UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

October 22, 1996

NRC INFORMATION NOTICE 96-55: INADEQUATE NET POSITIVE SUCTION HEAD OF EMERGENCY CORE COOLING AND CONTAINMENT HEAT REMOVAL PUMPS UNDER DESIGN BASIS ACCIDENT CONDITIONS

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to recent discoveries by licensees that the available net positive suction head (NPSH) requirements for emergency core cooling system (ECCS) and containment heat removal pumps may not be adequate under all postulated design basis scenarios. 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 are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

Haddam Neck

Insufficient NPSH for Residual Heat Removal Pumps (ECCS Recirculation Mode)

In November 1986, the Haddam Neck licensee determined that the existing NPSH analysis for the residual heat removal (RHR) pumps was in error. This analysis indicated that containment pressure in excess of the saturation pressure corresponding to the temperature of the sump fluid was not needed to satisfy NPSH requirements for the RHR pumps in the recirculation mode of ECCS operation. The revised analysis conducted to correct the error indicated, however, that credit for containment pressure above pre-event condition was necessary to satisfy RHR pump NPSH requirements for recirculation operation.

A re-analysis conducted by the licensee in 1995 to reflect changing plant conditions indicated that a required containment overpressure that was a significant fraction of peak calculated containment design pressure was necessary to meet NPSH requirements. Key assumptions of the analysis were minimum design basis heat removal conditions, including minimum service water flow, maximum service water temperature, and maximum fouling of the

containment air coolers. A primary concern of the staff was the fact that the containment overpressure relied upon was significantly greater than any previously approved calculation.

On August 30, 1996, in Licensee Event Report 50-213/96-016, Accession Number 9609090320, the licensee stated that calculations performed in August 1996, to determine the available NPSH to the RHR pumps operating in recirculation mode may not be adequate under all postulated design basis scenarios. The licensee indicated that the assumption of sufficient containment overpressure to meet NPSH requirements used in previous analyses could not be supported since recent sump temperature analyses cannot assure that the necessary containment overpressure would be available. In particular, for the preferred recirculation flow path, the necessary overpressure would be approximately 136kPa [5 psig] and would exist for the duration of the transient. However, an alternate recirculation flow path exists which is more restrictive, thus the necessary overpressure is greater and would be unlikely to exist for the duration of short-term (single path) recirculation. The alternate path exists to mitigate a potential failure of the preferred path.

The licensee attributed the apparent cause of the inadequate NPSH available to the failure to fully analyze containment pressure and sump temperature response to support the NPSH calculation. The licensee intends to replace the piping between the containment sump and the RHR pump suction with larger diameter piping to reduce the frictional losses so that containment overpressure will not be relied on to satisfy NPSH requirements for the pumps.

Insufficient NPSH for Charging Pumps (ECCS Recirculation Mode) due to Inadequate Procedures

Another issue at Haddam Neck was reported on April 12, 1996, in Licensee Event Report 50-213/96-06, Accession Number 9604190045, which involves inadequate NPSH for a single centrifugal charging pump when the pump suction is aligned to the discharge of the RHR pumps. The postulated scenario would occur for a design basis loss of coolant accident (LOCA) during the switchover to ECCS sump recirculation from the refueling water storage tank (RWST) for the purpose of long-term recirculation cooling, with offsite power and only one of the two centrifugal charging pumps available. With one of the charging pumps unavailable, the available pump would generate all of the flow, thereby requiring a greater NPSH. The licensee determined that under these conditions, the currently allowable minimum RWST volume specified in the emergency response procedures would be insufficient to provide the required NPSH as RWST level decreases during the switchover.

The licensee attributed the cause of the potential inadequate NPSH available to an error in the analysis supporting the applicable emergency response procedures. The minimum allowable RWST volume was based on providing sufficient NPSH and protecting against vortex air ingestion for the high pressure injection pumps. The licensee incorrectly assumed that these requirements were more limiting than any associated with the charging pumps. Corrective actions included revising the emergency response procedures to

caution the plant operators of the potential for charging pump cavitation and to advise the operators to reduce charging pump flow.

Maine Yankee

Insufficient NPSH for Containment Spray Pumps (Sump Recirculation Mode)

Calculations performed in 1995 by the licensee for Maine Yankee indicate a worst case condition where the available NPSH for the containment spray (CS) pumps would be approximately 0.21m [0.7 ft] below the required NPSH specified by the manufacturer (4.66m [15.3 ft] at 0.25m^3/s [3900 gpm]) for the first five minutes following the switchover of pump suction from the RWST to the recirculation sump after a design basis LOCA.

