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

October 7, 1997

NRC GENERIC LETTER 97-04: ASSURANCE OF SUFFICIENT NET POSITIVE SUCTION HEAD FOR EMERGENCY CORE COOLING AND CONTAINMENT HEAT REMOVAL PUMPS

Addressees

All holders of operating licenses for nuclear power plants, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this generic letter (GL) to request that addressees submit information necessary to confirm the adequacy of the net positive suction head (NPSH) available for emergency core cooling (including core spray and decay heat removal) and containment heat removal pumps.

Background

As a result of recent inspection activities, licensee notifications, and licensee event reports (LER), the NRC has identified a safety-significant issue that has generic implications and warrants action by the NRC to ensure that the issue is adequately addressed and resolved. The issue is that the NPSH available for emergency core cooling system (ECCS) (including core spray and decay heat removal) and containment heat removal pumps may not be adequate under all design-basis accident scenarios.

In some cases, this inadequacy may be a result of changes in plant configuration, operating procedures, environmental conditions, or other operating parameters over the life of the plant. In other cases, a plant's NPSH analysis may not bound all postulated events for a sufficient time, or assumptions used in the analysis may be non-conservative or inconsistent with assumptions and methodologies traditionally considered acceptable by the staff. For example, some licensees have recently discovered that they must take new or additional credit for containment overpressure to meet the NPSH requirements of the emergency core cooling system and containment heat removal pumps. In the examples the NRC staff is familiar with, the need for crediting this overpressure in NPSH analyses has arisen because of changes in plant configuration and operating conditions, and/or errors in prior NPSH calculations. As a result, the overpressure being credited by licensees may be inconsistent with the plant's respective licensing basis.

Current NPSH analyses (including any corresponding containment pressure analyses) may not be available to the staff in docketed material (such as final safety analysis reports) because some licensees have changed their analyses. Consequently, this generic letter requests that addressees provide current information regarding the NPSH analyses for emergency core cooling and containment heat removal pumps. This generic letter applies only to ECCS and containment heat removal pumps that meet the following criteria:

(1) pumps that take suction from the containment sump or suppression pool following a design-basis loss-of-coolant accident (LOCA) or secondary line break, or

(2) pumps used in "piggyback" operation that are necessary for recirculation cooling of the reactor core and containment (that is, pumps that are supplied by pumps which take suction directly from the sump or suppression pool).

New NPSH analyses are neither requested nor required to be performed to respond to this information request. However, new NPSH analyses may be warranted if an addressee determines that changes in plant design or procedures have occurred which may have reduced the available NPSH. In such cases, each affected addressee must take appropriate corrective action to restore its facility to compliance, in accordance with the requirements stated in Appendix B to 10 CFR Part 50.

The following is a sample of the NRC staff's recent findings concerning the NPSH issues addressed by this generic letter.

Haddam Neck

In 1986 and 1995, the licensee identified conditions for which the NPSH available for residual heat removal (RHR) pumps may be insufficient when the pumps are operating in the emergency core cooling mode. In 1986, the licensee determined that the only extant NPSH analysis, which was performed in 1979 as part of the Systematic Evaluation Program, did not properly account for hydraulic losses in suction piping. As a result, that analysis erroneously indicated that containment overpressure was not needed to satisfy NPSH requirements for the pumps in the recirculation mode of operation. A subsequent analysis showed that the licensee needed to take credit for 41.36 kPa (6 psig) of containment overpressure. In another analysis conducted in 1995 using increased service water temperature, the licensee found that additional containment overpressure was necessary to meet NPSH requirements for the same pumps. This additional overpressure constituted a significant fraction of the peak calculated containment accident pressure.

On August 30, 1996, the licensee reported in LER 96-016 that calculations recently performed to determine the NPSH available for the RHR pumps may have been in error for the alternate, short-term recirculation flow path, because of insufficient containment overpressure for a period of pump operation. The licensee attributed this error to its failure to fully analyze the containment pressure and sump temperature responses under design-basis accident conditions.

