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SUBJECT: Submits response to RAI re reactor bldg overpresssure for reactor bldg spray pumps net positive suction head. Calculations requested in Question 1 contained in Attachments 2 & 3 to ltr.

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November 20, 1998

U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Document Control Desk

Subject: Oconee Nuclear Station, Units 1, 2, and 3
Docket Nos. 50-269, 270, and 287
TAC Nos. MA3765, MA3766, and MA3767
Response to Request for Additional Information Related to Reactor Building Overpressure for Reactor Building Spray Pumps Net Positive Suction Head.

In a letter dated October 2, 1998, Duke Energy Corporation (Duke) submitted a proposed amendment to the Oconee Nuclear Station (ONS) Facility Operating License to address an Unreviewed Safety Question (USQ) related to the use of reactor building overpressure to assure net positive suction head for the reactor building spray pumps during the recirculation phase. In a letter dated October 26, 1998, the NRC issued a request for additional information related to this proposed amendment.

The questions contained in the October 26, 1998 NRC letter and the corresponding Duke answers are provided in Attachment 1. In response to Question 1, Duke commits to provide any applicable updates to the requested calculations which may become available prior to the approval of this proposed amendment. Additionally, the calculations requested in Question 1 are contained in Attachments 2 and 3 to this letter.

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If there are any additional questions, please call J. E. Burchfield, Jr. at (864) 885-3292.

Very truly yours,

W. R. McCollum, Jr., Site Vice President
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Attachments

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ATTACHMENT 1

Questions and Responses

Question 1:

Provide the NPSH calculations of record for the RBS and low pressure injection (LPI) pumps for both the injection and recirculation phases. Include the supporting documentation as necessary. According [to your] license amendment request, DEC is currently performing additional analyses to determine if additional margin can be established regarding the RBS NPSH requirements. Please provide any applicable update to the requested NPSH calculations as they become available.

Response 1:

NPSH calculation OSC-4467, for the RBS pumps and LPI pumps in the sump recirculation phase of operation, is provided in Attachment 2. NPSH calculation OSC-7248, for the RBS and LPI pumps in the injection phase of post-LOCA operation, is provided in Attachment 3. There have been no updates to the NPSH analysis for the RBS pumps in the sump recirculation mode (OSC-4467) since this proposed amendment was submitted on October 2, 1998. Duke Energy Corporation (Duke) will submit applicable updates to the provided NPSH calculations which become available prior to the approval of this amendment.

Question 2:

Page 12 of the October 2, 1998, submittal states that the RBS NPSH analysis utilizes design inputs that include NPSH requirements provided by the pump manufacturer and adjusted by application of high temperature correction factors. Provide the source of the high temperature correction factors (e.g., Hydraulics Institute) and explain why it is acceptable to use them in this analysis. The use of hot fluid correction factors was discussed in the background section of Generic Letter 97-04, "Assurance of Sufficient

Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps."

Response 2:

Hot fluid correction factors were taken from the Hydraulic Institute (HI) Standards (1983). These factors are empirically determined, and their publication in the HI Standards would indicate that they are widely accepted as appropriate inputs to NPSH analyses for any application when used within the restrictions provided by the HI Standards. These correction factors may also be found in other industry publications such as Cameron Hydraulic Data published by Ingersoll Rand Co. in 1988, and Pump Handbook, authored by Igor J. Karassik and published in 1986 (second edition). The validity of high temperature correction factors for NPSH is also supported by their inclusion in Section 3.2.2.1 of NUREG 0897 (page 3-10), and a graph of the correction factors as a function of fluid temperature is also included there (page 3-12). Section 3.2.2.1, titled "Cavitation", contains the following statement: "The cavitation behavior of pumps changes at elevated liquid temperatures. Figure 3.6, which is extracted from the Hydraulic Institute Standards (Hydraulic Institute, 1975), shows that as liquid temperatures increase, less NPSH is required by the pump."