In light of these recent calculations, the licensee discussed the results of the 1995 analysis with the pump manufacturer to assess the impact of the results on long- and short-term pump reliability. The manufacturer agreed with the licensee's engineers that the pumps would not be damaged during the five minute transient where minimum NPSH conditions exist and would operate reliably following the transient. In support of this assessment, the licensee cited various tests conducted by the manufacturer which show: (1) that similar pumps are routinely operated at up to 50-percent degraded NPSH conditions for 1-3 minutes without sustaining damage; (2) the installed CS pumps at Maine Yankee could operate indefinitely with an available NPSH of 4.45m [14.6 ft] at 0.25m^3/s [3900 gpm] without an adverse impact on mechanical integrity; and (3) the installed pumps could operate for up to 15 minutes with an available NPSH of 3.47m [11.4 ft] at 0.25m^3/s [3900 gpm] with no impact on mechanical integrity or long-term hydraulic performance.

The licensee concluded that the CS pumps remain capable of performing under postulated LOCA conditions and that their NPSH calculations accurately reflect sump temperature at the time CS pump suction is switched from the RWST to the recirculation sump. The staff has not yet completed its evaluation of the licensee's analysis.

Crystal River Unit 3

Insufficient NPSH for Low Pressure Injection Pumps (ECCS Recirculation Mode) due to Inadequate Procedures

On March 22, 1995, the licensee for Crystal River, Unit 3, indicated that for a given ECCS configuration, it is procedurally possible to have inadequate NPSH for a low pressure injection (LPI) pump during design basis LOCAs, potentially resulting in LPI pump cavitation. The configuration consists of one LPI pump suction aligned to the reactor building sump with its discharge directed to the reactor vessel, while the same pump simultaneously provides flow to both high pressure injection pumps delivering their maximum flowrates. The configuration would occur as a result of the Emergency Operating Procedures (EOPs) directing plant operators to cross-connect the high pressure injection piping when only one of the two LPI pumps is available. With just one LPI pump supplying both high pressure

injection pumps, the flow through the LPI pump would increase, resulting in a required NPSH greater than that available from the sump. The problem would not exist if the single LPI pump were supplying both high pressure injection pumps from the borated water storage tank.

The licensee indicated that the cause of the event was a procedural discrepancy resulting from insufficient review during the EOP change process. The change to allow one LPI pump to be aligned to both charging pumps was not reviewed in terms of NPSH since it was not thought that the flow demand of the available LPI pump would significantly increase. Prior to the change, the EOPs directed that two LPI pumps be aligned to the high pressure injection pumps. The EOPs were revised to address the concern.

Discussion

It is important that the emergency core cooling and containment spray system pumps have adequate NPSH available for all design basis accident conditions such that the systems can reliably perform their intended functions under these conditions. Inadequate NPSH could cause voiding in the pumped fluid, resulting in pump cavitation, vapor binding, and potential common mode failure of the pumps. Such failure would result in the inability of the ECCS system to provide adequate long-term core cooling and/or the inability of the containment sprays to maintain the containment pressure and temperature to within design limits. Loss of the containment spray pumps would also reduce the ability to scrub fission products from containment atmosphere following a LOCA, and damage to ECCS or CS pump seals from elevated fluid temperatures and cavitation induced vibration could result in increased leakage of coolant outside containment.

For the analyses used to determine the available NPSH, NRC Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps," issued November 2, 1970, establishes the regulatory position that ECCS and containment heat removal system pumps should be designed so that adequate NPSH is available assuming maximum expected temperatures of pumped fluids and no increase in containment pressure from that present prior to postulated LOCAs. Because containment pressure can vary considerably depending on the accident scenario, the staff concluded in the Regulatory Guide that sufficient NPSH should be available for all postulated coolant accidents without crediting containment overpressure.

However, in the past, the staff has selectively allowed limited credit for a containment pressure slightly above the vapor pressure of the sump fluid (i.e., an overpressure) on a case-by-case basis for satisfying NPSH requirements. In these cases, licensees have typically been requested to calculate the peak containment pressure resulting from the most limiting design basis LOCA using the models described in Branch Technical Position CSB 6-1. The models in CSB 6-1 includes such provisions as maximizing heat transfer coefficients to containment heat sinks, maximizing the containment free volume, and mixing of subcooled ECCS water with steam in the containment, all of which effectively maximize heat transfer from the containment atmosphere, thereby minimizing the calculated

containment pressure and resulting in a conservative overpressure. Generally speaking, this minimum overpressure is substantially greater than the needed overpressure for assuring adequate NPSH.

With regard to those cases where plant procedures would have directed system configurations resulting in inadequate NPSH, the staff stresses the importance of ensuring that the actions and the results of actions directed by the procedures do not result in situations where safety-related equipment would be incapable of performing its intended function, or of performing in a non-degraded manner.

