Safety Evaluation

No. 2971

RTYPE A9.03

SAFETY EVALUATION
PILGRIM NUCLEAR POWER STATION

Initiator	Dept.	Division	Document No.	Calc. No.	System Name
P.D. Harizi P.J. Doody	NESG	Mech. Eng. S&SA	PDC 83-62	M-662	Drywell

Description of Proposed change, test, or experiment: Replace all piping thermal insulation in the drywell with Owens-Corning NUKON fiberglass blanket insulation. This Safety Evaluation supersedes SE No. 1638, Rev. 1 dated 8-6-84.

SAFETY EVALUATION CONCLUSIONS:

	Yes	No	
1.	☐	☒	May the proposed activity increase the probability of occurrence of an accident previously evaluated in the Final Safety Analysis Report?
2.	☐	☒	May the proposed activity increase the consequences of an accident previously evaluated in the Final Safety Analysis Report?
3.	☐	☒	May the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the Final Safety Analysis Report?
4.	☐	☒	May the proposed activity increase the consequences of a malfunction of equipment important to safety previously evaluated in the Final Safety Analysis Report?
5.	☐	☒	May the proposed activity create the possibility of an accident of a different type than any previously evaluated in the Final Safety Analysis Report?
6.	☐	☒	May the proposed activity create the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the Final Safety Analysis Report?
7.	☐	☒	Does the proposed activity reduce the margin of safety as defined in the basis for any Technical Specification?

BASIS FOR SAFETY EVALUATION CONCLUSIONS: The replacement of the drywell piping thermal insulation does not constitute an unreviewed safety question - see Attachment 1.

Safety Evaluation Performed by P.D. Harizi / Patrick J. Doody Date 3-25-96

Safety Evaluation
No. 2971

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PILGRIM NUCLEAR POWER STATION

A. APPROVAL

Comments: None

Thomas White J. 3/25/96
Discipline Division Mgr./Date

NA
Supporting Discipline Division Mgr./Date

B. REVIEW/APPROVAL

☐ Comments: None

[signature] 3/25/96
S&SA Division Mgr./ Date

NOTES: 1) Items (14) and (15) are not required for Safety Evaluation prepared by the Plant Department.

2) The independent technical review of Plant Department Safety Evaluations is documented in Item C below.

C. ORC REVIEW

☐ This proposed change involves an unreviewed safety question and a request for authorization of this change must be filed with the NRC prior to implementation.

☑ This proposed change does not involve an unreviewed safety question.

ORC Chairperson [signature] Date 3/29/96

ORC Meeting Number 96-15

cc:

Safety Evaluation

No. 2971

D. FSAR Review Sheet

List FSAR text, diagrams, and indices affected by this change and corresponding FSAR revision.

Affected FSAR Section	Preliminary revision to the affected FSAR Section is shown on:
Section 4.8.5.1 (revise)	Attachment 2
Section 6.4.3 (revise)	Attachment 2
Section 14.5.3.1.3 (revise)	Attachment 2
Figure 14.5-9 (replace figure)	Attachment 3
Figure 14.5-10 (replace figure)	Attachment 3
Figure 14.5-13 (replace figure)	Attachment 3

PRELIMINARY FSAR REVISION (to be completed at time of Safety Evaluation preparation).

Prepared by: P.D. Harizi / Patrick J. Doody Date: 3-25-96

Approved by: Thomas White / J. Mogan Date: 3/25/96

FINAL FSAR REVISION - Prepared in accordance with NOP83E4 following operational turnover of related systems, structures, or components for use at PNPS.

Safety Evaluation

No. 2971

E. SAFETY EVALUATION WORK SHEET

A. System/Component Failure and Consequence Analyses.

	System/Component	Failure Modes	Effects of Failure	Comments
1.	Drywell Piping Thermal Insulation	Compaction of fibers reduces thermal resistance.	Increased drywell temperatures.	Drywell temperature limits are given in Tech Specs 3.2.H. See Attachments.
2.	same	Wetting of fibers reduces thermal resistance.	same	same
3.	same	LOCA or MSL pipe break jet impingement destroys insulation and transports debris into torus.	Debris accumulation on torus suction strainers for RHR and Core Spray pumps increases suction head losses.	Effect of debris was evaluated and the increased suction head loss is within the margin for NPSH available to the ECCS pumps. See Attachments.

General Reference Material Review

FSAR SECTION	PNPS TECH. SPECS	CALCULATIONS DESIGN SPECS. PROC.	REGULATORY GUIDES STANDARDS CODES
4.8.5.1	Section 3.2.H	Calculation M-662 Rev. 0	Reg. Guide 1.1
6.4.3	Section 3.5.A & B	GE Report GE-NE-B13-01805-11	Reg. Guide 1.82 Rev. 1
14.5	Section 3.7.A		NUREG-0800 Sec. 6.2.2 Rev. 4
	Section 4.7.A.2		

B. For the proposed hardware change, identify the failure modes that are likely for the components consistent with FSAR assumptions. For each failure mode, show the consequences to the system, structures, or related components. Especially show how the failure(s) affects the assigned safety basis (FSAR text for each system) or plant safety functions (FSAR Chapter 14 and Appendix G.)

Prepared by P.D. Harizi / Patrick J. Doody Date 3-25-96

Safety Evaluation - Attachment 1

A. Description of Change

As part of the recirculation pipe replacement project and related drywell restoration, the piping thermal insulation used in the drywell was replaced. The new insulation is low density fiberglass enclosed in a woven fiberglass cloth to form blankets fitted to wrap around piping, valves, and pump casings. The material is Owens-Corning NUKON insulation.

This Safety Evaluation supersedes SE No. 1638, Rev. 1 dated 8-6-84. The General Electric report attached to the original SE has been replaced with a later revision which has been captured under the BECo SUDDS process and is referenced in this evaluation. In addition, this evaluation contains expanded background information and interpretations related to the issue of pump NPSH and the Pilgrim design basis.

B. Purpose of the Change

The original drywell piping insulation was in need of replacement due to deteriorated physical condition. The Owens-Corning NUKON fiberglass insulation was selected based on its superior thermal properties and simpler installation. Previous drywell high temperature problems were partly due to the degraded condition of the original insulation.

C. Systems, Subsystems, Components Affected

1. Directly Affected:

   Reactor Recirculation System Piping
   Feedwater System Piping
   Main Steam System Piping
   RWCU System Piping
   RHR Piping
   HPCI and RCIC Piping
   Reactor Instrumentation Piping
   Drywell Cooling System

2. Indirectly Affected:

   Residual Heat Removal Pumps
   Core Spray Pumps
   HPCI Pump
   RCIC Pump

3. List drawings, FSAR, Tech. Spec., other documents.
The following documents will be referred to by [Ref. #] in this evaluation:

[1] Regulatory Guide 1.1 (formerly Safety Guide 1) "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps"
[2] Regulatory Guide 1.82, Rev. 1 - "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident"
[3] Standard Review Plan NUREG-0800 Section 6.2.2 Rev. 4 "Containment Heat Removal Systems"
[4] 10 CFR Part 50, Appendix A, "General Design Criteria"
[5] PNPS Safety Evaluation Report (SER) dated August 25, 1971
[6] PNPS Final Safety Analysis Report (FSAR)
[7] PNPS License Technical Specifications
[8] GE Report GE-NE-B13-01805-11 "Effects of Fiberglass Insulation Debris on Pilgrim ECCS Pump Performance" SUDDS/RF #96-02
[9] Calculation M-662 Rev. 0 "RHR and Core Spray Pump NPSH and Suction Pressure Drop"

D. Functions of Affected Systems/Components

The design for the affected piping systems in the drywell assumed that the piping would be insulated to reduce thermal losses from the process fluid to the drywell atmosphere. The piping structural and stress analyses included nominal allowances for insulation mass. NUKON low density fiberglass insulation is lower in weight than other alternative materials including that which it replaced.

The drywell cooling system is designed to maintain the drywell temperature at acceptable levels. This is accomplished by a system of fan coil air coolers that transfer heat to the Reactor Building Closed Cooling Water System (RBCCW). The cooler unit sizing was based on expected heat loads in the drywell which include primarily thermal losses from the reactor and associated piping and from the Reactor Recirculation Pump motors.

The Residual Heat Removal (RHR) Pumps, Core Spray (CS) Pumps, and High Pressure Coolant Injection (HPCI) Pump are part of the Core Standby Cooling Systems (CSCS)(FSAR Section 6). The RHR Pumps provide low pressure coolant injection (LPCI) to the reactor after depressurization either due to a Loss of Coolant Accident (LOCA) or by operation of the Automatic Depressurization System (ADS). The RHR Pumps also provide for decay heat removal in the Suppression Pool Cooling and Containment Spray modes of operation (FSAR Section 4.8). The CS Pumps provide low pressure core spray (LPCS) flow to the vessel in a continuous recirculation mode from the suppression pool. Both the LPCI and LPCS are required to mitigate the consequences of the various postulated LOCA and Main Steam Line Break (MSLB) accidents by providing emergency core cooling and containment cooling via the RHR operating modes.

The HPCI Pump provides core cooling in the event of a small break in the nuclear system which does not result in rapid depressurization of the reactor vessel. The HPCI system permits the reactor to be shut down while maintaining sufficient reactor water inventory

until the vessel is depressurized. HPCI continues to operate until reactor pressure is below the level at which the LPCI and/or Core Spray systems maintain core cooling. The HPCI system is configured to initially draw water from the condensate storage tanks but may be switched to draw water from the suppression pool if necessary.

The Reactor Core Isolation Cooling (RCIC) System provides makeup water to the reactor following vessel isolation and loss of the normal feedwater system. The RCIC system is configured to initially draw water from the condensate storage tanks but may be switched to draw water from the suppression pool if necessary.