Question 3:

If the high temperature correction factors are from the Hydraulic Institute Standard, explain how the limitations and precautions are included in the NPSH calculation. The Hydraulic Institute Standards (currently American National Standard for Centrifugal Pumps) provide limitations and precautions for use of the NPSH-required temperature reduction, including considerations of entrained air or other gases present in the liquid and consideration of the susceptibility of the suction system to transient changes in temperature and absolute pressure.

Response 3:

Some, but not all of the limitations and precautions contained in the Hydraulic Institute Standards are directly addressed in the NPSH calculations. However, all of these limitations and precautions are satisfied for this specific application. Each of these limitations and precautions are addressed below:

a) NPSH reduction should be limited to 50% of the NPSH required by the pump for cold water.

   The NPSH reduction is about one foot as compared to a required NPSH of 17 ft. The NPSH reduction therefore represents about 6% of the NPSH required by the pump for cold water.

b) Where dissolved air or other noncondensables are present, and where the absolute pressure at the pump inlet would be low enough to release such noncondensables from solution, the NPSH available may have to be increased above that required for cold water to avoid deterioration of pump performance due to such release.

   This same guidance is provided in NUREG 0897, and has been considered in the NPSH analyses. For fluid at the high temperatures expected in the emergency sump, no significant quantity of dissolved air is expected to be present. A rough estimate of solubility of air in water (using Henry's constant) indicates that at 70°F and one atmosphere pressure the water could contain 0.0015% air, whereas at the worst accident conditions the solubility increases to 0.0037%. Using guidance from NUREG 0897 for entrained air (see page 5-15), the adjustment for NPSH would be:

   NPSHr Corrected = NPSHr x β

   where $\beta = 1 + 0.5\ \alpha_p$ and α_p = air ingestion rate in volume percent

So, $\beta = 1 + 0.5 \times 0.0037 = 1.002$

This adjustment for dissolved air is beyond the accuracy of either modeling or testing capabilities for NPSH, and is considered insignificant.

Also, due to the presence of floor grating in two orthogonal planes around the emergency sump, and the ample submergence of the sump outlet lines, vortex suppression is expected to be complete, and air entrainment is not expected. Therefore, Duke concludes that a correction factor for dissolved air or other noncondensables would have a negligible impact on the results of the NPSH calculations.

c. For hydrocarbon mixtures, vapor pressure may vary significantly with temperature and specific vapor pressure determinations should be made for actual pumping temperatures.

Not applicable to this analysis, as the pumped fluid is not a hydrocarbon mixture.

d. Due consideration must be given to the susceptibility of the suction system to transient changes in temperature and absolute pressure, which might necessitate provision of a margin of safety of NPSH far exceeding the reduction otherwise available for steady state operation.

There are transient conditions present at the suction of the RBS and LPI pumps while in the sump recirculation phase of post-LOCA operation. These include the changes in sump fluid temperature and reactor building pressure which are typical for a large break LOCA response. These conditions have been evaluated in detail in the containment response analysis and their effects are included in the NPSH analysis by choosing the bounding conditions from the accident analysis as inputs to the NPSH calculations. Due to the detailed treatment of these boundary conditions, application of an additional safety factor is not required in the NPSH calculation.

e) Extrapolation of the NPSH reduction data beyond 10 feet is not recommended.

No extrapolation of NPSH reduction data was used in the NPSH analyses.

Question 4:

Page 6 of your October 2, 1998, submittal refers to additional data provided by the pump vendor to support the NPSH analyses for the LPI and RBS pumps. Discuss the additional data received by the vendor and explain how it is being relied upon in the NPSH analysis.