The events described herein highlight the importance of ensuring sufficient available NPSH for ECCS and containment heat removal system pumps for the applicable spectrum of postulated LOCAs or secondary/main steam line breaks, such that the ability for long-term core cooling and containment heat removal are not compromised. It is important that licensees know the NPSH requirements of the pumps and the bases on which the NPSH available is considered adequate under a spectrum of primary and secondary break sizes and locations. It is also important that licensees know the containment heat removal conditions assumed in these analyses. If credit has been taken for a containment over-pressure above the vapor pressure of the sump fluid, it is important for licensees to know the basis for the amount of overpressure credited, including the modeling assumptions of the analysis used to determine it. Finally, system configurations that result from following plant procedures should not result in situations where the NPSH available would be inadequate under design basis accident conditions.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

GBMatthews

for Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Howard Dawson, NRR
(301) 415-3138
Email: hfd@nrc.gov

William Long, NRR
(301) 415-3026
Email: wol@nrc.gov

Attachment: List of Recently Issued NRC Information Notices

Attachment filed in Jacket

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
96-54	Vulnerability of Stainless Steel to Corrosion When Sensitized	10/17/96	All materials licensees
96-53	Retrofit to Amersham 660 Posilock Radiography Camera to Correct Inconsistency in 10 CFR Part 34 Compatibility	10/15/96	All industrial radiography licensees
95-04, Supp. 1	Excessive Cooldown and Depressurization of the Reactor Coolant System Following Loss of Offsite Power	10/11/96	All holders of OLs or CPs and vendors for nuclear power reactors
96-40, Supp. 1	Deficiencies in Material Dedication and Procurement Practices and in Audits of Vendors	10/07/96	All holders of OLs or CPs for nuclear power reactors
96-52	Cracked Insertion Rods on Troxler Model 3400 Series Portable Moisture Density Gauges	09/26/96	All U.S. Nuclear Regulatory Commission portable gauge licensees and vendors
92-68, Supp. 1	Potentially Substandard Slip-On, Welding Neck, and Blind Flanges	09/16/96	All holders of OLs or CPs for nuclear power reactors

OL = Operating License
CP = Construction Permit

containment pressure and resulting in a conservative overpressure. Generally speaking, this minimum overpressure is substantially greater than the needed overpressure for assuring adequate NPSH.

With regard to those cases where plant procedures would have directed system configurations resulting in inadequate NPSH, the staff stresses the importance of ensuring that the actions and the results of actions directed by the procedures do not result in situations where safety-related equipment would be incapable of performing its intended function, or of performing in a non-degraded manner.

The events described herein highlight the importance of ensuring sufficient available NPSH for ECCS and containment heat removal system pumps for the applicable spectrum of postulated LOCAs or secondary/main steam line breaks, such that the ability for long-term core cooling and containment heat removal are not compromised. It is important that licensees know the NPSH requirements of the pumps and the bases on which the NPSH available is considered adequate under a spectrum of primary and secondary break sizes and locations. It is also important that licensees know the containment heat removal conditions assumed in these analyses. If credit has been taken for a containment over-pressure above the vapor pressure of the sump fluid, it is important for licensees to know the basis for the amount of overpressure credited, including the modeling assumptions of the analysis used to determine it. Finally, system configurations that result from following plant procedures should not result in situations where the NPSH available would be inadequate under design basis accident conditions.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Howard Dawson, NRR
(301) 415-3138
Email: hfd@nrc.gov

William Long, NRR
(301) 415-3026
Email: wol@nrc.gov

Attachment: List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCES

Tech Editor reviewed and concurred on
DOCUMENT NAME: 96-55.IN

To receive a copy of this document, indicate in the box: "C" = Copy w/o attachment/enclosure "E" = Copy w/attachment/enclosure "N" = No copy

OFFICE	CONTACTS	C/PECB:DRPM	D/DRPM		
NAME	HDawson* WLong*	AChaffee *	TMartin for		
DATE	09/23/96	10/15/96	10/22/96		

OFFICIAL RECORD COPY

containment pressure and resulting in a conservative overpressure. Generally speaking, this minimum overpressure is substantially greater than the needed overpressure for assuring adequate NPSH.

With regard to those cases where plant procedures would have directed system configurations resulting in inadequate NPSH, the staff stresses the importance of ensuring that the actions and the results of actions directed by the procedures do not result in situations where safety-related equipment would be incapable of performing its intended function, or of performing in a non-degraded manner.