The RHR, CS, and HPCI Pumps are referred to herein as Emergency Core Cooling System (ECCS) pumps to conform with the abbreviation most widely used.

E. Effect on Functions

The drywell cooling system was designed for a heat load that assumed a nominal effectiveness for the piping thermal insulation. If the insulation is degraded, the heat load may exceed the design level, resulting in increased drywell temperature. Fiberglass insulation is degraded mainly by two mechanisms, compaction of the fibers and absorption of moisture, both of which effectively reduce the thermal resistance (R-factor) for the insulation. The Pilgrim Technical Specifications [Ref. 7] require that certain actions be taken if the drywell temperature exceeds Section 3.2.H limits.

As a consequence of a LOCA or MSLB, the NUKON insulation in the vicinity of the break may be damaged or destroyed by the jet impingement forces. The fiberglass debris generated by the line break may then be transported from the drywell into the suppression pool. Insulation shreds and fibers in various forms may continue to transport through the suppression pool water and ultimately some portion may accumulate on the suction strainers of the operating ECCS pumps. The accumulated debris on the strainers would increase the head loss of the strainer and thereby decrease the Net Positive Suction Head (NPSH) available to the ECCS pumps. If a sufficient amount of debris accumulates on the strainer, the margin for NPSH available to the pump may be exceeded resulting in cavitation, reduced performance, and potential damage to the pump.

F. Analysis of Effect on Functions

F.1 Effects on Thermal Resistance

The potential degradation of the thermal resistance qualities of NUKON insulation does not have significant adverse safety consequences. If the degradation is such that drywell heat loads exceed the design cooling capacity, the drywell temperature will increase. The drywell temperature increase would be gradual and readily trended. Should the drywell temperature exceed the Technical Specification Section 3.2.H limits, the plant would be forced to evaluate and/or mitigate the condition or shut down if 215°F is exceeded for 30 minutes. If degraded insulation was a contributor, the affected sections would require replacement to restore the expected thermal qualities.

F.2 Effect of Insulation Debris

Potential effects from insulation debris were evaluated for the RHR and Core Spray pumps which comprise the low pressure ECCS systems. HPCI is not considered to be significantly affected by the postulated debris generation and transport due to the HPCI design mission, which is to operate during the time necessary to depressurize the reactor following a small break LOCA in which the vessel does not immediately depressurize. The small break LOCA generates less debris and provides less transport to the torus. The HPCI pump is initially drawing water from condensate storage and switches to the torus only when required by torus or condensate tank level. The RCIC pump was similarly considered to be unaffected by debris since the design function is to perform reactor isolation cooling. Although both of these systems are initiated by LOCA events, their function during a large break LOCA event is minimal and they are not used for long term core cooling for any postulated accidents.

The effect from insulation debris accumulating on RHR and Core Spray pump suction strainers was evaluated by General Electric in GE Report GE-NE-B13-01805-11 [Ref. 8]. The methods used to determine debris generation quantities, transport mechanisms, and accumulation on the strainers were in accordance with Regulatory Guide 1.82, Rev. 1 [Ref. 2]. The additional suction head loss due to the postulated insulation debris was estimated to be:

RHR Pump = 13.8 ft @ 5000 GPM
Core Spray Pump = 5.5 ft @ 3750 GPM

These head loss figures were increased by BECo Calculation M-662 [Ref. 9] to be consistent with the maximum pump flow rates assumed in other LOCA analyses as follows:

RHR Pump = 14.5 ft @ 5100 GPM
Core Spray Pump = 8.6 ft @ 4400 GPM

The minimum margin for NPSH available to the RHR and Core Spray pumps [Ref. 9] after a design basis LOCA (see Section F.4) is:

RHR Pump = 17.3 ft NPSH Margin @ 5100 GPM
Core Spray Pump = 11.5 ft NPSH Margin @ 4400 GPM

The conclusion is that the increase in suction head loss from the postulated debris accumulation is within the margin for NPSH available to the ECCS pumps. If the NPSH available at the pump suction meets the NPSH required, the pump will achieve its rated performance. Pump performance is not increased by providing additional NPSH above that which is required to prevent cavitation. Therefore, the utilization of NPSH margin does not affect ECCS pump performance. Refer to the attached Figure A-2 from [Ref. 2] which shows the evaluation process as it applies to the Pilgrim ECCS pumps.

F.3 NPSH Calculation Methods

There are issues related to ECCS pump NPSH that are worthy of discussion and clarification in this Safety Evaluation. It is necessary to provide this lengthy discussion so that the margin for NPSH available, as it is presented in the FSAR, may be fully understood.

The limiting event for peak bulk suppression pool temperature is the Loss-of-Coolant Accident caused by a worst case recirculation piping line break, referred to herein as the DBA LOCA. This accident was evaluated by General Electric using a thermal-hydraulic analytical model of the reactor and primary containment structure. This analytical tool generated the temperature/pressure profiles presented in Section 14 of the FSAR for the post-accident conditions in the drywell and wetwell. In addition, and via the application of the analytical methods described below, the NPSH available to the ECCS pumps was determined using the predicted suppression pool temperature profile and these results are also presented in Section 14 of the FSAR.

The most critical input assumptions for the DBA LOCA analysis are the following:

1. Initial drywell/wetwell temperature/humidity conditions and suppression pool temperature.
2. Time of actuation and flowrates for LPCI and Core Spray pumps.
3. Time of actuation, flowrates, and configuration for decay heat removal from containment.
4. Decay heat.
5. Thermal effectiveness of decay heat removal heat exchangers.
6. Temperature of ultimate heat sink.
7. Primary containment leakage rate.

The DBA LOCA temperature profile for the suppression pool is a key input to the evaluation of available NPSH for the ECCS pumps. The calculation of NPSH involves the use of the formulations described below.

Terms Used in Equations 1 to 5:

NPSHA	=	Net Positive Suction Head Available (ft)
NPSHR	=	Net Positive Suction Head Required at Maximum Required Pump Flow Rate (ft)
P_A	=	Total Absolute Pressure Acting on Pool Surface (ft)
P_{VP}	=	Water Vapor Pressure (ft)
P_S	=	Total Suction Pressure at Pump Suction Centerline (ft)
P_{GAS}	=	Partial Pressure of Air/Nitrogen in Gas/Vapor Mixture (ft)
h_Z	=	Elevation Head Referenced to Pump Suction Centerline (ft)
h_S	=	Suction Line Head Losses at Maximum Required Flow Rate (ft)
V	=	Total Volume of Drywell and Wetwell Airspace (ft^3)

m	=	Total Mass of Dry Air/Nitrogen in Containment (lbm)
R	=	Gas Constant for Air/Nitrogen (ft-lbf/lbm-°R)
T	=	Gas Temperature (°R)

NPSH provided at the pump suction (NPSHA) is equal to the total absolute suction pressure minus the vapor pressure of water at the suppression pool temperature. The NPSH required at the pump suction (NPSHR) is the minimum pressure over and above the vapor pressure that must be present in order to keep the water in the liquid state as it enters the impeller. A centrifugal pump adds energy to the water by imparting a high velocity to it, which is exchanged for pressure head by the velocity decrease that occurs upon exiting the impeller into the volute or diffuser. As water is first pulled into the impeller, there is an initial velocity increase which is at the expense of the existing suction pressure head. This initial drop of the pressure head will cause vaporization to begin if the pressure is lowered to equal the vapor pressure. The subsequent increase in pressure head that occurs upon exiting the impeller causes the aforementioned vapor bubbles to collapse back to liquid form. This is the classic cavitation phenomenon.

The NPSH available to the ECCS pumps is defined by:

$$NPSHA = P_A - P_{VP} + h_Z - h_S \quad (ft) \qquad \text{Eq. 1}$$

The above formula may be rewritten in terms of the total suction pressure (P_S) that is present at the pump suction as follows:

$$P_S = P_{VP} + NPSHA = P_A + h_Z - h_S \quad (ft) \qquad \text{Eq. 2}$$

The significance of the second formulation becomes apparent when one considers the case of a pump drawing its suction from a closed vessel to which the water is ultimately returned in a closed loop system. The suppression pool and primary containment comprises just such a system. In a closed vessel containing water above which there is an airspace (air or nitrogen), there is an equilibrium condition between the liquid water and water vapor in the airspace such that there will exist a partial pressure of water vapor at the corresponding saturation pressure for the water temperature. Thus, the total absolute pressure (P_A) acting on the water surface consists of the sum of the partial pressures of the noncondensible gas (air or nitrogen) and the partial pressure of the water vapor:

$$P_A = P_{GAS} + P_{VP} \quad (ft) \qquad \text{Eq. 3}$$

This is aptly summarized by Dalton's rule for partial pressures applied to an air/water vapor mixture as follows:

> When the mixture and the condensed phase are at a given pressure and temperature, the equilibrium between the condensed phase and its vapor is not influenced by the presence of the other component. This means that when equilibrium is achieved, the partial pressure of the vapor will be equal to the saturation pressure corresponding to the temperature of the mixture.

Substituting Equation 3 into Equation 1 yields:

$$NPSHA = P_{GAS} + P_{VP} - P_{VP} + h_Z - h_S \quad (ft) \qquad \text{Eq. 4}$$

Of interest in this formulation for pump suction from a closed vessel is that the vapor pressure (P_{VP}) cancels itself out. The benefit from this phenomenon is that as temperature increases, with corresponding increase in vapor pressure, the NPSH available to the pump remains essentially constant and equal to the partial pressure of the noncondensible gas (P_{GAS}) plus elevation head (h_Z) minus the suction line losses (h_S).