Response 4:

In previous revisions of the NPSH analysis for the RBS pumps in the sump recirculation mode of operation, Duke has used NPSHr data from the most conservative BS pump performance curves on file. The pump manufacturer has subsequently advised Duke that the existing curves are excessively conservative with respect to the Oconee model of RBS pumps. Also, the remaining curves in Duke's possession do not have NPSH data plotted at the flow rate of interest (throttled to a nominal 1000 gpm) for Oconee RBS pumps in the sump recirculation mode. The manufacturer provided expected NPSH requirements for the Oconee RBS pumps at low flow rates (lower than the design flow of 1500 gpm) based upon testing of the same model pump at the manufacturer's facility. This information was used to determine the NPSH requirements for the ONS RBS pumps at the expected flow rate for sump recirculation operation. The NPSH calculations now use this information to demonstrate adequate NPSH availability for operation of the RBS pumps in the post-LOCA sump recirculation mode. These data were subsequently confirmed as conservative specifically for the Oconee RBS pumps by testing performed at the pump manufacturer's facility on November 13, 1998.

Question 5:

Page 12 of your October 2, 1998, submittal states that a single failure of one low pressure injection train, RBS train, and one reactor building cooling unit (RBCU) was assumed. However, Section 15.14.3.3.6, ECCS Performance and Single Failure Assumption, of the Oconee Final Safety Analysis Report states "historically, the worst single failure for a LOCA [loss-of-coolant accident] is the loss of one bus of emergency power which results in the loss of one train of HPI [high pressure injection] and one train of LPI. The failure of transformer CT-4 has been identified as a more limiting single failure for the large break LOCA. The failure of transformer CT-4 results in a longer delay until delivery of ECCS [emergency core cooling system] fluid to the reactor coolant system (RCS). However, two ECCS trains are available with this single failure. Reference 33 demonstrates that having two ECCS trains injection at a later time is more limiting than having one ECCS train injecting at an earlier time." Since a large break LOCA is limiting for NPSH considerations, explain why this new single failure is not more limiting than one being assumed in the NPSH analysis.

Response 5:

The single failure discussion presented in Section 15.14.3.3.6 relates to the maximum peak cladding temperature following a LOCA. The failure of transformer CT-4 increases the time delay until emergency power is restored by 10 seconds. This increase in the time delay is significant for determining peak cladding temperatures, since the time frame of concern is the first minute.

However, for the determination of the containment response for RBS pump NPSH, this time delay is not as significant a factor as the loss of one train of equipment. It is conservative to assume that one LPI train, one RBS train, and one RBCU train are failed for the duration of the transient. Having these trains disabled, with ECCS flow returning within 23 seconds after the transient initiation, is more conservative for the recirculation mode NPSH analysis than having all ECCS flow and all RBCUs available at 33 seconds. The additional RBCU capacity removes more energy from the Reactor Building in the latter case (all trains available), with the additional LPI flow removing more energy once sump recirculation mode is entered. The earlier entry into sump recirculation mode with two trains of LPI and RBS draining the Borated Water Storage Tank (BWST) results in a higher Reactor Building pressure at swapover than in the case with one train of LPI and RBS failed (even though pressure is decreasing more rapidly with the additional RBS flow from the BWST). Therefore, with all trains available, there would be additional pressure available to ensure adequate NPSH to the RBS pumps at swapover.

Question 6:

Provide a graph that depicts the NPSH required in pounds per square inch for the RBS and LPI pumps versus time and the calculated NPSH available versus time. A sample of the type of graph that is requested is provided for your convenience.

Response 6:

The following graphs depict the NPSH required (NPSHr) and NPSH available (NPSHa) for the RBS and LPI pumps for both the injection and recirculation phases. There are three graphs for the recirculation mode (Charts 2A, 2B, and 2C), each shows NPSH assuming a different Reactor Building Cooling Unit (RBCU) cooling capacity. The NPSH available curves shown on the graphs for the recirculation mode include containment overpressure.

As stated in the proposed amendment, the worst case assumed in the calculation for the recirculation phase is the single failure of one low pressure injection (LPI) train, RBS train, and RBCU train. The transfer from the injection phase to the recirculation phase will occur at approximately 50 minutes (3000 seconds) based on this assumption. Therefore, the data shown on the graphs for the recirculation phase begins at 3000 seconds. The worst case assumption for the injection phase calculation is that both trains of LPI, RBS, and all RBCUs are operating. Therefore, the transfer to recirculation phase will occur at approximately 25 - 35 minutes. The graph for the injection phase (Chart 1) shows data out to 35 minutes.

