ATTACHMENT PLG-0459
ST-HL-AE- 1606
PAGE 1 OF 17

SUMMARY OF RESULTS

SOUTH TEXAS PROJECT PRELIMINARY SCOPING STUDY REQUANTIFICATION

Revised Models for Electrical Auxiliary Building HVAC, Positive Displacement Charging Pump, and Letdown Line Isolation

by
Shobha B. Rao
Wee Tee Loh
Thomas J. Mikschl
John W. Stetkar

Prepared for
HOUSTON LIGHTING AND POWER COMPANY
Houston, Texas
January 29, 1986

Pickard, Lowe and Garrick, Inc.
Engineers • Applied Scientists • Management Consultants
Newport Beach, CA Washington, DC

INTRODUCTION

The results from the South Texas Project Preliminary Scoping Study completed in May 1985 identified several important sources of uncertainty in the plant response models. These uncertainties contributed substantially to the quantitative results from the Preliminary Scoping Study and made detailed identification of individually important event sequences quite difficult. One of the principal sources of uncertainty identified in the Preliminary Scoping Study was lack of information about the heatup and response of electrical and electronic components in the electrical auxiliary building (EAB) following failures of EAB cooling and ventilation systems. The second major source of uncertainty related to the timing and characteristics of possible reactor coolant pump seal failures after loss of all seal cooling.

Extensive analysis work has been completed since the Preliminary Scoping Study to provide more detailed information about plant and equipment response during scenarios of degraded HVAC system operation and after loss of normal cooling for the reactor coolant pump seals. The HVAC analyses have addressed all aspects of the problems identified in the Preliminary Scoping Study. Realistic heat loads have been used to calculate temperature profiles for several rooms and floor areas in the EAB for a wide range of HVAC equipment operating configurations. These configurations include normal closed loop HVAC operation, with EAB heat being removed through the essential chilled water system, and open loop smoke purge operation, with heat being exhausted to the outside air. Detailed models have been developed for EAB room air flow distributions and chiller performance. Historical profiles for the frequency of exceeding various peak daytime temperatures and the average diurnal variation in temperature for the South Texas plant site have also been used in these calculations. Manufacturers' information about component temperature ratings has been used as input for the development of fragility distributions for equipment failures as a function of surrounding room temperature. The Preliminary Scoping Study plant response models have been revised to explicitly identify all possible combinations of operating HVAC equipment and chillers, possible electrical and electronic component failures that could occur in each degraded HVAC scenario, and the functional effects on plant response if these failures were to occur. The models also account for operator actions to initiate smoke purge operation and, if necessary, to provide enhanced air circulation for specific rooms and cabinets according to procedures being developed for the more severe HVAC failure scenarios.

The revised plant response models account for operation of the positive displacement charging pump to provide an alternate source of reactor coolant pump seal injection flow. This pump was not included in the Preliminary Scoping Study models. The pump can be powered from the technical support center diesel generator, and it does not require external cooling from the component cooling water system or the essential cooling water system. Planned modifications to valves in the normal reactor coolant system letdown line have also been incorporated into the revised model. These modifications will allow the letdown line to be isolated inside the containment after loss of all onsite AC power.

This report summarizes the results from requantification of the Preliminary Scoping Study models after incorporation of the changes noted above. Many details of the South Texas plant model structure and development remain the same as reported in the Preliminary Scoping Study. Important differences in the models and remaining assumptions are noted. The results are presented in a point estimate form for the two most important remaining assumption sets, with the most important contributing event sequences described for each. The uncertainty analysis results combine these two assumption sets with the results from the Preliminary Scoping Study review of external events to produce a probability distribution for the revised frequency of core damage.

Although this effort represents a substantial refinement of the South Texas plant models in the areas described, it should not be considered as an overall extension of the Preliminary Scoping Study to the level of detail of a full-scope, level 1 PRA. This work is continuing according to a broader program plan for implementation of the phased PRA approach described in the Preliminary Scoping Study.

IMPORTANT ASSUMPTIONS ABOUT SYSTEM AND EQUIPMENT RESPONSE

Several fundamental assumptions have been made regarding performance of the EAB HVAC system, the turbine-driven auxiliary feedwater pump, and the positive displacement charging pump. These assumptions provide the basic framework for evaluation of operator recovery actions after equipment failures occur. The assumptions are based on written and verbal information from engineers at HL&P and Bechtel Power Corporation who have been closely involved with supporting analyses for the Preliminary Scoping Study model revisions.

a. If at least 600 tons of chiller capacity are available, two trains of EAB HVAC supply and return fans, operating in the closed loop mode, can adequately remove the EAB heat load during normal plant power operation and during stable hot shutdown with the auxiliary feedwater system running.

b. A single 150-ton chiller will trip from excessive load if the 300-ton chiller in its train has failed. Failure of a 300-ton chiller results in loss of all chilled water heat removal capacity from the affected train.