Applying the Dalton principle to the closed suppression pool, it is also observed that the partial pressure of the noncondensible air/nitrogen may be considered separately from the equilibrium water vapor pressure. As the pool heats up, the vapor pressure will increase to remain in equilibrium with the pool water. The air/nitrogen will also seek temperature equilibrium with the water vapor in the mixture and thus its partial pressure will increase with temperature following the ideal gas law:

$$P_{GAS} V = mRT \qquad \text{Eq. 5}$$

The effect of the increase in partial pressure P_{GAS} with temperature can be seen in Equation 4 to be a corresponding increase in NPSHA. The net effect with increasing pool temperature is that the air/nitrogen partial pressure increases NPSHA, whilst the vapor pressure change cancels itself out thus having no effect on NPSHA.

For the closed suppression pool, the maximum limit for normal continuous power operation is 80°F and slightly greater than one atmosphere absolute pressure due to the containment inerting performed using nitrogen gas. The NPSH margin with atmospheric pressure and 80°F water is approximately 20 ft @ 5100 GPM for the RHR Pumps and 14 ft @ 4400 GPM for the Core Spray Pumps. It is a valid conclusion from Equation 4 that if adequate NPSH is present at this normal cold condition, then there will be adequate NPSH at elevated temperatures up to the physical limits of the containment pressure boundary. However, there are two other factors, containment leakage and drywell versus wetwell initial conditions, that must also be included in the NPSHA evaluation.

Containment leakage due to an impaired pressure boundary must be included in a conservative design analysis of long term NPSH available during post-accident conditions. Positive containment pressure due to the P_{GAS} heatup and equilibrium vapor pressure will result in a leakage rate that increases with containment pressure. The mixture leaked from containment will consist of water vapor and gas (air/nitrogen). The water vapor that leaks is replaced since the vapor pressure component P_{VP} will always seek equilibrium saturation pressure via more water evaporating from the pool. However, the air/nitrogen component P_{GAS} will steadily decrease since the gas component of the leaked mixture is not replaced. This process continues until total pressure P_A is one atmosphere as a result of leakage and/or the cooldown of the pool.

The drywell versus wetwell initial conditions also affect the analysis. Primary containment consists of the drywell and wetwell connected by submerged downcomers in the suppression pool such that the initial conditions in the two airspaces may be different. The

wetwell airspace is normally in equilibrium with the suppression pool at a temperature not greater than 80°F whereas the drywell is assumed to be at 150°F and, for conservatism, at 80% minimum humidity. The normal inerting pressures are 1.4 psig in the drywell and 0.23 psig in the wetwell. After a LOCA and vessel depressurization, the drywell/wetwell air volumes are assumed to be uniformly mixed when the drywell vacuum-breakers open as the steam in the drywell condenses and lowers the drywell pressure below that in the wetwell. The result of mixing the hot humid drywell atmosphere with the cooler wetwell humid atmosphere is that the P_{GAS} partial pressure at the temperature of the hot mixture is lower than it would have been if the wetwell atmosphere alone had been heated to the higher temperature. As Equation 4 would indicate, this decreases the NPSHA by what typically amounts to a few feet.

Equation 4, with sufficient accounting for containment leakage and drywell/wetwell initial mixing, comprises a basic model for the evaluation of NPSH available margin. The other necessary ingredient is a post-LOCA suppression pool temperature profile. After the first ten minutes into the event, the initial vessel blowdown pressure transient has largely dissipated and the pool has been heated to the starting point temperature for such an NPSH evaluation. This is the type of evaluation that was performed as part of the original plant design as described in the FSAR [Ref. 6] and in Calculation M-662 [Ref. 9].

The above method for NPSH evaluation is concerned with simple equilibrium phenomenon that are functions only of suppression pool temperature, initial conditions, and the assumption of a closed volume with an assumed leakage rate. The complete DBA LOCA analysis, using the thermal-hydraulic model of the reactor and containment, predicts the more complex transient behavior of containment gas/vapor temperature and pressure. For the DBA LOCA, this includes the effects from the vessel blowdown, steam superheat and condensation, the compression of the noncondensible gasses within containment, as well as the more fundamental gas and vapor pressure effects described above. An evaluation of pump available NPSH could therefore be based on this calculated containment pressure rather than that based on the simpler equilibrium conditions that inherently exist. The simpler equilibrium evaluation is the more conservative of the two approaches since the equilibrium containment pressures are lower than those predicted by the transient analysis.

F.4 FSAR Analysis of NPSH

Original FSAR Figures 14.5-9, 10, and 13 [Ref. 6] (see attached FSAR revision sheets) show the design margin for NPSH available to the ECCS pumps. In Figure 14.5-10, the effect from the initial blowdown is shown in the portion of the plot under 10^3 seconds but is not part of the relevant long term conditions which begin after the suppression pool reaches 130°F (approximately 600 seconds). The long term response beyond 10^3 seconds was determined using the following assumptions:

1. The water vapor pressure in containment increases to be in equilibrium with the suppression pool temperature.

2. The partial pressure of the containment air/nitrogen increases with the pool temperature per the ideal gas laws after the initial mixing of the drywell and wetwell air has occurred.

3. There is impaired containment integrity resulting in leakage that is included at the original design value (0.5% per day) and at ten times the design value (5% per day).

Included with this Safety Evaluation is a revision to the FSAR to replace Figures 14.5-9, 10, and 13 with updated figures generated from Calculation M-662 [Ref. 9]. The new figures are based on updated values for pump NPSHR, suction line loss, containment initial conditions, and the application of leakage calculated as a function of pressure rather than a flat mass reduction taken at initial conditions. The new figures also show that containment pressure does not continue to decrease below atmospheric pressure since this is not possible but was depicted as such on the original FSAR figures. In addition, the design value for containment leakage is now included as 1% per day at a reference pressure of 45 psig to be consistent with Tech Spec 4.7.A.2, and at 5% per day as before.

The original analysis assumed the drywell initial conditions to be 150°F, 100% RH, and 0 psig. These are not credible conditions to exist prior to the postulated accident. Therefore, in the new analysis, the initial conditions are assumed to be 150°F, 80% RH, 1.3 psig in the drywell, and 80°F, 100% RH, 0 psig in the wetwell. Although the original analysis appears more conservative in this regard, there was no basis for the inconsistent assumptions on the drywell conditions. The new analysis remains conservative by assuming unusually high humidity in the drywell at otherwise normal pressure.

Containment spray is essential to reduce containment temperature and pressure when superheated steam is present at high temperature, such as after a steam line break, and to prevent the drywell shell from exceeding the design temperature of 281°F. Although the effect of spray is to temporarily reduce the NPSH margin when it is employed for cooling containment, it is not necessary to use containment spray to mitigate the consequences of a DBA LOCA. This is because the recirculation of subcooled water through the core prevents steaming and the large break flow from the reactor vessel serves to effectively reduce the drywell pressure and temperature to relatively low values. The DBA LOCA is the bounding accident for NPSH analysis because it results in the highest bulk suppression pool temperature coupled with the lowest containment pressure and, hence, the least NPSH margin.

The original FSAR Figure 14.5-13 included a curve showing the effect of continuous containment spray on available containment pressure for a DBA LOCA. As shown for the spray case, the containment pressure is at or above atmospheric pressure while the pressure required to meet NPSH requirements is always less than atmospheric pressure, hence NPSH available exceeds NPSH required during continuous spray for the nominal design case. The original FSAR Figure 14.5-13 does not reflect the drywell spray reduction implemented via PDC86-52A or the potential effects of fibrous debris on available NPSH.

Throughout the accident response, the containment pressure reflected by FSAR Figure 14.5-5 for Case C "One RHR Loop Containment Spray Mode" exceeds the containment pressure predicted in the NPSH analysis FSAR Figure 14.5-10 presented with this evaluation. The conservatism of the NPSH analysis is largely due to the assumption that the temperature of the containment atmosphere is no higher than the suppression pool temperature which results in a lower bound value for containment pressure. FSAR Figure 14.5-5 also does not reflect the effect of the drywell spray reduction (drywell nozzle

capping) and therefore would be expected to under-predict the actual long-term containment pressure with continuous spray.

There is also the case to be considered for post-accident containment where venting or purging is performed that lowers the containment pressure by releasing or purging the equilibrium air/vapor mixture at a time when pump NPSH may require the vapor pressure component. If the wetwell is intentionally or inadvertently vented, per the Dalton rule the higher wetwell vapor pressure will seek equilibrium with the lower vapor pressure in the atmosphere outside containment. When venting is ceased and the containment boundary is reestablished, the wetwell vapor pressure will increase to the saturation pressure corresponding to the pool temperature and the positive pressure in containment will again be at the equilibrium value.

F.5 Pump Cavitation Effects

Cavititation causes a decrease in pump performance immediately upon its inception, due to the vapor formation within the impeller. 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. Short term operation in a cavitating regime, as might occur due to use of containment sprays when not required or inadvertent venting, would not be expected to damage these pumps.

F.6 Review of Regulatory Guidance

This evaluation of NPSH criteria for the ECCS pumps was done using guidance provided in the referenced Regulatory Guides, Standard Review Plan, Pilgrim SER, FSAR, and Technical Specifications. The original Pilgrim licensing design basis was formed prior to the finalization of the referenced Regulatory Guides and Standard Review Plan. The Pilgrim design basis must therefore be evaluated with regard to the context in which it was developed and has been subsequently modified.

