Entergy

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ENGC Ltr. 2.99.089

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Docket No. 50-293
License No. DPR-35

REQUEST FOR LICENSE CHANGE CONCERNING ECCS NPSH AND BULLETIN 96-03 SUBMITTAL

Purpose

Entergy Nuclear Generation Company (Pilgrim Nuclear Power Station) requests NRC review and approval for the use of new values for post-accident containment pressure in Pilgrim's net positive suction head (NPSH) analyses performed for the emergency core cooling system (ECCS) pumps. The new values are required to accommodate the postulated pump suction strainer head loss due to loss-of-coolant accident (LOCA) generated debris conservatively calculated in accordance with NRC Bulletin 96-03 and Regulatory Guide 1.82, Revision 2. The new strainer head loss values are higher than previous analytical values and are considered to be bounding for all postulated events or accidents. The attached "No Significant Hazards Considerations" evaluation is provided to assist the NRC in its review.

This request supplants Pilgrim's request submittal dated January 21, 1999 (Boston Edison Letter 99-001). The earlier request is changed to reflect new data.

Background

On January 20, 1997, Pilgrim requested the NRC to review and approve credit for post-accident containment pressure in Pilgrim's NPSH analyses performed for the emergency core cooling system pumps. The request was supplemented with additional information on January 30, February 27, April 11, May 14, and June 20, 1997. On July 3, 1997, the NRC issued License Amendment 173 and its associated Safety Evaluation Report (SER). The SER described the bases for allowing the use of particular amounts of containment pressure in NPSH analyses. At the time of these NPSH evaluations, the suction strainer debris head loss was based on earlier analyses using Regulatory Guide 1.82, Revision 1. As stated in the SER, the strainer debris analysis was expected to be reevaluated pursuant to NRC Bulletin 96-03. The debris analysis performed in accordance with NRC Bulletin 96-03 and Regulatory Guide 1.82, Revision 2, resulted in an increase in strainer estimated debris loading and head loss, but the head loss remained within the total NPSH margin available to the residual heat removal (RHR) and core spray (CS) pumps. The method for calculating NPSH available and NPSH margin are the same as those reviewed for the Amendment 173 SER.

In the attached analysis, the method of estimating strainer debris loading and calculating strainer debris head loss has been updated. In addition, the runout flow rate for the core spray pump has been increased based on an updated hydraulic analysis, resulting in slightly less

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total available NPSH margins. The containment pressure limits approved for NPSH analysis in Amendment 173 are not sufficient to accommodate the new debris head loss. The attached information and "No Significant Hazards Considerations" are provided to demonstrate higher containment pressure values are justified for use in Pilgrim's NPSH analyses.

Please contact P.M. Kahler at (508) 830-7939 if you should require further information on this issue.

Mike Bellamy

Commonwealth of Massachusetts)
County of Plymouth)

Then personally appeared before me, Mike Bellamy, who being duly sworn, did state that he is Site Vice President of Entergy Nuclear Generation Company and that he is duly authorized to execute and file the submittal contained herein in the name and on behalf of Entergy Nuclear Generation Company and that the statements are true to the best of his knowledge and belief.

My commission expires: September 20, 2002 DATE NOTARY PUBLIC

Attachments
1) Updated NPSH Evaluations for RHR and Core Spray Pumps.
2) Proposed "Updated Final Safety Analysis Report" changes.
3) Determination of No Significant Hazards Considerations.
4) Bulletin 96-03 Submittal, Pilgrim Station

PMK/

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Updated NPSH Evaluation for RHR and Core Spray Pumps

The NPSH analyses referenced by this submittal were performed using a methodology that has been previously reviewed by the NRC as part of License Amendment 173 (TAC No. M97789). The July 3, 1997, Safety Evaluation Report (SER) related to Amendment 173 describes the results from a review of PNPS Calculation M-662, which is the Pilgrim design basis calculation for available NPSH to the RHR and core spray pumps. The thermal equilibrium method used in Calculation M-662 for calculating containment pressure and NPSH available is consistent with the original Pilgrim FSAR and has not been changed for this submittal. The current Calculation M-662, Revision E4 (attached) was updated to be based on the new suppression pool temperature profile from the containment analysis using two-sigma decay heat per the requirements of Amendment 173 and to include a higher runout flow rate of 4950 gpm for the core spray pump. PNPS Calculation M-734, Revision 2, (attached) evaluated the effect of the new suction strainer debris head loss on RHR and core spray pump NPSH. This calculation was updated to include the new debris head loss described in this submittal.