The events described herein highlight the importance of ensuring sufficient available NPSH for ECCS and containment heat removal system pumps for the applicable spectrum of postulated LOCAs or secondary/main steam line breaks, such that the ability for long-term core cooling and containment heat removal are not compromised. It is important that licensees know the NPSH requirements of the pumps and the bases on which the NPSH available is considered adequate under a spectrum of primary and secondary break sizes and locations. It is also important that licensees know the containment heat removal conditions assumed in these analyses. If credit has been taken for a containment over-pressure above the vapor pressure of the sump fluid, it is important for licensees to know the basis for the amount of overpressure credited, including the modeling assumptions of the analysis used to determine it. Finally, system configurations that result from following plant procedures should not result in situations where the NPSH available would be inadequate under design basis accident conditions.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Howard Dawson, NRR
(301) 415-3138
Email: hfd@nrc.gov

William Long, NRR
(301) 415-3026
Email: wol@nrc.gov

Attachment: List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCES

Tech Editor reviewed and concurred on

DOCUMENT NAME: 96-55.IN

To receive a copy of this document, indicate in the box: "C" = Copy w/o attachment/enclosure "E" = Copy w/attachment/enclosure "N" = No copy

OFFICE	CONTACTS		C/PECB:DRPM		D/DRPM					
NAME	HDawson* WLong*		AChaffee		TMartin					
DATE	09/23/96		10/15/96		10/ /96					

OFFICIAL RECORD COPY

containment pressure and resulting in a conservative overpressure. Generally speaking, this minimum overpressure is substantially greater than the needed overpressure for assuring adequate NPSH.

With regard to those cases where plant procedures would have directed system configurations resulting in inadequate NPSH, the staff stresses the importance of ensuring that the actions and the results of actions directed by the procedures do not result in situations where safety-related equipment would be incapable of performing its intended function, or of performing in a non-degraded manner.

The events described herein highlight the importance of ensuring sufficient available NPSH for ECCS and containment heat removal system pumps for the applicable spectrum of postulated LOCAs or secondary/main steam line breaks, such that the ability for long-term core cooling and containment heat removal are not compromised. It is important that licensees know the NPSH requirements of the pumps and the bases on which the NPSH available is considered adequate under a spectrum of primary and secondary break sizes and locations. It is also important that licensees know the containment heat removal conditions assumed in these analyses. If credit has been taken for a containment over-pressure above the vapor pressure of the sump fluid, it is important for licensees to know the basis for the amount of overpressure credited, including the modeling assumptions of the analysis used to determine it. Finally, system configurations that result from following plant procedures should not result in situations where the NPSH available would be inadequate under design basis accident conditions.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Howard Dawson, NRR
(301) 415-3138
Email: hfd@nrc.gov

William Long, NRR
(301) 415-3026
Email: wol@nrc.gov

Attachment: List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCES

Tech Editor reviewed and concurred on
DOCUMENT NAME: 96-55.IN

To receive a copy of this document, indicate in the box: "C" = Copy w/o attachment/enclosure "E" = Copy w/attachment/enclosure "N" = No copy

OFFICE	CONTACTS		C/PECB:DRPM		D/DRPM					
NAME	HDawson* WLong*		AChaffee		TMartin					
DATE	09/23/96		10/15/96		10/ /96					

OFFICIAL RECORD COPY

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Howard Dawson, NRR
(301) 415-3138
Email: hfd@nrc.gov

William Long, NRR
(301) 415-3026
Email: wol@nrc.gov

Attachment: List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCES

DOCUMENT NAME: G:\EJB1\NPSH.IN

To receive a copy of this document, indicate in the box: "C" = Copy without attachment/enclosure "E" = Copy with attachment/enclosure "N" = No copy

OFFICE	Contacts	BC/SCSB:DSSA	D/DSSA	C/PECB:DRPM	D/DRPM
NAME	HDawson* WLong*	CBerlinger*	GHolahan*	AChaffee	TMartin
DATE	09/23/96 09/23/96	09/23/96	09/30/96	/ /96	/ /96

OFFICIAL RECORD COPY

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below of the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Thomas T. Martin, Director
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical Contacts: Howard Dawson, NRR
(301)415-3138
Internet:hfd@nrc.gov

William Long, NRR
(301)415-3026
Internet:wol@nrc.gov

DOCUMENT NAME: G:\EJB1\NPSH.IN

To receive a copy of this document, indicate in the box: "C" = Copy without attachment/enclosure "E" = Copy with attachment/enclosure "N" = No copy

OFFICE	Contacts	E	BC/SCSB:DSSA		BC/SRXB:DSSA	C	D/DSSA	
NAME	HDawson WLong		CBerlinger		RJones		GHOlshan	
DATE	9/23/96 9/24/96		9/23/96		9/27/96		9/30/96	

OFFICE	C/PECB:DRPM		D/DRPM					
NAME	ACHaffee		TMartin					
DATE	/ /96		/ /96		/ /96		/ /96	

OFFICIAL RECORD COPY