A review of the regulatory guidance on the matter of ECCS pump NPSH reveals a technical basis that conservatively limits the assumptions to be used for the design of ECCS systems. Regulatory Guide 1.1 (formerly Safety Guide 1) [Ref. 1] states the fundamental design basis to be used:

> " Emergency core cooling and containment heat removal systems should be designed so that adequate net positive suction head (NPSH) is provided to system pumps assuming maximum expected temperatures of pumped fluid and no increase in containment pressure from that present prior to postulated loss of coolant accidents. "

The requirements applied to Pilgrim are reflected in SER Section 5.7 [Ref. 5]:

" During the course of the construction permit review on Pilgrim, we questioned whether the RHR and core spray pumps, and their respective systems, were designed to provide an adequate NPSH margin to assure their continued operation following a loss-of-coolant accident. In Amendment 9 to the application, Boston Edison Company furnished an analysis based on preliminary design assumptions showing that a positive NPSH margin would be available following the accident without requiring containment overpressure. The applicant provided further information in Amendment No. 24 with an analysis confirming the final design requirement that a positive NPSH margin be available even if the containment spray were operating following a design basis loss-of-coolant accident (LOCA). "

The Standard Review Plan [Ref. 3] provides the following guidance:

" In the recirculation phase; i.e., in the long term (after about one hour) following a LOCA, the containment spray system is required to circulate the water in the containment. The NPSH analysis will be acceptable if (1) it is done in accordance to the guidance in Regulatory Guide 1.82, Rev. 1 and (2) it is done in accordance with the guidelines of Regulatory Guide 1.1, i.e., is based on maximum expected temperature of the pumped fluid and with atmospheric pressure in the containment. For clarification, the analysis should be based on the assumption that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for containment pressurization during the transient. "

Additional guidance as to the basis for the regulatory position is given in the discussion section of Regulatory Guide 1.1 [Ref. 1]:

" It is important that the proper performance of emergency core cooling and containment heat removal systems be independent of calculated increases in containment pressure caused by postulated loss of coolant accidents in order to assure reliable operation under a variety of possible accident conditions. For example, if proper operation of the emergency core cooling system depends upon maintaining the containment pressure above a specified minimum amount, then too low an internal pressure (resulting from impaired containment integrity or operation of the containment heat removal systems at too high a rate) could significantly affect the ability of this system to accomplish its safety functions by causing pump cavitation. In addition, the deliberate continuation of a high containment pressure to maintain an adequate pump NPSH would result in greater leakage of fission products from the containment and higher potential offsite doses under accident conditions than would otherwise result. "

In addition, General Design Criterion 38 [Ref. 4] relates the following system requirement:

" Containment heat removal system being capable of reducing rapidly the containment pressure and temperature following a LOCA, and maintaining them at acceptably low levels. "

F.7 Conclusions on Regulatory Guidance

The original Pilgrim design basis for ECCS pump NPSH was submitted to the NRC as Amendment 9 to the license application in March 1968, the Final Safety Analysis Report (FSAR) was submitted to the NRC in December 1969, and Safety Guide 1 was issued in November 1970. With regard to Amendment 9, the NRC evaluated the adequacy of the NPSH margin in a favorable manner and noted that positive NPSH margin would be available without requiring containment overpressure. This is consistent with the intent of Safety Guide 1 but there was no criteria concerning overpressure that was explicitly applied to the Pilgrim ECCS pump design. It is concluded that Safety Guide 1 (later to become Regulatory Guide 1.1) is not part of the Pilgrim licensing basis.

The suction strainer head loss from debris considered herein represents a postulated degraded condition that has been shown to be within the available design margin. It is therefore of interest to interpret whether the NRC recognized the available margin as shown on the FSAR figures. It can be surmised that the margin as shown on Figure 14.5-10 was considered applicable since the SER discusses the containment spray case and the resulting decrease in margin that can occur, as described earlier. The use of spray affects pump NPSH only when the gas/vapor pressure equilibrium conditions in containment are included in the NPSH evaluation. That is, containment spray can reduce only that margin which exists due to containment pressure above atmospheric. By considering these effects and concluding that positive NPSH margin is still available for design conditions, it is evident that the NPSH design analysis was understood.

The potential effect from insulation debris accumulating on ECCS pump suction strainers has been evaluated [Ref. 8]. The conclusion is that the increase in suction head loss from the postulated debris accumulation is within the margin for NPSH available to the ECCS pumps. Since the NPSH available at the pump suction exceeds the NPSH required, the pump will achieve its rated performance. Therefore, there is no effect on ECCS pump performance and no change in the margin of safety as determined by the accident analyses or as defined in the basis for any Technical Specification.

Several points should also be considered regarding the creation of FSAR Figure 14.5-10 relative to the Regulatory Guidance cited above:

1. Containment pressure does not have to be maintained above a minimum calculated amount per se, the suppression pool merely has to be a maintained as a closed system such that the equilibrium vapor pressure condition is allowed to exist. The containment pressure thereby will increase with pool temperature and then decrease again after the peak pool temperature is reached.

2. There is no credit taken for the calculated transient containment pressurization that occurs from the LOCA blowdown. The partial pressure of the air/nitrogen in containment is only assumed to be from the original pressure plus the increase due to the gas temperature being in equilibrium with the vapor pressure component. The containment pressure is therefore independent of calculated increases in pressure due to any particular postulated LOCA transient. The assumed containment positive pressure is only that due to the equilibrium that will exist in the closed volume

between the gas/vapor mixture and the pool, regardless of what the temperature is or what has caused it to increase.

3. There is nothing to preclude operating containment heat removal at the highest rate possible. Utilization of containment spray has the potential to temporarily decrease containment pressure as described earlier but the condition of saturation and equilibrium at the pool temperature is restored once spray operation is ceased.

4. Impaired containment integrity is assumed via the leakage rate at or greater than the design value.

5. There is no deliberate continuation of high containment pressure to maintain adequate NPSH. The vapor pressure inherently follows the pool temperature as in item (1) above. In addition, the leakage from impaired integrity assumed in item (3) above continually diminishes the containment pressure such that at some point the sum of the vapor pressure and air/nitrogen pressure mixture equals atmospheric pressure and can decrease no further. It is thereby the goal of the NPSH evaluation to show that as leakage decreases wetwell pressure, the pool temperature also decreases sufficiently so that adequate NPSH is available at all times including at the end point with atmospheric pressure in the wetwell.

F.8 Conclusions on Design Basis

It is concluded that the ECCS system design analysis shows positive NPSH margin is available following the bounding design basis LOCA without containment positive pressurization. The design margin for NPSH available is that which exists between the minimum containment pressure that provides the required NPSH and the containment pressure that exists due to equilibrium conditions for the gas/vapor mixture with an accounting for containment initial conditions and leakage.

Debris on the ECCS pump suction strainers is regarded as a degraded condition. Calculation methods for debris generation, transport, and deposition are by no means generally accepted or based on established design parameters. Rather, they are done as worst-case bounding evaluations with compounded assumptions and conservatisms. One is led to the conclusion that the accumulation of debris on the suction strainers is not an engineering design parameter of the fundamental sort, as are flow, temperature, pressure, stress, or heat transfer, but rather is a consideration of potential degradation that has no inherent limits or bounds. Prescriptive regulatory guidance is required simply to achieve some degree of uniformity in the assessment of debris, and said guidance is the subject of continuing revision and refinement.

This conclusion is extended to the application of conservative design criteria to the ECCS system design basis for the purpose of establishing design margin at a sufficient level so that subsequent evaluations of potential degraded conditions demonstrate satisfactory performance utilizing assumptions that are consistent with the plant as a whole. This translates into the assumption that primary containment integrity is impaired due to leakage but remains a closed system. With that assumption made, the equilibrium vapor pressure phenomenon described earlier is considered valid and provides inherently satisfactory

performance for the ECCS pumps up to the well defined, and fundamental, limits of containment temperature and pressure, with reasonable allowance for leakage.

Regarding the assumption of containment integrity when evaluating degraded conditions, it is indeed a fundamental basis for Pilgrim Technical Specifications [Ref. 7] for Containment Systems (Section 3.7.A) which states:

> " The integrity of the primary containment and operation of the core standby cooling system in combination limit the off-site doses to values less than those suggested in 10 CFR 100 in the event of a break in the primary system piping. "

The key words above are "in combination" with respect to containment and cooling, which is a fundamental assumption when evaluating the accident response of the plant as a whole. The design of individual components and systems often use assumptions which are conservative but inconsistent with overall plant design assumptions. Such methods are used to build margin into the plant design. This margin is necessary when subsequent evaluations of postulated degraded conditions are performed. There is an important, and fundamental, distinction made herein between design conditions and degraded conditions. The design change being considered in this Safety Evaluation is the installation of thermal insulation on the drywell piping. It is postulated that certain worst-case line breaks may damage and destroy portions of this insulation. Various assumptions are made regarding the transport and accumulation of this debris in the drywell and suppression pool with the ultimate deposition of the debris on the ECCS pump strainers. The debris-laden strainer is a postulated degraded condition which is shown to not adversely affect the performance of the pump because there is adequate design margin to accommodate such events.

G. Summary

1. Q: May the proposed activity increase the probability of occurrence of an accident previously evaluated in the Final Safety Analysis Report?

   A: No, the new piping insulation does not induce or change the initiating conditions for any of the analyzed accidents.

2. Q: May the proposed activity increase the consequences of an accident previously evaluated in the Final Safety Analysis Report?

   A: No, the analyses performed show that the piping insulation does not change the plant response from that assumed for the analyzed accidents. The potential insulation debris generated by pipe break accidents has been shown to have no effect on the performance of ECCS pumps.

3. Q: May the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the Final Safety Analysis Report?

   A: No, although the potential for insulation debris accumulating on the ECCS pump suction strainers is a consideration, it is shown that the margin for NPSH available will accommodate the postulated debris without affecting pump performance using prescribed Reg. Guide 1.82 Rev. 1 guidance and the original design acceptance criteria.

4. Q: May the proposed activity increase the consequences of a malfunction of equipment important to safety previously evaluated in the Final Safety Analysis Report?

   A: No, there is no equipment malfunction for which the consequences are affected by the piping insulation.