Maine Yankee

In July and August 1996, an NRC Independent Safety Assessment Team (ISAT) conducted an inspection to determine if Maine Yankee was operating in conformance with its design and licensing bases. During that inspection, the ISAT identified potential weaknesses in the NPSH analysis conducted by the licensee for the containment spray pumps. These potential weaknesses included concerns regarding the validity of the containment sump temperature analysis, incorrect calculation of bounding pump suction head losses, and use of a hot-fluid correction factor to reduce NPSH requirements.

The licensee's calculation of record, performed in 1995 for a power level of 2700 thermal megawatts (MWt) and which does not include the hot-fluid correction factor, indicates that the available NPSH for the containment spray pumps would be below the required NPSH for the first 5 minutes after pump suction is switched from the refueling water storage tank to the recirculation sump. When the licensee repeated the analysis using the hot-fluid correction factor (the use of which the ISAT viewed as a non-conservative assumption as implemented by Maine Yankee), the available NPSH was only slightly greater than the required NPSH for the same 5-minute period. For the remainder of the transient, the licensee's analysis showed that NPSH available to the containment spray pumps would exceed the amount required. As a basis for the contention that the containment spray pumps were operable despite the 5-minute period with available NPSH below the required NPSH, the licensee cited recent pump tests showing that the pumps could operate for a 15-minute period with NPSH below the required value without damage to the hydraulic performance or mechanical integrity of the pumps.

The licensee performed another analysis for a power level of 2440 MWt, which showed that adequate NPSH margin would be available for the containment spray pumps in the recirculation mode of operation. This analysis did not include use of the hot-fluid correction factor. The ISAT concluded that it was appropriate to consider the containment spray pumps operable at a power level of 2440 MWt.

Pilgrim

As indicated in the NRC safety evaluation for licensing of the Pilgrim plant, and in documents referenced by that evaluation, containment overpressure was not necessary to satisfy RHR and core spray pump NPSH requirements at the time of licensing. When the plant was modified in 1984, the licensee's safety evaluation related to the modification stated that the available NPSH was determined assuming (1) maximum debris loading conditions on the sump strainers for the RHR and core spray pumps and (2) no credit for containment

overpressure. The licensee reaffirmed this assumption on April 14, 1994, in its response to NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated March 23, 1993, stating that the NPSH available to the residual heat removal and core spray pumps was analyzed assuming no overpressure condition in the torus.

However, in an analysis conducted by the licensee in 1995 in support of a proposal to raise the design seawater injection temperature to 75°F, credit was needed and taken for containment overpressure. At the time of this analysis, the licensee also indicated that the assumption of no overpressure in the torus, stated in its response to Bulletin 93-02, was incorrect. This example illustrates that the potential exists that other licensees may have made modifications to their plants that could be inconsistent with the plant's licensing basis, and could reduce the NPSH available to the ECCS pumps.

Crystal River, Unit 3

In July 1996, an NRC inspection team conducted an Integrated Performance Assessment of Crystal River, Unit 3. As part of that assessment, the team reviewed the licensee's calculation which established the minimum post-LOCA reactor building water level required to ensure that adequate NPSH would be available for the reactor building spray pumps. When the team compared this level with the minimum predicted level, they found that for one of the pumps, there was only a slight difference between the available water level and the level required to ensure adequate NPSH during the post-accident recirculation phase of pump operation.

The team found that the licensee used non-conservative assumptions in calculating the available NPSH for the spray pump. For example, the licensee failed to account for uncertainty in data regarding the required NPSH, as well as for uncertainties associated with with the hydraulic resistance of check valves in the spray lines. In addition, the licensee used a hot fluid correction factor to reduce the required NPSH without considering the effects of non-condensable gases in the pumped fluid. Conservative assumptions included in the licensee's calculation were those detailed in Regulatory Guide (RG) 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps," dated November 2, 1970 (originally Safety Guide 1), regarding the use of maximum reactor building fluid temperature and lack of credit for containment overpressure.

The team concluded that the non-conservative assumptions used in the licensee's NPSH calculation raise questions concerning the cavitation-free operation of reactor building spray pump 1B during the recirculation phase of operation. However, the team also concluded that this issue did not constitute an immediate safety concern since the licensee's calculations conservatively assumed no credit for containment overpressure and used the maximum expected reactor building water temperature.