The RHR and core spray pumps are not degraded by the postulated suction strainer debris head loss since there is sufficient NPSH margin available to accommodate the head loss without causing pump cavitation when the calculated containment pressure is used for the NPSH analysis. The new debris head loss nonetheless constitutes a nonconforming condition because the allowable containment pressure that may be assumed for NPSH analysis per FSAR Section 14.5.3.1.3 does not provide sufficient NPSH margin. These FSAR containment pressure limits that were approved by Amendment 173 are not sufficient to accommodate the updated debris head loss. The basis for the previous limits was an earlier debris analysis that postulated a lower strainer head loss and, consequently, a lesser amount of containment pressure was required. Although it is shown there is sufficient NPSH margin to accommodate the updated debris head loss, the FSAR currently limits the amount of pressure that may be considered. This licensing submittal requests NRC review of the updated debris analysis and containment pressure requirements.

It is proposed the containment pressure that may be assumed in pump NPSH and suction strainer evaluations be limited in the FSAR to the following pressure profile:

Time After Accident (sec)	Time After Accident (hour)	Containment Pressure (psig)	Containment Pressure (psia)
0 to 1,200	0.00 to 0.33	0.0	14.7
1,200 to 1,800	0.33 to 0.50	1.9	16.6
1,800 to 3,600	0.50 to 1.0	3.0	17.7
3,600 to 57,600	1.0 to 16.0	5.0	19.7
57,600 to 108,000	16.0 to 30.0	2.5	17.2
108,000 to 172,800	30.0 to 48.0	1.0	15.7
172,800 to 864,000	48.0 to 240.0	0.0	14.7

This containment pressure profile is enveloped by the containment pressure calculated using the conservative equilibrium method to determine the available NPSH. Containment pressure within these limits provides sufficient NPSH margin to accommodate the suction strainer debris head loss for the RHR and core spray pumps following a DBA-LOCA.

The first time step for which positive containment pressure (overpressure) is assumed is at 1200 seconds. This ensures the RHR pumps in the LPCI mode and a core spray pump can perform the initial recovery of core cooling without requiring any amount of containment pressurization during the initial 1200 seconds for the bounding DBA-LOCA. This is consistent with the analysis reviewed for Amendment 173.

The design basis loss-of-coolant-accident (DBA-LOCA) is the reactor recirculation system line break, which results in the most rapid heatup of the suppression pool to its highest peak temperature. The DBA-LOCA case provides a bounding analysis with respect to NPSH. The containment heatup analysis that produces the suppression pool temperature profile was performed using the GE computer code SHEX for primary containment thermodynamic analysis. The containment modeling and assumptions were set to maximize the pool temperature. The DBA-LOCA pool profile is based on a single loop of containment heat removal, the highest ultimate heat sink temperature (75°F), ANSI/ANS 5.1 two-sigma decay heat, and initial conditions for power level, operating history, containment conditions, flow rates, and heat exchanger performance that maximize pool temperature.

The results from the DBA-LOCA NPSH analysis are illustrated in attached Figures 1 and 2. Figure 1 shows the containment pressure available and the pressure required to provide adequate NPSH to the RHR and core spray pumps with a clean strainer and with the new debris head loss included. The new proposed FSAR containment pressure limits are also shown on Figure 1. The core spray pumps are more limiting for NPSH than the RHR pumps. Figure 2 shows, in units of feet, the corresponding total NPSH margin available with a clean strainer, the postulated debris head loss, and the margin available for the most limiting ECCS pump based on the proposed FSAR containment pressure limits. The total NPSH margin depicted in the figures is based on the conservative lower bounding containment pressure existing due to thermal equilibrium principles for an enclosed volume (primary containment) as described in FSAR Section 14.5.3.1.3.