5. Q: May the proposed activity create the possibility of an accident of a different type than any previously evaluated in the Final Safety Analysis Report?

   A: No, there is no new or different type of accident created by the NUKON style insulation versus that previously used.

6. Q: May the proposed activity create the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the Final Safety Analysis Report?

   A: No, there are no new or different types of equipment malfunctions introduced by the change in piping insulation. The potential for insulation debris accumulating on the ECCS pump suction strainers is a consideration, but the potential for strainer plugging is not a fundamentally new failure. The suction strainers are part of the original design and were potentially subject to blockage by debris from the previous metal insulation and/or other potential sources for drywell debris.

7. Q: Does the proposed activity reduce the margin of safety as defined in the basis for any Technical Specification?

A: No, the potential effect from insulation debris accumulating on ECCS pump suction strainers has been evaluated [Ref. 8]. The conclusion is that the increase in suction head loss from the postulated debris accumulation is within the margin for NPSH available to the ECCS pumps. Since the NPSH available at the pump suction exceeds the NPSH required, the pump will achieve its rated performance. Therefore, there is no effect on ECCS pump performance and no change in the margin of safety as determined by the accident analyses. The bases for the Technical Specification requirements regarding Core Spray, LPCI, and Containment Cooling (Sections 3.5.A & B) do not prescribe NPSH criteria per se but it is an implicit assumption for the pump performance criteria that adequate NPSH be provided. There is no requirement that a specific amount of excess NPSH margin be available after all postulated degradations have been included in the analysis. Furthermore, the attached Figure A-2 from [Ref. 2] explicitly defines a design as adequate when NPSHA is simply greater than NPSHR (corrected for air ingestion when appropriate). The assumptions made in this evaluation are also consistent with the bases used for the Technical Specification requirements applicable to the Primary Containment Systems (Section 3.7.A) which affirms that the integrity of the primary containment and operation of the core standby cooling systems in combination limit the off-site doses in the event of a break in the primary system piping.

Therefore, it is concluded that the design change reviewed by this safety evaluation does not constitute an unreviewed safety question.

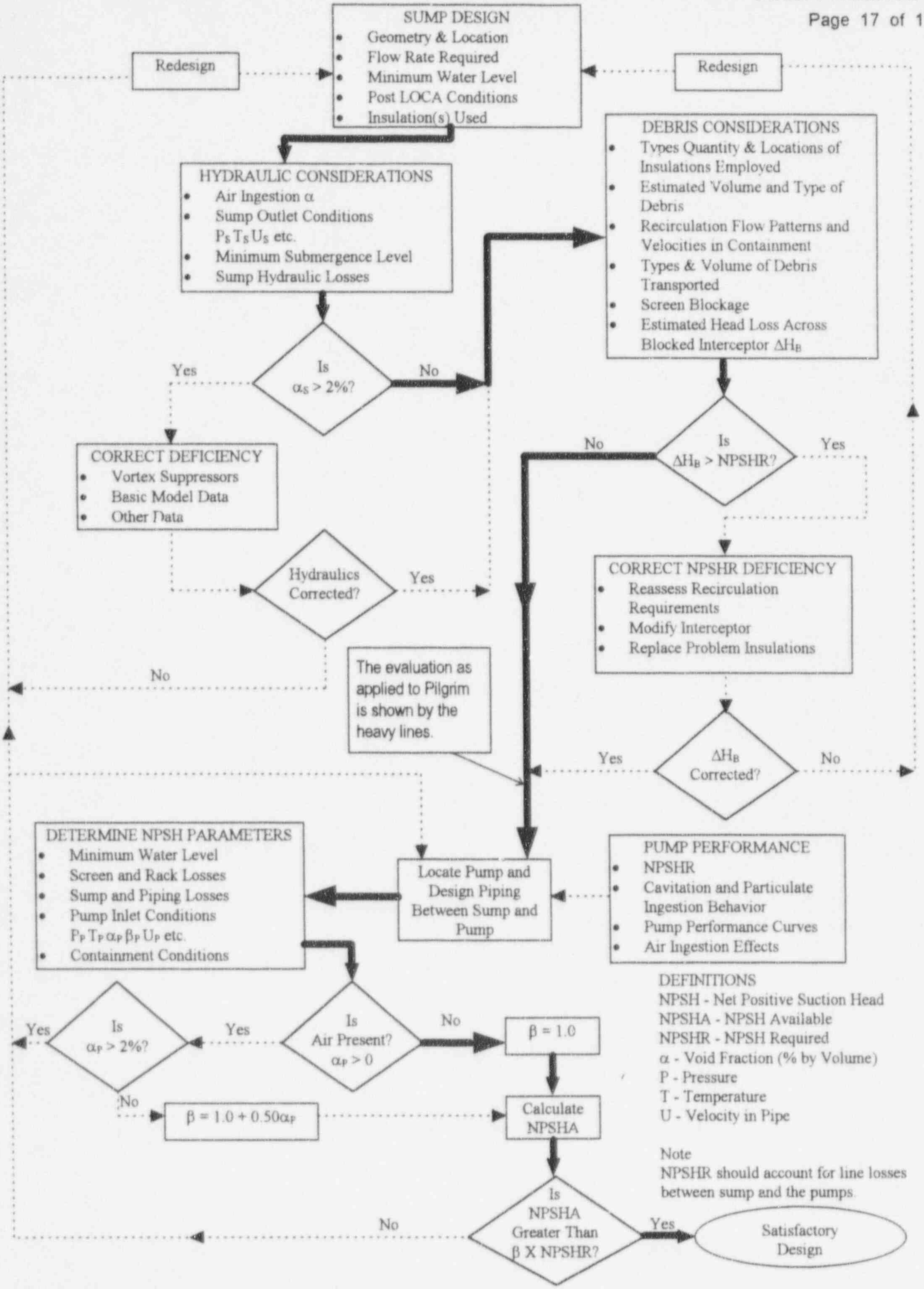


Figure A-2 from Reg. Guide 1.82 Rev. 1 "Combined Technical Considerations for Sump Performance"

Safety Evaluation - Attachment 2

REVISION TO FSAR

Insert to Section 4.8.5.1 as shown on markup (append to existing paragraph):

The increase in suction head loss from the postulated debris accumulation is within the margin for NPSH available to the RHR pumps following the bounding design basis LOCA. Refer to Section 14.5.3 for the NPSH evaluation.

Insert to Section 6.4.3 as shown on markup (append to existing paragraph):

The increase in suction head loss from the postulated debris accumulation is within the margin for NPSH available to the core spray pumps following the bounding design basis LOCA. Refer to Section 14.5.3 for the NPSH evaluation.

The core spray pumps and all automatic valves can be operated individually by manual switches in the main control room. Operating information is provided in the main control room with pressure indicators, flow meters, and indicator lights.

The major equipment for one loop is described in the following paragraphs.

When the system is actuated, water is taken from the suppression pool. Flow then passes through a normally open butterfly valve and a motor operated valve which can be closed by a remote manual switch from the main control room. This motor operated valve is normally open. The butterfly valve is located in the core spray pump suction line as close to the suppression pool as practical. This valve is equipped with an extension operator to permit manual closure of the valve from the floor above the suppression chamber.

The core spray pumps are located in the Reactor Building below the water level in the suppression pool to assure positive pump suction. The pump, piping, controls, and instrumentation of each loop are separated and protected so that any single physical event, or missiles generated by rupture of any pipe in any system within the containment drywell, cannot make both core spray loops inoperable. The switchgear for each loop is in a separate cabinet for the same reason. This arrangement satisfies safety design basis 9.

The effects on available NPSH of the core spray pump due to a postulated clogging of the core spray suction strainers in the suppression pool by soft insulation debris during or post LOCA was evaluated (Ref. GE Report ~~AE-076-0884~~) GE-NE-B13-01805-11. The core spray suction strainers were replaced to increase the available surface area. [INSERT ATTACHED TEXT HERE]

A shaft seal drain line is provided from the pump casings which drains to the Radwaste System.

A low flow bypass line is provided from the pump discharge to below the surface of the suppression pool. The bypass flow is required to prevent the pump from overheating when pumping against a closed discharge valve. An orifice limits the bypass flow. A manual valve, normally locked open, is used to close the bypass line for maintenance.

A relief valve, set for 500 psig, protects the low pressure Core Spray System upstream of the outboard shutoff valve from reactor pressure. The relief valve discharges to the Radwaste System.

A full flow test line permits circulating water to the suppression pool for testing the system during planned operations. A normally closed, motor operated valve in the line is controlled by a remote manual switch in the main control room. Partial opening of the valve combined with an orifice in the test line permits test operation at rated core spray flow at a pressure drop equivalent to discharging into the reactor vessel. A flow indicator is provided in the main control room to monitor Core Spray System flow rate.

SE 2971
ATTACHMENT 2
Pg 3 of 5

4.8.5 Description

4.8.5.1 General

The RHRS is designed for four modes of operation to satisfy all the objectives and bases. To provide clarity to the information presented herein, each mode of operation is defined as a subsystem of the RHRS and is discussed separately. It is shown how each subsystem contributes toward satisfying all the objectives and bases of the RHRS. The four modes of RHRS operation are:

1. (SDC) Mode
2. (LPCI) Mode
3. (SPC) Mode
4. Containment Spray Mode

The major equipment of the RHRS consists of two heat exchangers and four main system pumps. The heat exchangers (tube side) are cooled by the Reactor Building Closed Cooling Water System, which is in turn cooled by the station Salt Water Service System (see Section 10.6 and 10.8). The equipment is connected by associated valves and piping, and controls and instrumentation are provided for proper system operation. A schematic diagram of the RHRS is shown on Figure 4.8-1 and 4.8-2.