The gap in time (35 to 50 minutes) between the end of the injection mode graph and the beginning of the recirculation mode graphs is due to the differing single failure assumptions used for the NPSH analysis in these two modes. With both trains of LPI and RBS operating, as assumed for the injection mode, the BWST is depleted more quickly than it is with one train of LPI and RBS unavailable as assumed for the recirculation mode. In both cases, the single failure assumptions yield the worst case bounding NPSH conditions for each respective operating mode.

NPSH AVAILABILITY FOR BS AND LPI PUMPS IN THE INJECTION MODE

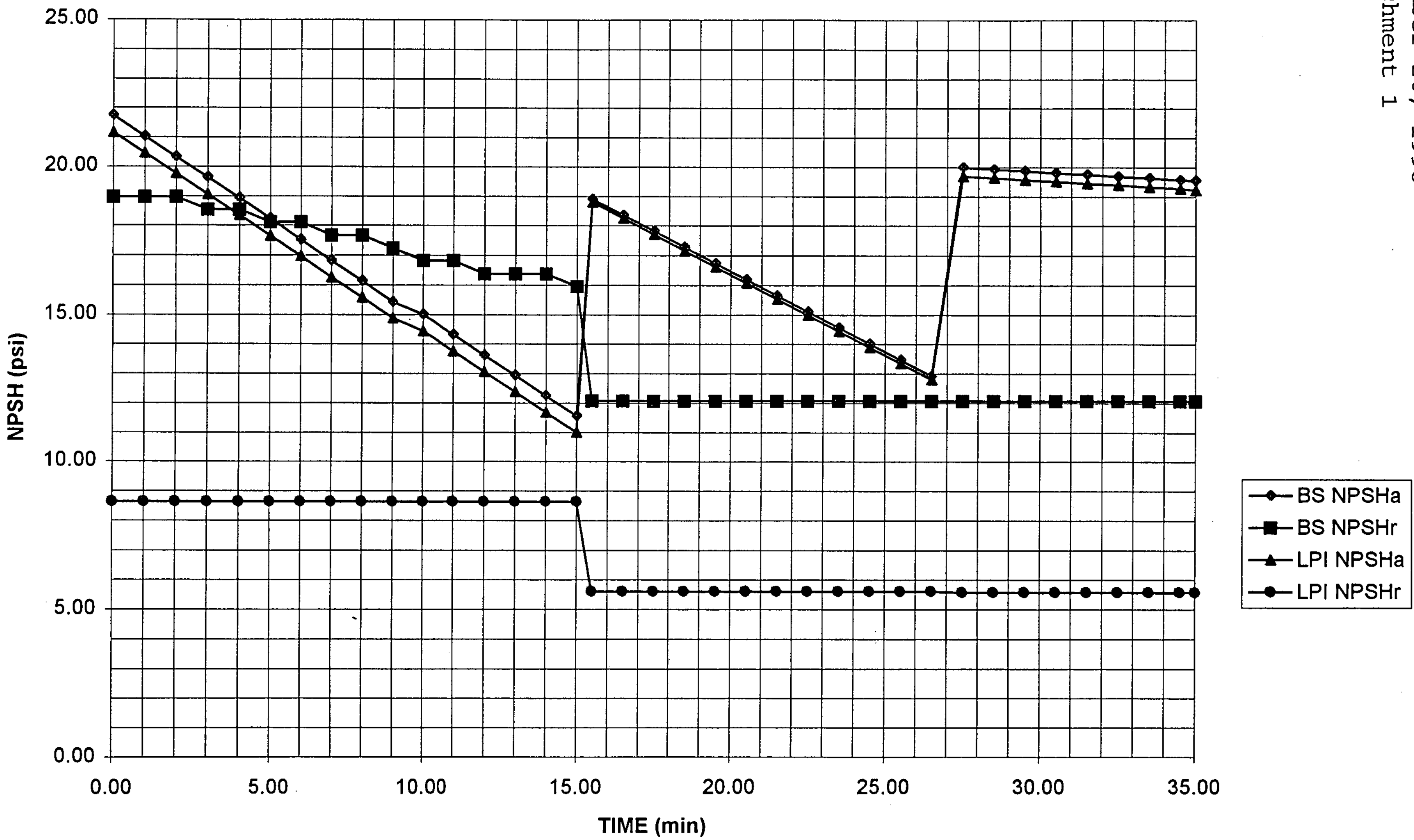


CHART 1

EXPLANATION OF DATA ON CHART 1

There are three distinct regions shown on Chart 1 for the injection phase. These are discussed individually below:

1. The first region is from 0 to 15 minutes following the onset of the LOCA. The 'C' High Pressure Injection (HPI) pump is assumed to be throttled to approximately 500 gpm at 10 minutes into the event. No other pump throttling is