As illustrated in Figures 1 and 2, the proposed FSAR containment pressure limits provide sufficient NPSH margin to accommodate the new debris head loss. The proposed FSAR limits are less than the available containment pressure determined using the thermal equilibrium method. These NPSH calculations are based on the suppression pool temperature profile for the DBA-LOCA with a 75°F SSW heat sink, which has a peak pool temperature of 182.3°F. In addition, NPSH was evaluated at the design peak suppression pool temperature of 185°F and the 5.0 psig proposed limit provides sufficient margin for the RHR and core spray pumps with the DBA-LOCA debris head loss at that point in time.

It is also shown on Figure 2 that the FSAR limits are not intended to include the additional two feet of NPSH margin allocated to uncertainty and pump inservice testing (IST) as described in Calculation M-662. However, there is a two foot or greater NPSH margin between the debris head loss profile and the margin provided by the containment pressure as determined in Calculation M-662 using the FSAR thermal equilibrium method up to and through the peak pool temperature and at all times during the first 48 hours after a DBA-LOCA. The 48 hour period of time is significant because containment positive pressure (overpressure) is credited for providing sufficient NPSH up to 48 hours. The NPSH margin based on the proposed FSAR pressure limits is intended to envelop the bounding DBA-LOCA strainer debris head loss. The two foot head loss allocated to IST represents additional margin provided to account for uncertainty and it is considered sufficient to demonstrate that this unused margin exists during the period of time that containment pressure greater than atmospheric is credited.

As indicated below, the suction strainer head loss caused by debris is less than or equal to the available NPSH margin provided by the proposed FSAR pressure limits. Also, during the period of time in the accident response that any pressure greater than atmospheric is credited (i.e., 48 hours), the available margin based on the equilibrium method is at least two feet more than the debris head loss. The criteria is summarized as follows:

				FSAR
Debris		*FSAR*		*Equilibrium Method*
Head	≤	*Pressure Limit*	≤	*NPSH Margin*
Loss		*NPSH Margin*		*2 ft Above Debris*
				First 48 Hours

The DBA-LOCA includes an immediate blowdown of the reactor vessel to primary containment resulting in the most rapid initial heatup of the suppression pool to approximately 130°F. The subsequent transfer of heat from the reactor core to the pool is also maximized by the continuous core flooding provided by the operation of one core spray and two RHR pumps at maximum flow for the first two hours. In addition, the DBA-LOCA provides the maximum generation, transport, and accumulation of debris on the suction strainer. The assumption of three ECCS pumps operating for two hours on a common suction strainer provides the maximum debris accumulation and head loss on the strainer; that is, the accumulation of debris from the pool is essentially maximized at the two hour point and no further debris is present to accumulate on the strainer. At this point, it is assumed that one RHR pump is shut off and a mode of LPCI with Heat Rejection with one RHR pump begins and is maintained for the duration of the recovery. As shown on Figure 2, the debris head loss drops from the peak of 9.9 feet to 5.4 feet at the two hour cutoff of the second RHR pump due to the decrease in the total flow through the common strainer. The debris head loss remains less than 5.4 feet until the peak pool temperature has passed and the long term cooldown begins. The steady increase in debris head loss that begins after 8 hours is due solely to the effect of viscosity increasing as the pool temperature drops.

At approximately 73 hours after the DBA-LOCA, the containment equilibrium pressure decreases to atmospheric pressure and the NPSH margin is at its minimum point for the entire event. The pool temperature is 132°F at the point of minimum NPSH margin and atmospheric pressure. At the minimum point, there is 9.4 feet of total available NPSH margin and 7.7 feet of debris head loss. From the minimum point onward, the NPSH margin and debris head loss increase in equal proportion such that sufficient NPSH remains out to the final 240 hour (10 day) point at which the pool temperature is 112°F. Based on the data up to the 240 hour point, this trend will continue as the pool cools down to lower temperatures. After the 73 hour minimum margin point, the containment remains at atmospheric pressure and it is shown that there is sufficient NPSH for all temperatures below 132°F at atmospheric pressure (i.e., without overpressure). The analysis does not assume any favorable change in conditions has occurred. However, it is reasonable to assume additional water will have been added to the suppression pool before 73 hours. Each foot of additional water level adds one foot to the NPSH margin, plus the water added from an external source is expected to be cooler and will lower the bulk suppression pool temperature. In addition, the other RHR loop may be restored to service and/or better heat removal achieved due to better pump or heat exchanger performance or lower heat sink temperature.