The main system pumps are sized on the basis of the flow required during LPCI mode of operation, which is the mode requiring the maximum system flow rate. The heat exchangers are sized on the basis of their required duty for the SDC function, which is the mode requiring the maximum heat exchanger surface area. A summary of the design data of the main system pumps and the heat exchangers is resented on Table 4.8-1. The pump head may degrade from design value and still deliver the required LPCI flows. A total dynamic head of 380 ft at 4800 gpm will ensure that required LPCI flows are obtained or exceeded for all pump combinations.

SP

The effects on available NPSH of the RHR pumps due to a postulated clogging of the RHR suction strainers in the suppression pool by soft insulation debris during or post LOCA were evaluated (Ref. GE Report ~~AE-076-0884~~ GE-NE-B13-01805-11). The RHR suction strainers were replaced to increase the available surface area. INSERT ATTACHED TEXT HERE

One loop, consisting of one heat exchanger, two main system pumps in parallel, and associated piping, is located in one corner compartment of the Reactor Building. The other heat exchanger, pumps, and piping, forming a second loop, are located in the diagonally opposite corner compartment of the Reactor Building to minimize the possibility of a single physical event causing the loss of the entire system.

Revise Subsection in Section 14.5.3 "Loss of Coolant Accident" as follows:

14.5.3.1.3 Core Standby Cooling System Pump Net Positive Suction Head

To assure proper operation of the CSCS pumps following a design basis LOCA, the primary containment and CSCS pump system design is such that Net Positive Suction Head (NPSH) margin is available to the pumps at all times.

The NPSH available (NPSHA) at the suction to the CSCS pumps is equal to the total absolute pressure minus the vapor pressure of water at the suppression pool temperature. The NPSH required at the pump suction (NPSHR) is the minimum pressure over and above the vapor pressure that must be present in order to prevent pump cavitation. For the RHR and Core Spray pumps, the NPSH margins (the difference between available and required NPSH) are shown in Figures 14.5-10 and 13. NPSH margin is based on calculations that include the effect from the increase in wetwell vapor pressure and air/nitrogen partial pressure in equilibrium with increasing suppression pool temperature with an accounting for containment initial conditions and leakage.

The design margin for NPSH available to the RHR and Core Spray pumps is determined using the following assumptions:

1. The primary containment is assumed to contain the minimum credible mass of noncondensible gas (air/nitrogen) prior to the design basis LOCA. The drywell initial condition is 150°F, 80% RH, 1.3 psig, and the wetwell is 80°F, 100% RH, 0 psig.

2. The water vapor pressure in containment increases to be in equilibrium with the suppression pool temperature.

3. The partial pressure of the containment air/nitrogen increases with the pool temperature per the ideal gas laws after the initial mixing of the drywell and wetwell air has occurred.

4. Where stated on the figures, containment leakage has been calculated based on a leak rate of 1% per day for design basis conditions and 5% per day to demonstrate conservative design margin with impaired containment integrity. The leakage values represent percent mass per day at a reference pressure of 45 psig using the mass leakage formulation described in Appendix R.5.4.2 "Long Term Containment Response".

5. The suppression pool temperature profile is based on minimum primary containment system cooling, i.e., one RHR loop in containment cooling is assumed, with an initial suppression pool temperature of 80°F and a Salt Service Water heat sink temperature of 65°F.

6. Minimum initial water volume in the suppression pool is assumed (84,000 ft^3).

7. Drywell free volume temperature is equal to wetwell temperature following the accident. This is based on the redistribution of noncondensible gases between the drywell and wetwell via the vacuum-breaker system following the vessel depressurization phase.

8. Maximum required flow rates are used for the CSCS pumps to maximize the suction line losses and NPSH required by the pumps. The NPSHR is 23 ft at 5100 GPM for the RHR pumps and 29 ft at 4400 GPM for the Core Spray pumps.

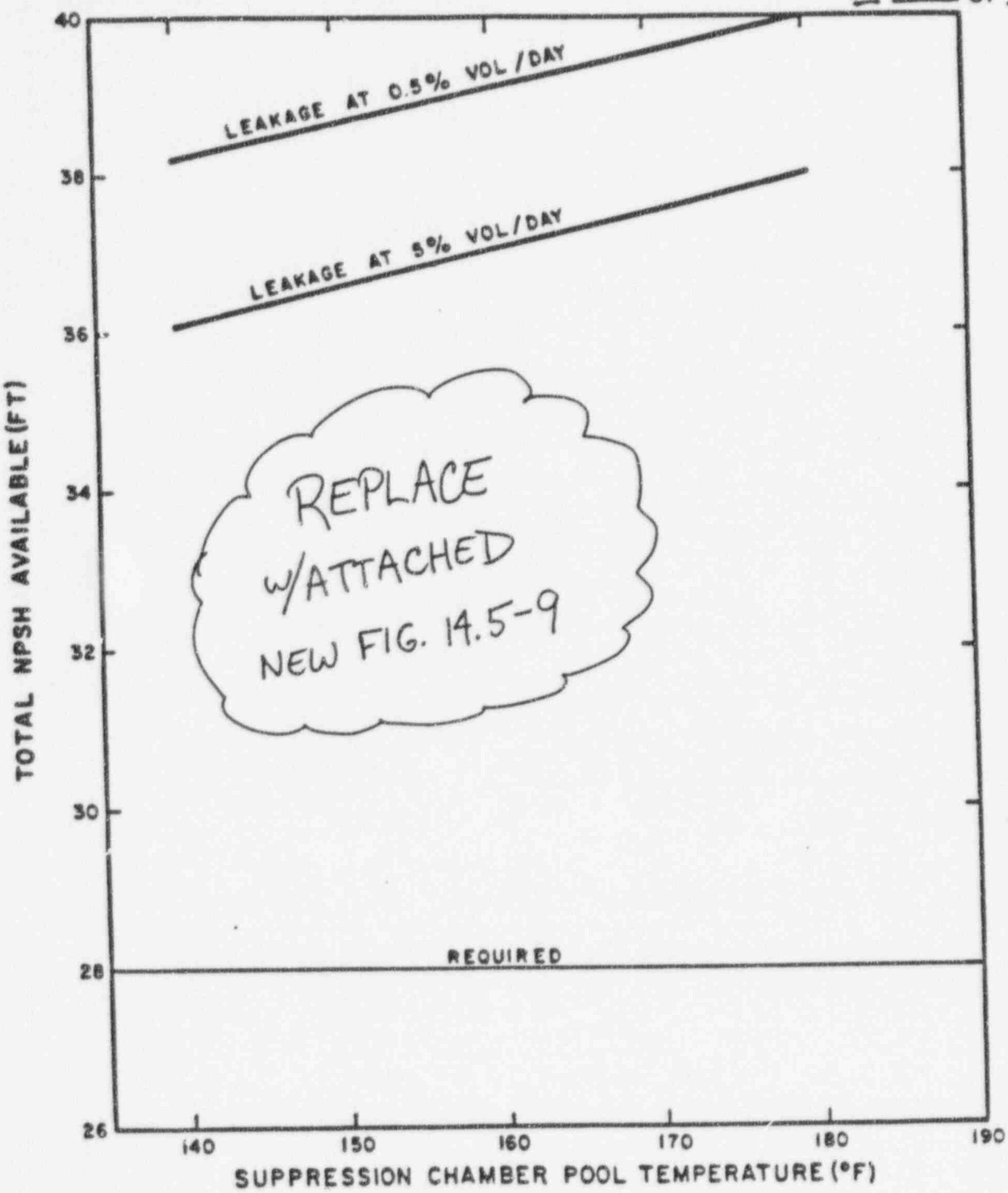
Based on the above conservative assumptions, the margin for NPSH available was evaluated for the limiting accident event which is the design basis LOCA. Figure 14.5-9 shows the NPSH available as a function of pool temperature with zero containment leakage which makes this curve independent of time. Since no leakage effect is included, Figure 14.5-9 represents the highest NPSH margin that can be obtained using the above assumptions and as can be seen, a large margin exists for all pool temperatures. NPSH margin, with leakage effects included, is presented in a different format on Figure 14.5-10 and 13. Here, the suppression pool temperature and containment pressure are shown as a function of time. Also shown is the primary containment pressure required to provide the required NPSH to the RHR and Core Spray pumps at their maximum required flow rates. As can be seen, substantial margin exists throughout the duration of the event. Therefore, it can be concluded that adequate NPSH will be available at all times following a design basis LOCA.

The RHR and Core Spray system design analysis shows positive NPSH margin is available following the bounding design basis LOCA without containment positive pressurization. The design margin for NPSH available is that which exists between the minimum containment pressure that provides the required NPSH and the containment pressure that exists due to equilibrium conditions for the gas/vapor mixture with an accounting for containment initial conditions and leakage.