assumed during this time period. Simulator testing has demonstrated that all ECCS and Building Spray pumps will be throttled within this 15 minute window. However, for analytical purposes, The Low Pressure Injection (LPI) pumps and Building Spray pumps are assumed to be throttled at 15 minutes for conservatism.

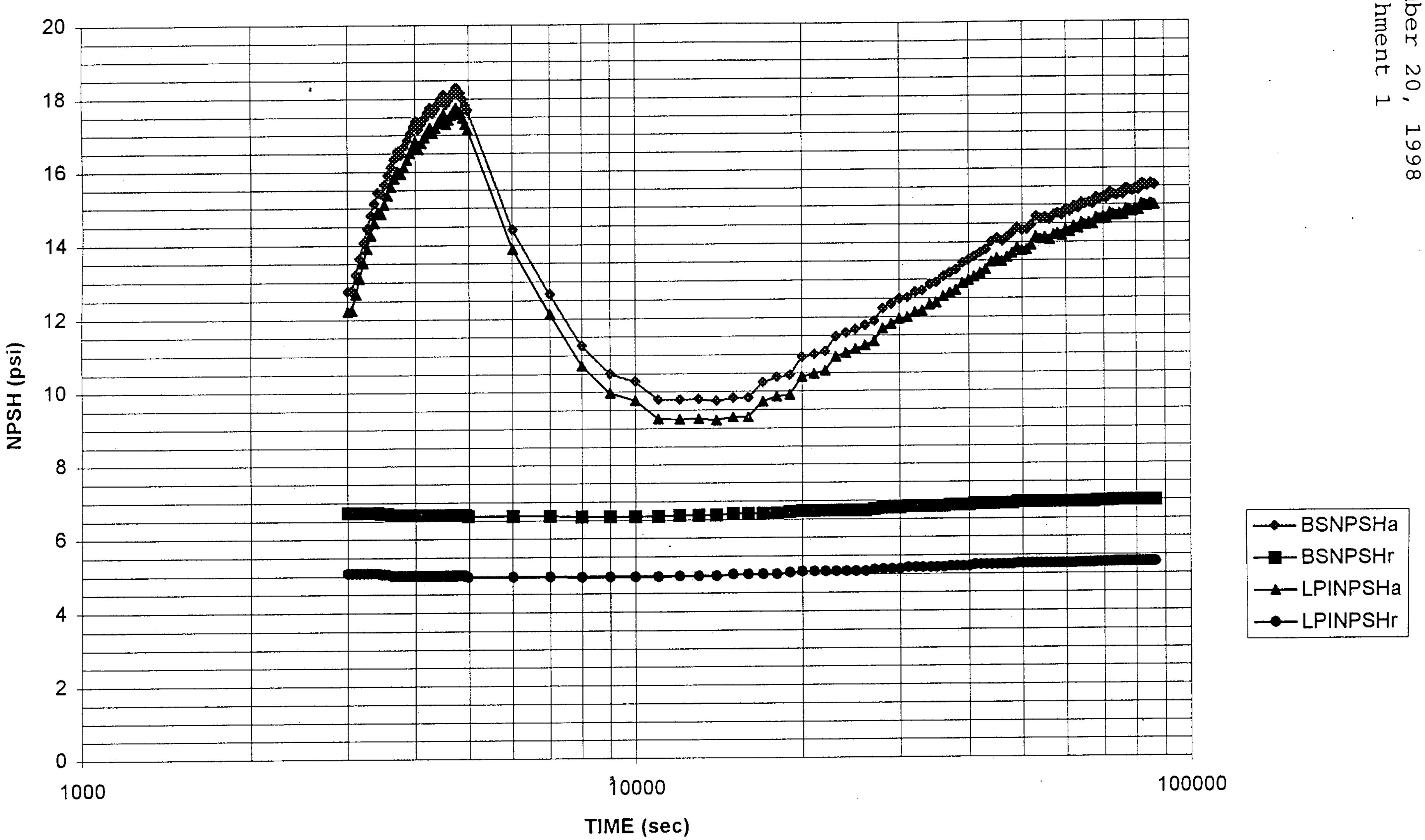
   The available NPSH decreases below the required NPSH for the Building Spray (BS) pumps at approximately 5 minutes into the event. The available NPSH is approximately 4.5 psi below the required NPSH prior to throttling at 15 minutes into the event. This NPSH deficiency has been documented and evaluated under Duke's Problem Investigation Process (PIP) and reported to the NRC in Licensee Event Report (LER) 269/1998-12 submitted on November 2, 1998. The operability of the Building Spray pump under these conditions has been verified by test. Testing was performed on a pump of the same model and size as the Oconee Building Spray pumps at the pump manufacturer's facility on November 13, 1998.