c. If the EAB is cooled by only one 300-ton chiller, the chiller will have to be operating in the smoke purge mode. The chiller is expected to fail if the HVAC system remains in the closed loop mode.

d. If all essential chiller trains have failed and EAB smoke purge operation cannot be initiated, EAB temperatures will rise above 160°F. These conditions are modeled as causing failure of all AC power, DC power, and instrumentation power.

e. Air from the battery charger and inverter rooms will mix completely with air from the surrounding areas if the inverter room doors are opened, fans are placed in the doorways, and "elephant trunks" are used to distribute air to and from cooler floor areas. The inverter room temperatures will remain the same as temperatures in the surrounding areas if these actions are completed in a timely manner.

f. The turbine-driven auxiliary feedwater pump, if started successfully, does not require DC power to keep operating.

g. The positive displacement charging pump powered from the technical support center diesel generator has no support system dependencies for motor cooling, pump oil cooling, or room cooling.

h. The positive displacement charging pump has a capacity of approximately 35 gpm, not sufficient for bleed-and-feed cooling.

i. Valves LCV0465, LCV0468, MOV0023, and MOV0024 in the normal reactor coolant system letdown line are AC motor-operated valves. Based on current information from HL&P, it has been assumed that the operators for letdown orifice block valves MOV0012 and MOV0013 will be modified to allow these valves to close after loss of all onsite AC power.

j. If the reactor coolant system letdown line remains unisolated (i.e., valves LCV0465, LCV0468, MOV0012 and/or MOV0013, MOV0023, and MOV0024 remain open), the positive displacement charging pump alone cannot provide sufficient flow to maintain reactor coolant inventory. Engineers at HL&P have completed preliminary calculations showing that more than 3 hours are required to drain the steam generator tubes under these conditions. This provides the minimum time for operator actions to locally close letdown line containment isolation valve MOV0024.

k. The positive displacement charging pump cannot provide sufficient flow to maintain RCP seal cooling and to make up for inventory lost through the letdown line 600-psig relief valve. If only the positive displacement pump is available and the letdown line remains open upstream from the relief valve, the HL&P preliminary calculations indicate that at least 3 hours will be available before the steam generator tubes are drained. This provides the minimum time to restore capability to close the upstream valves or to restore increased injection capacity from the centrifugal charging or high head safety injection pumps.

EAB HVAC ASSUMPTION SETS FROM PRELIMINARY SCOPING STUDY

The Preliminary Scoping Study identified seven different assumption sets about the effects from EAB HVAC failures. The revised models for this study incorporate all facets of the previous assumption sets directly into the event trees, rather than treating them externally as was done in the Preliminary Scoping Study. Room heatup calculations are based on a realistic assessment of EAB heat loads, the configuration and equipment operating in the HVAC system, and historically based profiles for peak daytime temperature and diurnal temperature variations at the South Texas site. Explicitly modeled operator actions include shifting the HVAC system from normal closed loop operation to open loop smoke purge operation, providing additional air circulation to specific rooms and cabinets by opening doors, using portable fans, and transferring electrical instrumentation loads. These actions have been reviewed with South Texas plant operations and engineering personnel. The models also include distributions for thermal fragilities of selected electrical and electronic components that are based on equipment temperature ratings supplied by the manufacturers. The event tree models are used to quantify the conditional frequencies of various possible degraded EAB HVAC system operating configurations, the corresponding conditional frequencies of electrical and electronic equipment failures, and the effects on plant response if these failures occur.

REACTOR COOLANT PUMP SEAL FAILURE ASSUMPTION SETS FROM PRELIMINARY SCOPING STUDY

The Preliminary Scoping Study identified two assumption sets about the timing of reactor coolant pump seal failure after loss of all seal cooling. These assumption sets are retained for this study and are treated externally as before.

Assumption Set	Probability
S1 - RCP Seal LOCA Occurs in 2 Hours	0.22
S2 - RCP Seal LOCA Occurs in 16 Hours	0.78

The models for assumption set S2 include additional (unspecified) recovery actions to provide alternate sources for RCP seal cooling after failure of component cooling water heat removal and failure of injection from the positive displacement charging pump. These recovery actions could include cooling from demineralized water, fire protection water, or other sources not explicitly modeled in this study.

RESULTS

The results from the requantified Preliminary Scoping Study models are summarized in the attached figures and tables.

Figure 1 shows the probability distribution for total core damage frequency including the results from all uncertainty analyses. Figure 2 illustrates the contributions to this total from "internal" plant event sequences and from "external" events, such as fires, floods, earthquakes, etc. The internal event scenarios are based on the revised plant response models discussed in this report. The analysis of external events remains unchanged from the Preliminary Scoping Study. The results in Figures 1 and 2 illustrate a substantial reduction of the uncertainties from the Preliminary Scoping Study. This reduction is directly related to the improved models for EAB HVAC failure scenarios and modeling of the positive displacement charging pump.

- The revised models for EAB HVAC equipment operating modes, better detailed room heatup analyses, and the improved information about component thermal fragilities have substantially reduced the uncertainties about HVAC system success criteria and electrical equipment response after total or partial HVAC failures.