[continue with existing FSAR in this subsection beginning with the following]

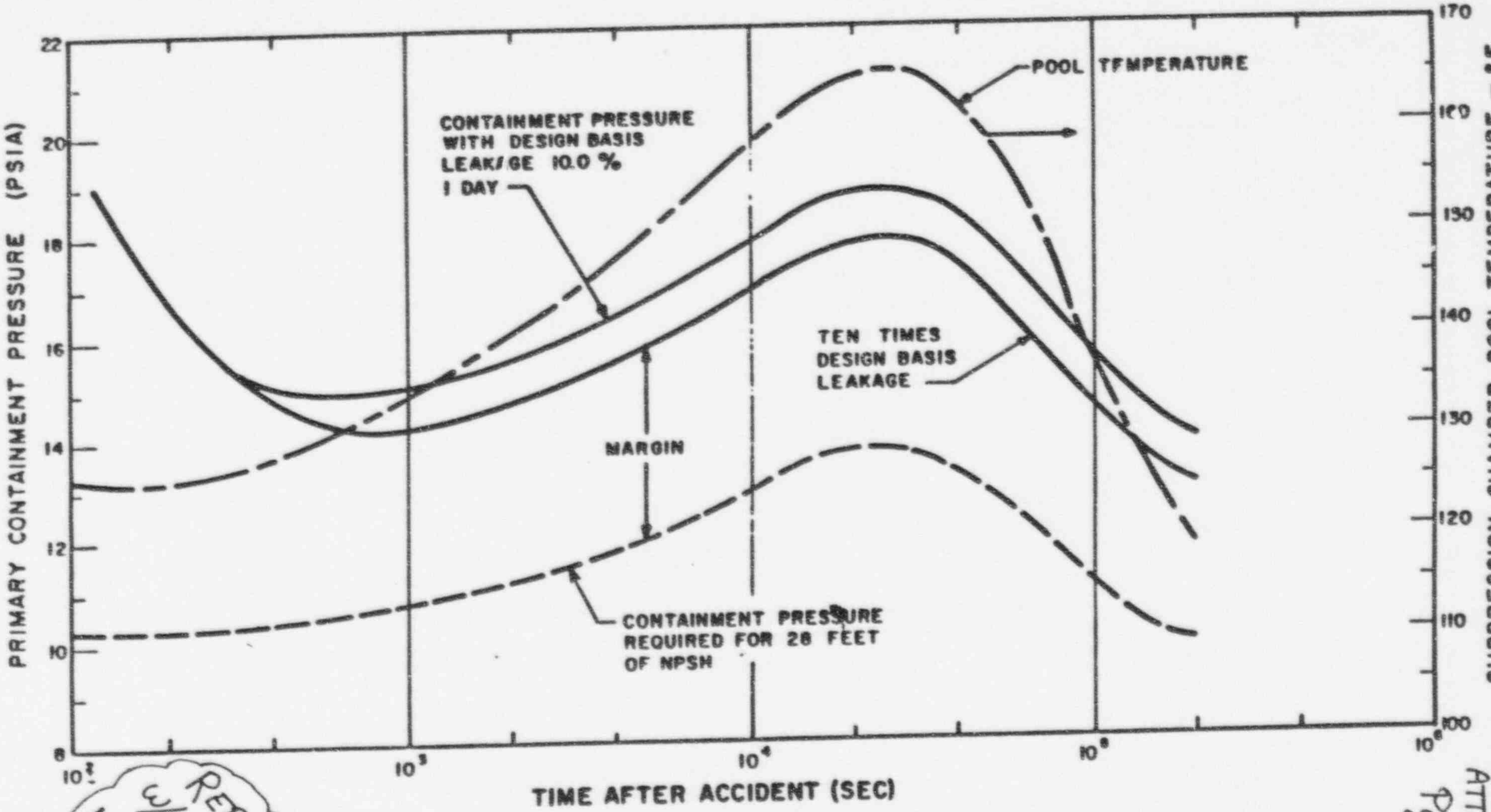
During the Reactor Core Isolation Cooling System (RCICS) operation, ...(continue)