Calculation M-662 determined the minimum NPSH available (NPSHA) to the RHR and core spray pumps for the bounding DBA-LOCA. The equilibrium method produced more conservative results than a complex computerized analysis performed by General Electric that used detailed models of the heat transfer mechanisms in primary containment. The DBA-LOCA and steam line break accidents were evaluated for NPSH using a computerized model of primary containment done with the GE computer code SHEX. The steam line break NPSH analysis was part of the updated containment heatup analysis using two-sigma decay heat per Amendment 173. The effects from containment leakage and passive heat sinks in the drywell, wetwell, and suppression pool are incorporated into the SHEX model for NPSH evaluations. The mechanistic analysis for the steam line break cases was done using containment spray as the means of transferring heat from the steam atmosphere to the suppression pool with only makeup water added to the reactor vessel by a core spray pump. For the steam line breaks, the reactor core continuously produces steam that pressurizes the containment and the containment spray flow from the RHR pump is required to transfer heat to the suppression pool. During the long-term recirculation period for the DBA-LOCA, the water exiting the reactor vessel is always subcooled (no steam production) since the vessel is continuously flooded by both the core spray and RHR pumps. Transfer of heat by subcooled liquid at relatively high flow rates, as compared to steam line break events, flushes the heat energy from the primary system and results in a higher pool temperature at lower containment pressure.

The DBA-LOCA analysis is based on a set of assumptions that maximize suppression pool temperature while the containment atmosphere remains in thermal equilibrium with the pool. This provides the most limiting case for NPSH analysis when combined with the operation of the ECCS pumps at runout flow rates. If the assumptions are changed to maximize cooling, lower the heat sink temperature, and/or minimize decay heat, this analysis remains controlling as the NPSH design basis. However, there are other potential scenarios that may require operator actions, although they are less challenging in that the ECCS systems are not required or intended to be operating at their maximum flow conditions.

Lower suppression pool temperatures are preferable and constitute a less challenging condition for accident recovery, but there are manipulations of pump operation that may be needed at lower pool temperatures due to the higher debris head losses for colder water. If one core spray and two RHR pumps are operated up to the two hour point at water temperatures lower than the 176.8°F given in Table 2 (see attached Calculation M-734), the peak debris head loss will be higher than the calculated 9.9 feet due solely to the increase in viscosity at lower water temperatures. As given in Calculation M-662, at 130°F with atmospheric pressure in containment (i.e., no overpressure), there is 9.7 feet of NPSH margin for the limiting core spray pump. The debris head loss may exceed 9.7 feet with 3 ECCS pumps running at water temperatures below 130°F. However, by shutting down one RHR pump, the head loss will decrease as it does on Figure 2 at the two hour point. At pool temperatures of 142°F and below, Figures 1 and 2 show there is sufficient NPSH assuming only atmospheric pressure in containment with one RHR and core spray pump operating and a debris head loss of 7.0 feet. Therefore, containment pressurization is only a necessary consideration for pump NPSH when the suppression pool is above 142°F with one RHR and core spray pump operating and maximum debris loading.

It should be noted that for all steam line break accidents there is less debris generation and the ECCS requirements for core and containment cooling are less challenging. Unlike the DBA-LOCA, the reactor water level is quickly recovered and easily maintained by operating a single core spray pump intermittently or at reduced flow following a steam line break. Furthermore, only a single RHR pump will be used for containment cooling and the LPCI mode of RHR is not required after reactor water level is recovered. These aspects of steam line break accidents reduce the severity of this type of accident with respect to pump performance and NPSH as compared to the DBA-LOCA.