2. The second region is represented by the period of time between 15 minutes and approximately 26.5 minutes. In this region, LPI pumps are throttled to 3000 gpm indicated flow, BS pumps are throttled to 1500 gpm indicated flow, and HPI pumps are assumed to operate throttled to 1500 gpm indicated flow. This region ends at a Borated Water Storage Tank (BWST) level of approximately 6 feet, when the transfer of pump suction source from BWST to Reactor Building Emergency Sump (RBES) is initiated. When throttling occurs at 15 minutes, the required BS NPSH is again satisfied, as the

NPSH requirements decrease and the available NPSH increases, both in a step change fashion. Available NPSH continues to decrease as the BWST is depleted.

3. The third region represents the time from the beginning of swapover (approximately 6 feet BWST level indicated) to the end of swapover (approximately 2 feet of BWST level indicated). When a BWST level of 6 feet (indicated level) is reached, HPI pumps are secured and sump isolation valves are opened. Flow from the BWST is substantially reduced when the HPI pumps are secured. There is an accompanying increase in available NPSH for the BS and LPI pumps due to the reduced friction losses at lower flow rates. Also, the opening of the sump isolation valves significantly reduces flow from the BWST, as flow begins to split between the sump and the BWST. This reduction in flow from the BWST also raises NPSHa due to the lower friction losses in the supply lines from the sump. At or before reaching a level of 2 feet (indicated) in the BWST, the BWST isolation valves are closed, and the injection phase of the event is terminated at approximately 35 minutes.