SE 2971
ATTACHMENT 3
Pg 1 of 6



NOTE
DRYWELL INITIALLY SATURATED
AT 150°F 0 PSIG

Figure 14.5-9. Total NPSH Available Rated Flow



REPLACE W/ATTACHED NEW FIG. 14.5-10

SE 2971
ATTACHMENT 3
Pg 2 of 6

Figure 14.5-10. NPSH Availability for RHR and Core Spray System

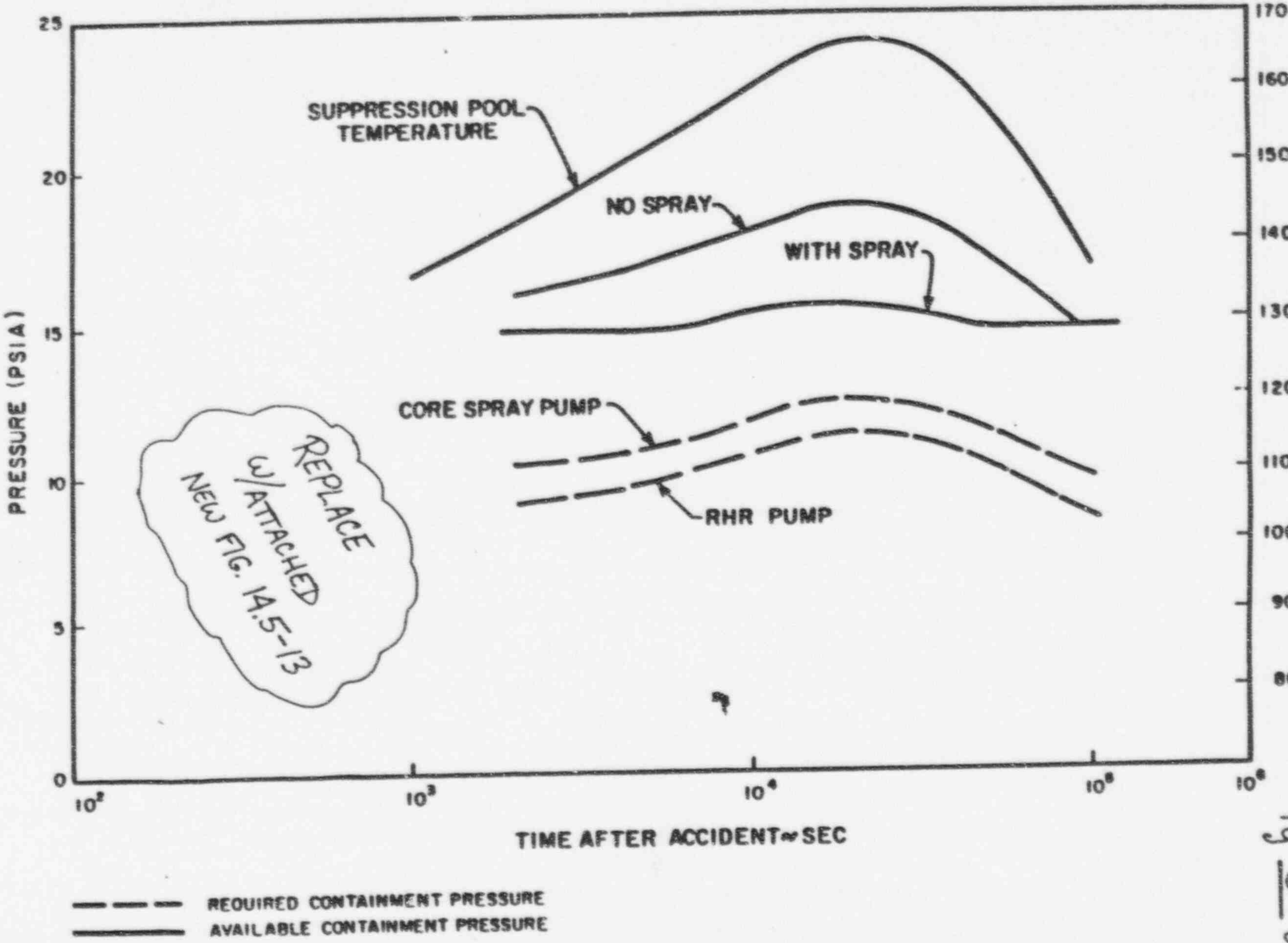


Figure 14.5-13. NPSH Availabile Following Design Basis LOCA

SE 2971
ATTACHMENT 3
Pg 3 of 6

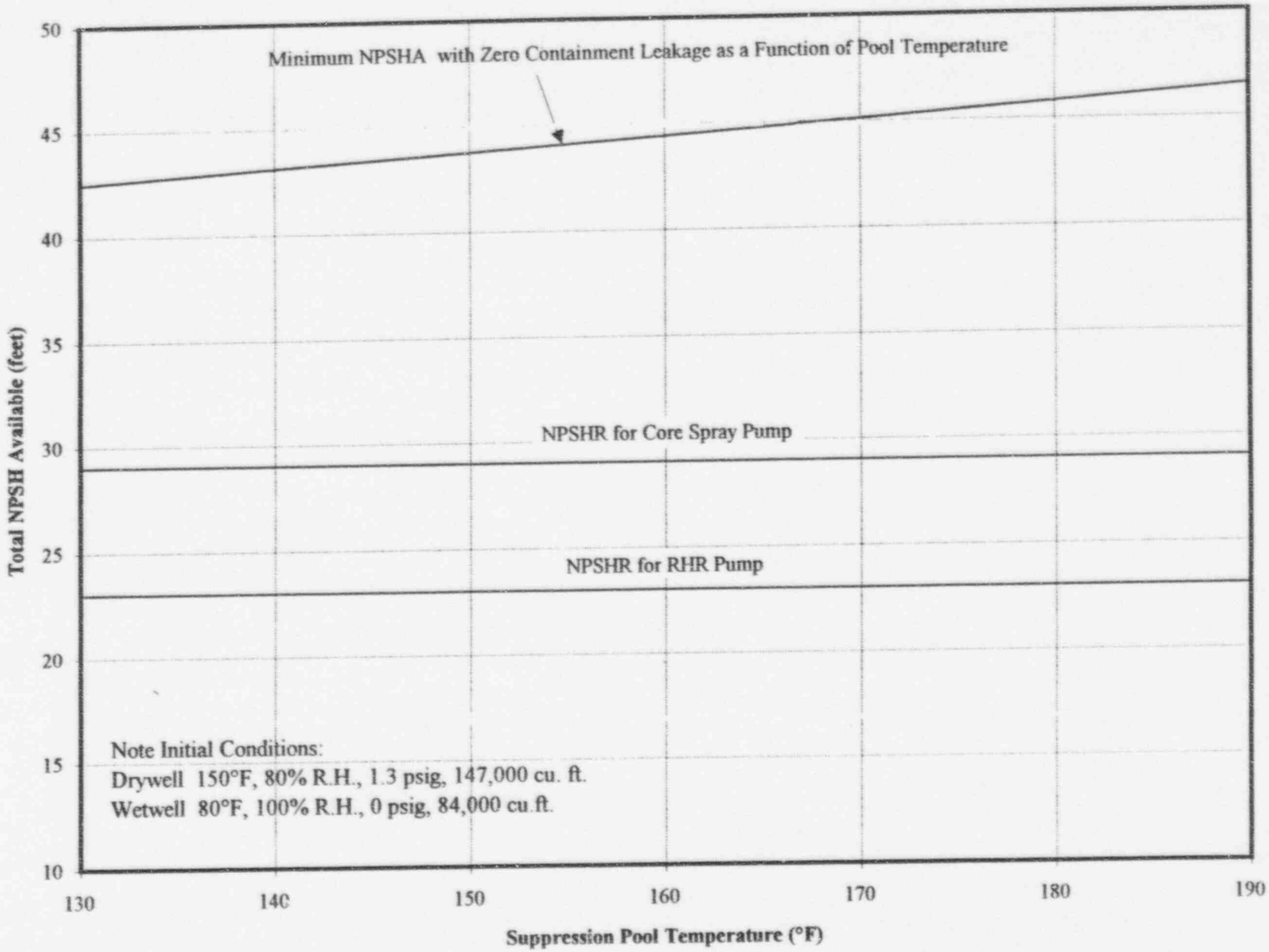


Figure 14.5-9 Total NPSH Available at Maximum Required Flow

SE 2971
ATTACHMENT 3
Pg 4 of 6

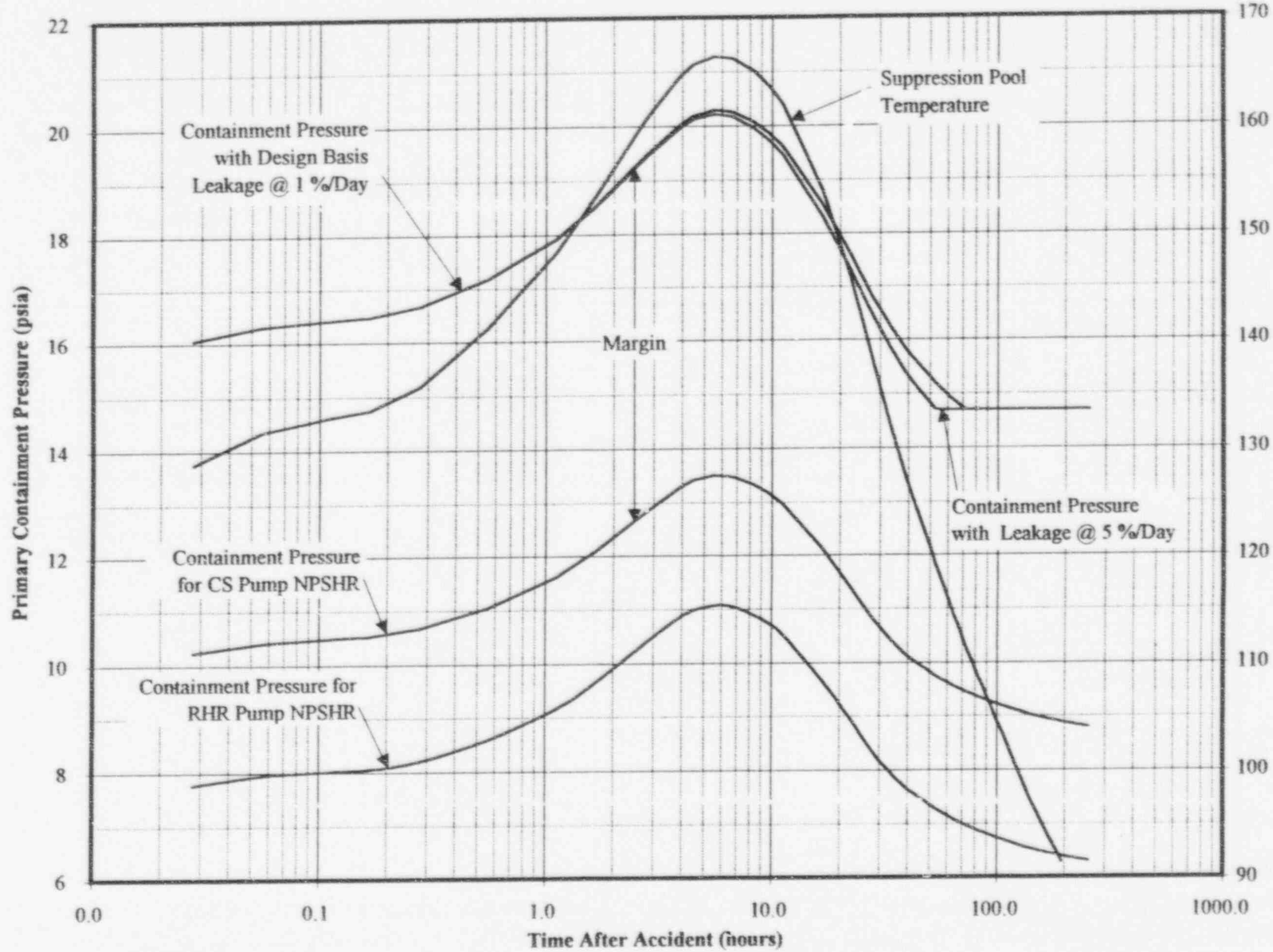


Figure 14.5-10 NPSH Availability for RHR and Core Spray Pumps After a DBA-LOCA

SE 2971
ATTACHMENT 3
Pg 5 of 6

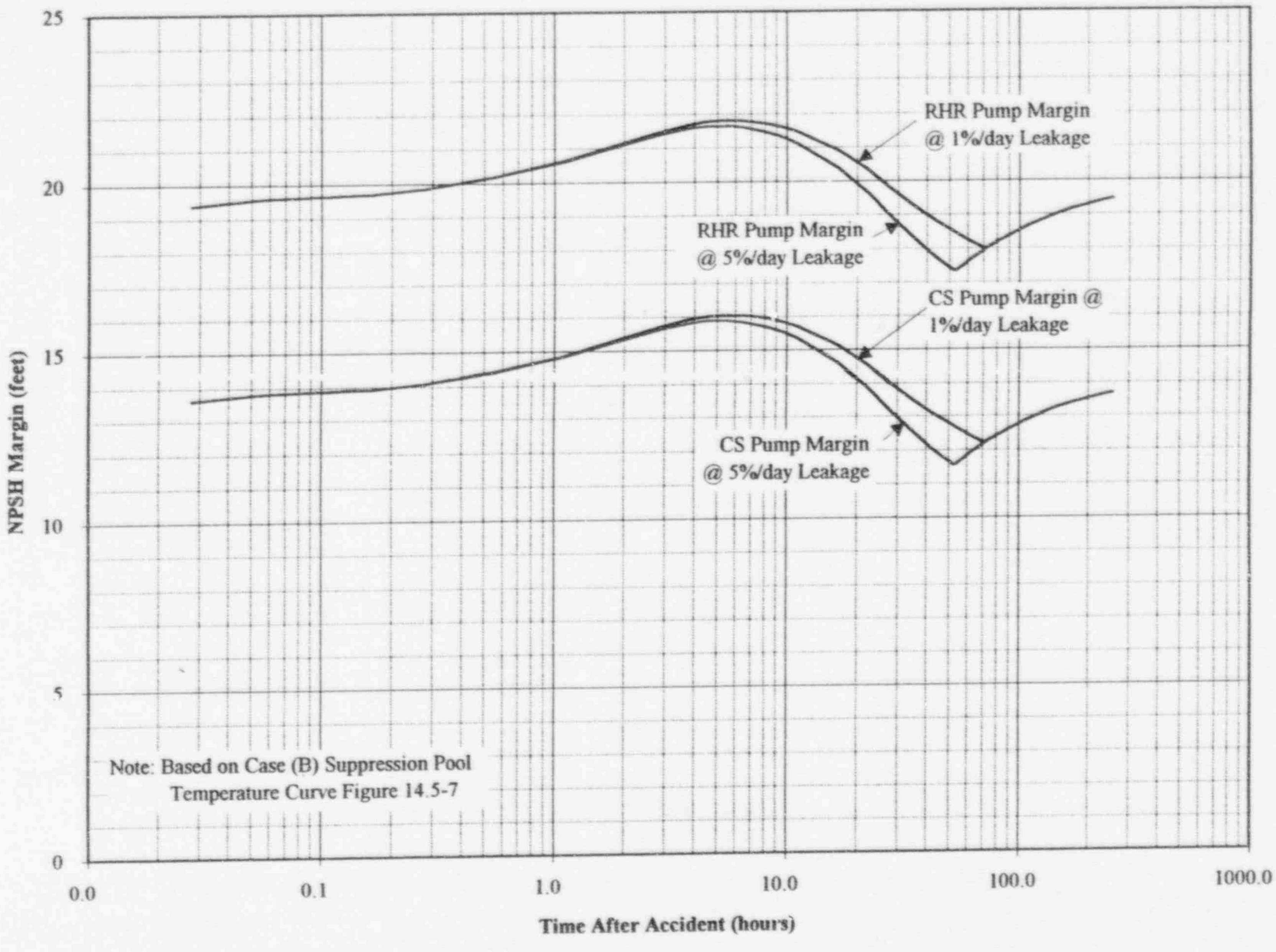


Figure 14.5-13 NPSH Margin for RHR and Core Spray Pumps After a DBA-LOCA