The most limiting case DBA-LOCA analysis assumes that the second RHR pump is shut down after the first two hours. As shown on Figure 1, the curve for containment pressure required with debris meets the 5.0 psig limit at this point in time. It is not necessary to assume more than the proposed 5.0 psig limit since shutting down the second RHR pump will mitigate any cavitation that occurs due to the maximized flow rate of three pumps.

The operating scenario for the RHR and core spray pumps following a DBA-LOCA is conservative for NPSH analysis. The pumps are assumed to be at maximum flow for the entire duration of long term cooling (i.e., no throttling of control valves is performed). The RHR loop is assumed to operate in the two-pump LPCI mode for the first two hours. The two hour time period is considered to be a bounding maximum for operators to change to the single pump LPCI mode in order to maximize containment heat removal. DBA-LOCA analysis involves the creation of a worst-case scenario with corresponding operator actions based on the symptoms and indications that will be observed, together with the procedures that will be used. It is expected this RHR pump transition will be performed earlier than at two hours, which is more favorable for both debris accumulation and suppression pool temperature.

The two hour point is also conservative because it is approximately the amount of time needed to accumulate all the available debris in the suppression pool onto the strainer. Therefore, should the two-pump LPCI mode be continued for longer than two hours there would not be a significant increase in the debris head loss above the value at the two hour point until the pool begins to cool down after six hours have passed. Furthermore, upon shutting down the second RHR pump beyond two hours the resulting debris head loss would not be significantly greater than given on Figure 2 for the same point in time.

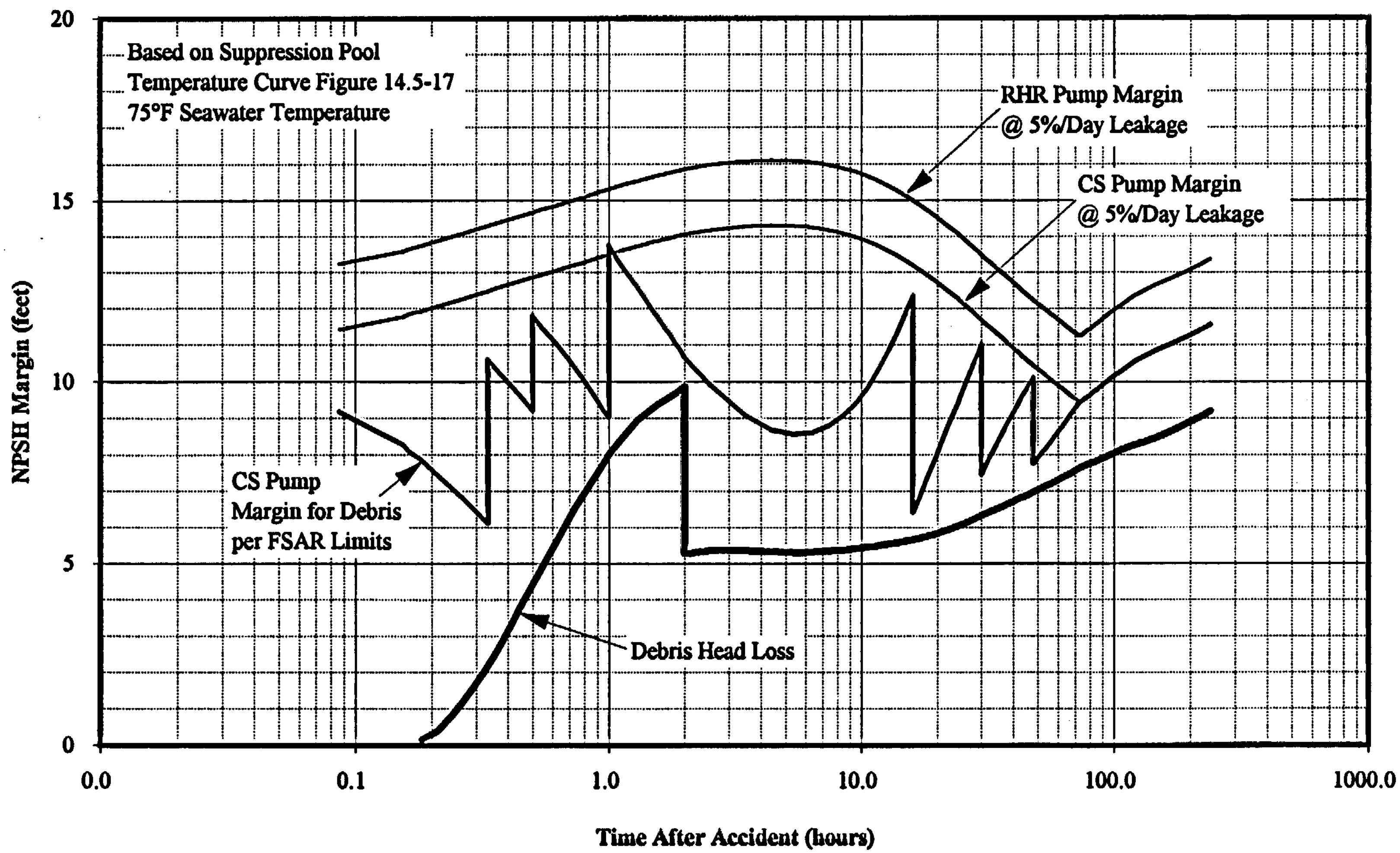
The FSAR analysis method does not require that containment pressure be greater than the minimum value that is inherently established by the containment being an enclosed airspace in thermal equilibrium with the suppression pool. These assumptions are applicable for the DBA-LOCA and all other events and transients that do not include the use of containment spray for containment cooling. The use of containment sprays, when appropriate for steam line breaks, has been evaluated mechanistically, as described above, and shown to be less limiting for NPSH analysis than the DBA-LOCA.