Dresden

By letter dated January 13, 1997, the licensee for Dresden submitted a license amendment request for approval of 13 kPa (2 psig) of containment overpressure for the first 10 minutes

following a design-basis LOCA. This overpressure is necessary to compensate for an NPSH deficiency for the low pressure coolant injection (LPCI) and core spray pumps. The licensee identified the need for overpressure after discovering that an incorrect value for the ECCS suction strainer head loss had been used in the design-basis NPSH calculation. As part of a design-basis review, the licensee determined that the actual head loss across the suction strainers was 1.8 m (5.8 feet) for clean strainers, rather than the 0.30 m (1 foot) head loss assumed in Dresden's original design basis as documented in the final safety analysis report and vendor drawings.

Because the licensee could not determine with certainty if overpressure was part of the original Dresden licensing basis, the licensee concluded that the use of overpressure constituted an unreviewed safety question and therefore requested staff approval to credit overpressure. In a license amendment dated January 28, 1997, the staff approved the requested use of 13 kPa (2 psig) of containment overpressure. In a subsequent license amendment issued on April 30, 1997, the staff approved the use of a maximum of 65 kPa (9.5 psig) of containment overpressure for NPSH, for the first 240 seconds following a design-basis LOCA. The need for this greater amount of overpressure arose primarily because of a higher calculated suppression pool temperature than that used in the analysis to support 13 kPa (2 psig) of overpressure.

Monticello

In a report submitted to the NRC on April 15, 1997, pursuant to 10 CFR 50.72, the licensee for Monticello reported that the NPSH available to its core spray pumps may not meet the required NPSH under all accident conditions. The licensee discovered this possibility during a review of ECCS pump NPSH requirements, when a higher head loss than had previously been assumed for the ECCS suction strainers was calculated. During discussions with the licensee, the staff learned that the head loss across the suction strainers is approximately 3.57 m (11.7 feet) per 38,000 liters/minute (10,000 gpm), rather than the 0.3048 m (1 foot) per 38,000 liters/minute (10,000 gpm) assumed in the original design-basis analysis.

The licensee determined that for a recirculation line break with a single failure of the LPCI loop select logic, and with credit for containment overpressure, the core spray pumps would have an NPSH deficit and the LPCI pumps would have approximately 0.15 m (0.5 feet) of margin in NPSH. Following discovery of the NPSH condition, the licensee conducted an operability evaluation of the LPCI and core spray pumps, and made this evaluation available to the staff for review. Subsequently, on May 9, 1997, the licensee for Monticello commenced a voluntary shutdown of the plant because of the possible NPSH deficit for the ECCS pumps that would occur as a result of postulated clogging of the ECCS suction strainers under design-basis LOCA conditions.

Related Generic Communications

On October 22, 1996, the staff issued Information Notice (IN) 96-55, "Inadequate Net Positive Suction Head of Emergency Core Cooling and Containment Heat Removal Pumps Under Design Basis Accident Conditions," to alert addressees to recent discoveries by

licensees of possible scenarios for which the NPSH available for ECCS and containment heat removal pumps is insufficient. Earlier INs describing similar events include IN 87-63, "Inadequate Net Positive Suction Head in Low Pressure Safety Systems," dated December 9, 1987, and IN 88-74, "Potentially Inadequate Performance of ECCS in PWRs During Recirculation Operation Following a LOCA," dated September 14, 1988.

Discussion

It is important that the emergency core cooling (including core spray and decay heat removal) and containment spray system pumps have adequate NPSH available to ensure that the systems can reliably perform their intended functions under all design-basis LOCA conditions. Inadequate NPSH could cause voiding in the pumped fluid, resulting in pump cavitation. While some ECCS and containment heat removal pumps can operate for relatively short periods of time while cavitating, prolonged operation of any pump under cavitation conditions can cause pump damage with potential common-mode failure of the pumps. Such common-mode failure would result in the inability of the ECCS to provide adequate long-term core cooling and/or the inability of the containment spray system to maintain the containment pressure and temperature below design limits.