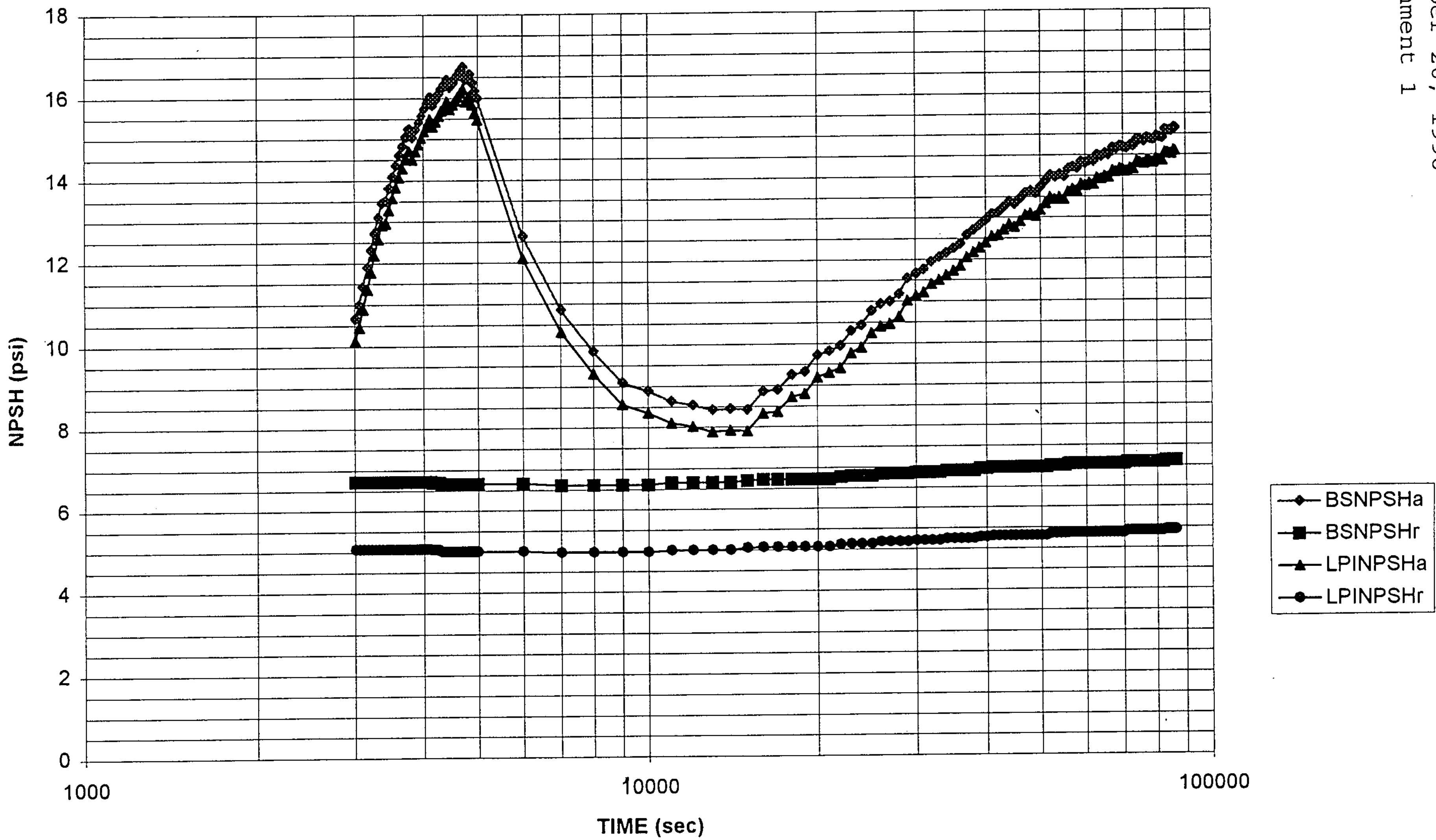
NPSH AVAILABILITY FOR BS AND LPI PUMPS IN SUMP RECIRCULATION MODE



(Assumes 60 Million Btu/Hr RBCU Capacity)

