material licensees.
88-31	Steam Generator Tube Rupture Analysis Deficiency	5/25/88	All holders of OLs or CPs for Westinghouse and Combustion Engineering-designed nuclear power plants.
88-30	Target Rock Two-Stage SRV Setpoint Drift Update	5/25/88	All holders of OLs or CPs for nuclear power reactors.
88-29	Deficiencies in Primary Containment Low-Voltage Electrical Penetration Assemblies	5/24/88	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit

expel the water down to the top of the core with the coolant in the affected cold leg at the level of a pump opening. Although in this case some steam condensation may occur in the steam generators, as the 1987 Diablo Canyon event showed, this will not prevent pressurization. Note that this mechanism, involving coolant expulsion through a cold leg opening, does not require plugging the steam generator nozzles. As with the previous mechanism, this hazard might be eliminated by venting the reactor vessel through a large opening, such as a hot leg steam generator plenum manway or pressurizer opening, before opening the cold leg.

The loss of residual heat removal capability during low reactor coolant level operation has proven to be a frequent occurrence; leading in several cases to boiling in the reactor vessel. If this should occur, pressurization of the reactor vessel can lead to sudden core uncovery by the expulsion of coolant through any opening in the cold leg side of the reactor coolant system. This hazard can be eliminated by providing a large vent for the reactor vessel space before opening the cold leg.

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Transmitted by memo to C. H. Berlinger from Dennis F. Kirsch dated March 21, 1988.
*SEE PREVIOUS CONCURRENCES

	D/DOEA:NRR	*C/OGCB:DOEA:NRR	*PPMB:ARM	*D/DEST:NRR
	CERossi	CHBerlinger	TechEd	LCShao
	06/27/88	05/26/88	05/12/88	05/18/88
*OGCB:DOEA:NRR	*RV	*SRXB:DEST:NRR	*C/SRXB:DEST:NRR	*SAD/DEST:NRR
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coolant would be forced up and out of the affected cold leg opening. As with the mechanism already discussed, only about 2 1/2 psi would be required to expel the water down to the top of the core with the coolant in the affected cold leg at the level of a pump opening. Although in this case some steam condensation may occur in the steam generators, as the 1987 Diablo Canyon event showed, this will not prevent pressurization. Note that this mechanism, involving coolant expulsion through a cold leg opening, does not require plugging the steam generator nozzles. As with the previous mechanism, this hazard might be eliminated by venting the reactor vessel air space through a large opening, such as a steam generator manway or pressurizer opening, before opening the cold leg.

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As this discussion indicates, loss of residual heat removal during low reactor coolant level operation has proven to be a frequent occurrence, leading in several cases to boiling in the reactor vessel. If this should occur, pressurization of the reactor vessel can lead to sudden core uncovery by the expulsion of coolant through any opening in the cold leg side of coolant system. This hazard can be eliminated by providing a large vent for the reactor vessel air space before opening the cold leg.

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As this discussion indicates, loss of residual heat removal during low reactor coolant level operation has proven to be a frequent occurrence, leading in several cases to boiling in the reactor vessel. If this should occur, pressurization of the reactor vessel can quickly lead to core uncovery by expulsion of coolant through any opening in the cold leg side of coolant system. This hazard can be eliminated by providing a large vent for the reactor vessel air space prior to making the cold leg opening.

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