There are potential sets of conditions involving the use of containment spray that, although they are more favorable than the severe conditions of the DBA-LOCA, may require that containment spray flow be reduced in response to operator observations of RHR pump cavitation. A small steam line break with maximized cooling and a low temperature heat sink can result in the containment atmosphere being reduced to a temperature below that of the suppression pool by the continuous use of containment spray. Under these conditions, the available NPSH margin will be reduced below the equilibrium value for the given pool temperature. However, if pump cavitation should occur, operators will recognize the condition using instruments available in the main control room and stop the use of spray, thus restoring sufficient NPSH. These low temperature cases are less challenging, in terms of accident mitigation, than the cases analyzed with maximized suppression pool temperature.

We conclude the RHR and core spray pumps have sufficient NPSH margin for all design basis emergency conditions, transients, and accidents. The NPSH analysis has been performed for the severest conditions where it is necessary to maximize pump flow rates to achieve sufficient cooling. Although pump cavitation is not expected to occur for the severe cases analyzed, there are potential scenarios in which pump operation can be extended into cavitation regimes, but never at a time when operators are not able to reduce pump flow rates. For cases where there is better cooling, lower heat sink temperature, and/or less decay heat, it is not required to operate at pump runout flow rates.

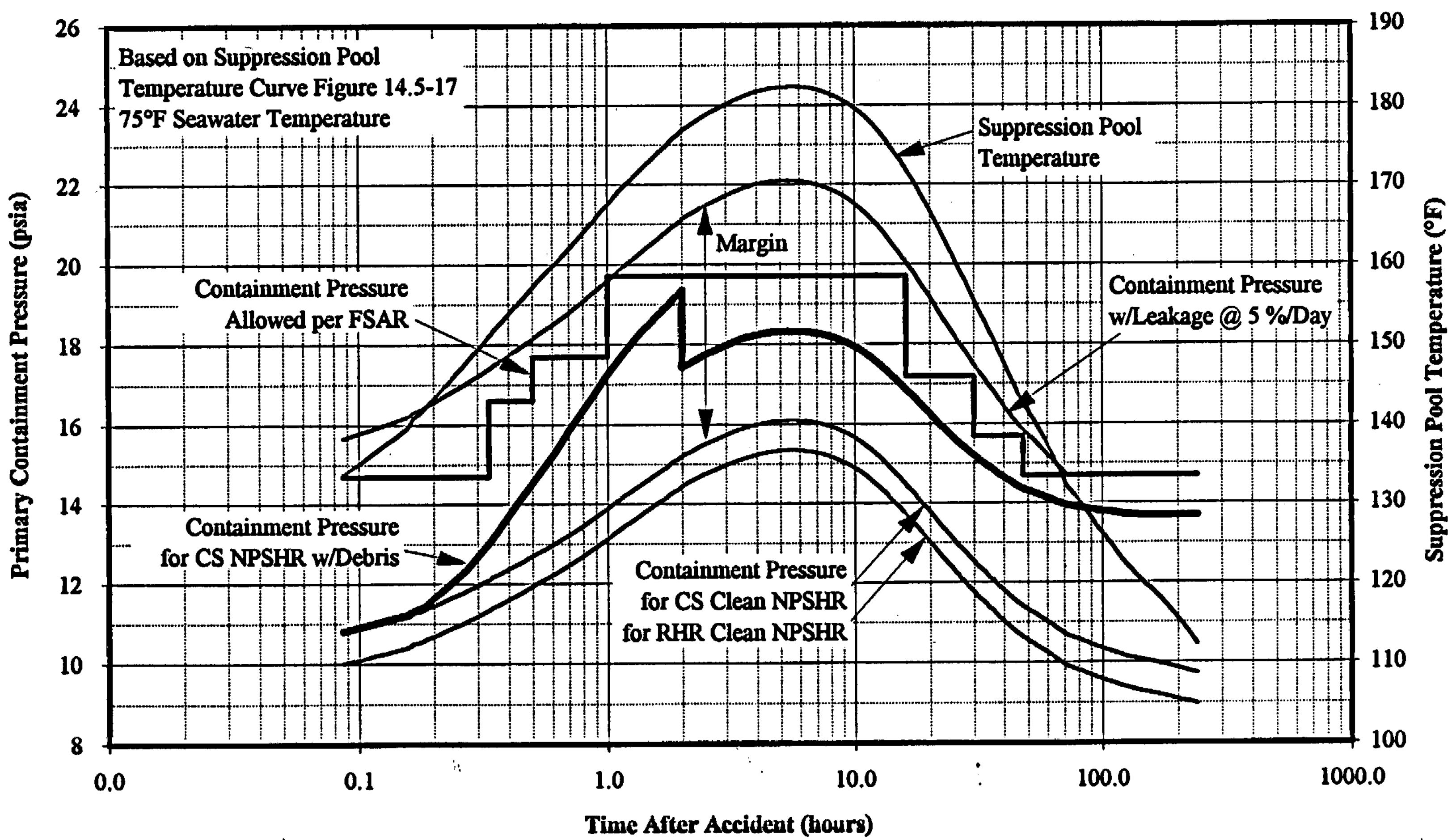