CHART 2A

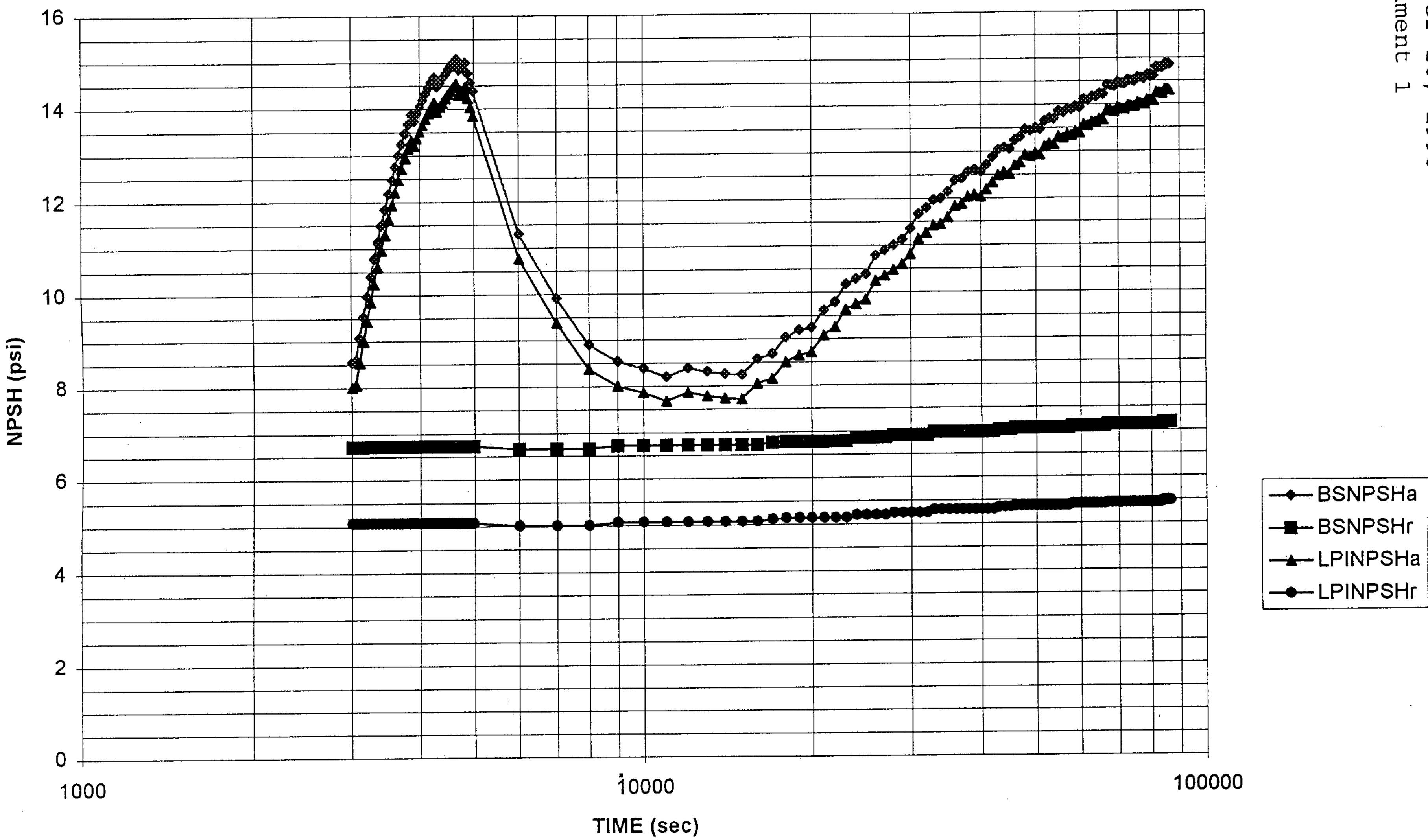
NPSH AVAILABILITY FOR BS AND LPI PUMPS IN THE SUMP RECIRCULATION MODE



(Assumes 100 Million Btu/Hr RBCU Capacity)

CHART 2B

NPSH AVAILABILITY FOR BS AND LPI PUMPS IN THE SUMP RECIRCULATION MODE



(Assumes 160 Million Btu/Hr RBCU Capacity)

CHART 2C