This generic letter addresses situations in which the NPSH available to the ECCS and containment heat removal pumps may be inadequate as a result of changing plant conditions and/or errors and non-conservative assumptions in NPSH calculations. In some cases, NPSH reanalyses conducted to support plant modifications may result in a substantial reduction of margin in available NPSH or a change in the original design basis of the plant. In particular, recent examples indicate that licensees have credited containment overpressure to satisfy NPSH requirements in response to changing plant conditions and errors discovered in earlier NPSH calculations.

RG 1.1 establishes the regulatory position that emergency core cooling and containment heat removal systems should be designed so that adequate NPSH is provided to system pumps assuming maximum expected temperatures of pumped fluids and no increase in containment pressure from that present before any postulated LOCAs. NRC Standard Review Plan (SRP) 6.2.2, "Containment Heat Removal Systems" (NUREG-0800, Revision 4, dated October 1985) clarifies RG 1.1 by stating that the NPSH analysis should be based on the assumption that the containment pressure equals the vapor pressure of the sump water, in order to ensure that credit is not taken for containment pressurization during the transient. As part of licensing and Systematic Evaluation Plan reviews, the NRC staff has, in the past, selectively allowed limited credit for a containment pressure that is above the vapor pressure of the sump fluid (i.e., an overpressure) to satisfy NPSH requirements on a case-by-case basis.

Requested Information

On the basis of the preceding discussion and examples, addressees are requested to review, for each of their respective reactor facilities, the current design-basis analyses used to

determine the available NPSH for the emergency core cooling (including core spray and decay heat removal) and containment heat removal pumps that meet either of the following criteria:

(1) pumps that take suction from the containment sump or suppression pool following a design-basis LOCA or secondary line break, or

(2) pumps used in "piggyback" operation that are necessary for recirculation cooling of the reactor core and containment (that is, pumps that are supplied by pumps which take suction directly from the sump or suppression pool).

Based on this review, within 90 days from the date of this generic letter, addressees are requested to provide the information outlined below for each of their facilities. New NPSH analyses are neither requested nor required.

1. Specify the general methodology used to calculate the head loss associated with the ECCS suction strainers.

2. Identify the required NPSH and the available NPSH.

3. Specify whether the current design-basis NPSH analysis differs from the most recent analysis reviewed and approved by the NRC for which a safety evaluation was issued.

4. Specify whether containment overpressure (i.e., containment pressure above the vapor pressure of the sump or suppression pool fluid) was credited in the calculation of available NPSH. Specify the amount of overpressure needed and the minimum overpressure available.

5. When containment overpressure is credited in the calculation of available NPSH, confirm that an appropriate containment pressure analysis was done to establish the minimum containment pressure.

Required Response

Within 30 days from the date of this generic letter, each addressee is required to submit a written response indicating (a) whether or not the requested information will be submitted, and (b) whether or not the requested information will be submitted within the requested time period. Addressees who choose not to submit the requested information, or are unable to submit the information within the requested period, must describe in their response an alternative course of action that is proposed to be taken, including the basis for the acceptability of the proposed alternative.

After reviewing responses to this generic letter, the NRC staff will notify individual addressees if concerns are identified with regard to their facilities.

Addressees should submit the required written response to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, D.C. 20555-0001, under oath or affirmation under the provisions of Section 182a, Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f).

Backfit Discussion

This generic letter only requests information from addressees under the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f). The requested information will enable the staff to determine whether addressees' NPSH analyses for the emergency core cooling (including the core spray and decay heat removal) and containment heat removal system pumps conform with the current licensing basis for their respective facilities, including the licensing safety analyses and the principal design criteria which require and/or commit that safety-related components and systems be provided to mitigate the consequences of design-basis accidents.

In particular, 10 CFR 50.46(a)(1)(i), which addresses the ECCS acceptance criteria for light-water nuclear power reactors, requires in part that the calculated cooling performance of the ECCS following a postulated LOCA conforms to the criteria set forth in 10 CFR 50.46, including provisions for peak cladding temperature and long-term cooling. The potential for loss of adequate NPSH for ECCS pumps, and the cavitation that would result, raises the concern that the ECCS would not be capable of maintaining the peak cladding temperature below acceptable limits, and/or would not be capable of providing core cooling over the duration of postulated accident conditions, as required by 10 CFR 50.46.