The over-cooling scenarios in which pump cavitation may occur all have in common that a reduction in pump flow is allowed in the applicable procedures. Although cavitation is not likely even for these cases, it has been considered a possibility in this evaluation. Cavitation temporarily decreases pump performance immediately upon its inception, due to the vapor formation within the impeller inlet that displaces the more dense liquid thereby decreasing the flow rate. At the higher pressures existing at the impeller periphery, the vapor condenses rapidly with a resulting impact or shock wave effect on the pump internals. There is a legitimate concern with damage occurring with a cavitating pump but the level of concern varies with the type of pump and the length of operation with cavitation. The Pilgrim RHR and core spray pumps are of a rugged single stage design with stainless steel internals. This pump design and the materials of construction are highly tolerant to cavitation. Short term operation in a cavitating regime will not damage these pumps.

We further conclude the NPSH analysis as performed for the DBA-LOCA is conservative and bounding. The basis for this conclusion is the NPSH margin for the DBA-LOCA is restricted by the limitations that the severe conditions impose on plant operators; that is, there are no options available except to maximize cooling with the remaining single loop of containment heat removal under the DBA-LOCA conditions. For other cases with lower pool temperatures, the NPSH margin can be improved by operator actions that would be allowed under the circumstances.



NPSH Margin for RHR and Core Spray Pumps After a DBA-LOCA w/Debris

Figure 2



NPSH Availability for RHR and Core Spray Pumps After a DBA-LOCA w/Debris

Figure 1