Furthermore, the licensing bases of some plants credit the operation of containment sprays for pressure control as well as for fission product control. The potential for the loss of adequate NPSH for containment spray pumps, and the cavitation that would result, raises the concern that containment spray would not be capable of reducing and maintaining the containment pressure and temperature below design values and would not be capable of reducing the radiological dose consequences consistent with plants' licensing bases.

Considering the safety significance of removing heat from the containment atmosphere and cooling the reactor core following a design-basis accident, the requested information is needed to verify addressee compliance with licensing-basis commitments regarding the performance of emergency core cooling (including core spray and decay heat removal) and containment heat removal system pumps. The evaluation required by 10 CFR 50.54(f) to justify this information request is included in the preceding discussion.

Federal Register Notification

A notice of opportunity for public comment was published in the *Federal Register* on February 20, 1997 (62 FR 7806) to solicit public comments on the draft of this generic letter. A total of 17 comments were received from interested parties, including one industry group, one legal group affiliated with the nuclear power industry, and two licensees. When

redundant comments are considered, 12 distinct comments were identified by the staff. Copies of the staff evaluation of these comments have been made available in the NRC Public Document Room.

Paperwork Reduction Act Statement

This generic letter contains information collections that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget, approval number 3150-0011, which expires on August 31, 2000.

The public reporting burden for this collection of information is estimated to average 200 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. The NRC is seeking public comment on the potential impact of the collection of information contained in the generic letter and on the following issues:

1. Is the proposed collection of information necessary for the proper performance of the functions of the NRC, including whether the information will have practical utility?

2. Is the estimate of burden accurate?

3. Is there a way to enhance the quality, utility, and clarity of the information to be collected?

4. How can the burden of the collection of information be minimized, including the use of automated collection techniques?

Send comments on any aspect of this collection of information, including suggestions for reducing this burden, to the Information and Records Management Branch, T-6 F33, U.S. Nuclear Regulatory Commission, Washington DC 20555-0001, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202 (3150-0011), Office of Management and Budget, Washington, DC 20503.

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

If you have any questions about this matter, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachment: List of Recently Issued NRC Generic Letters

LIST OF RECENTLY ISSUED GENERIC LETTERS

Generic Letter	Subject	Date of Issuance	Issued To
97-03	ANNUAL FINANCIAL SURETY UPDATE REQUIREMENTS FOR URANIUM RECOVERY LICENSEES	07/09/97	URANIUM RECOVERY LICENSEES AND STATE OFFICIALS
97-02	REVISED CONTENTS OF THE MONTHLY OPERATING REPORT	05/15/97	ALL HOLDERS OF OLs FOR NPRs, EXCEPT THOSE WHO HAVE PERMANENTLY CEASED OPERATIONS AND HAVE CERTIFIED THAT FUEL HAS BEEN PERMANENTLY REMOVED FROM THE REACTOR VESSEL
97-01	DEGRADATION OF CONTROL ROD DRIVE MECHANISM NOZZLE AND OTHER VESSEL CLOSURE HEAD PENETRATIONS	04/01/97	ALL HOLDERS OF OLs FOR PRESSURIZED WATER REACTORS, EXCEPT THOSE WHO HAVE PERMANENTLY CEASED OPERATIONS AND HAVE CERTIFIED THAT FUEL HAS BEEN PERMANENTLY REMOVED FROM THE REACTOR VESSEL
95-06, SUPP. 1	CHANGES IN THE OPERATOR LICENSING PROGRAM	02/31/97	ALL HOLDERS OF OLs (EXCEPT THOSE LICENSEES OF PERMANENTLY SHUTDOWN REACTORS WHO ARE NO LONGER REQUIRED TO UTILIZE LICENSED REACTOR OPERATORS) FOR NPRs

OL = OPERATING LICENSE
CP = CONSTRUCTION PERMIT
NPR = NUCLEAR POWER REACTORS

If you have any questions about this matter, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

original signed by

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Attachment: List of Recently Issued NRC Generic Letters

*SEE PREVIOUS CONCURRENCES

DOCUMENT NAME: 97-04. GL

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