- Incorporation of the positive displacement charging pump has made the results less sensitive to uncertainties about the timing and progression of reactor coolant pump seal failure scenarios.

Figure 3 shows the contributions from reactor coolant pump seal failure assumption sets S1 (seal LOCA in 2 hours) and S2 (seal LOCA in 16 hours). Although these assumption sets represent rather broad uncertainties about the effects from loss of all seal cooling, Figure 3 shows that differences in these assumptions do not cause large differences in the overall results. Table 1 presents the uncertainty analysis results in tabular form and lists important parameters of each distribution. The results from the Preliminary Scoping Study report are also shown for reference.

Tables 2 and 3 summarize the point estimate results and describe the most important sequences contributing to these results. Table 2 applies to seal LOCA assumption set S1, and Table 3 applies to seal LOCA assumption set S2. Each table lists individual event sequences with frequencies greater than 1.6×10^{-6} core damage event per year. No individual sequence in the "others" category has a frequency greater than 1.6×10^{-6} event per year. The principal difference between the results from Table 2 and those from Table 3 is the inclusion of additional recovery actions to provide alternate RCP seal cooling during the extended times in assumption set S2.

TABLE 1. SOUTH TEXAS PROJECT PERLIMINARY SCOPING STUDY REQUANTIFICATION UNCERTAINTY ANALYSIS RESULTS

Contributor	Core Damage Frequency, Event per Reactor Year			
	5th Percentile	Median	95th Percentile	Mean
All internal events (assumption sets S1 + S2)	1.4×10^{-5}	7.1×10^{-5}	5.7×10^{-4}	1.6×10^{-4}
• Assumption Set S1 (P=0.22)	1.7×10^{-5}	8.7×10^{-5}	7.4×10^{-4}	2.4×10^{-4}
• Assumption Set S2 (P=0.78)	1.3×10^{-5}	6.4×10^{-5}	5.0×10^{-4}	1.4×10^{-4}
External Events	4.2×10^{-8}	1.5×10^{-6}	1.1×10^{-4}	8.5×10^{-5}
Total Internal + External	1.7×10^{-5}	8.5×10^{-5}	7.1×10^{-4}	2.5×10^{-4}
Reference Total From May 1985 Study Report	3.0×10^{-5}	3.0×10^{-4}	5.0×10^{-3}	1.4×10^{-3}

ATTACHMENT
ST-HL-AE-1606
PAGE 7 OF 17

TABLE 2. SEQUENCES CONTRIBUTING TO ASSUMPTION SET S1
ASSUMPTION SET PROBABILITY: 0.22

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
1	Loss of All Three ECW Trains	Operators start EAB smoke purge, open inverter room doors, and start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal.	6.0×10^{-5}
2	General Transient	Failure of running and standby CCW trains. Operators start "off" trains of CCW and ECW. The third CCW train fails. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal.	1.5×10^{-5}
3	Small LOCA	ECCS switchover to core recirculation cooling attempted but sump recirculation valves fail. All other systems available.	Core recirculation cooling.	1.4×10^{-5}
4	General Transient	Failure of all four AFW trains. Operators reset AFW turbine and manually open motor-operated stop check valve in turbine-driven pump train. Turbine-driven AFW pump fails to restart. Operators fail to initiate bleed and feed cooling. All other systems available.	None.	1.1×10^{-5}
5	Loss of All Three CCW Trains	Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal.	9.2×10^{-6}

ATTACHMENT
ST-HL-AE-1606
PAGE 8 OF 17

TABLE 2 (continued)

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
6	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators and failure of turbine-driven AFW pump. Operators start PD charging pump to maintain RCP seal cooling. Operators reset AFW turbine, but turbine fails to restart. Operators fail to recover offsite power.	None.	5.3×10^{-6}
7	General Transient	Failure of running and standby ECW trains. Operators start "off" trains of ECW and CCW. The third ECW train fails. Operators start EAB smoke purge, open inverter room doors, and start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal	5.3×10^{-6}
8	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. Operators fail to recover offsite power. Turbine-driven AFW pump remains available.	RCP seal LOCA, ECCS injection, and containment heat removal.	3.9×10^{-6}
9	General Transient	Failure of both normally running trains of EAB ventilation fans. Operators start standby train, open EAB room doors, and transfer loads. Third train of ventilation fans fails. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. Turbine-driven AFW pump remains available.	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, and containment heat removal.	3.6×10^{-6}

ATTACHMENT
ST-HL-AE-1606
PAGE 9 OF 17

TABLE 2 (continued)

Sheet 3 of 4

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
10	Small LOCA	Successful injection and switchover to high pressure recirculation. Failure of all three trains of containment fan coolers.	Core recirculation cooling.	3.5×10^{-6}
11	General Transient	Failure of running CCW train. Standby ECW train fails to start. Operators start "off" trains of ECW and CCW. The third ECW train fails. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal.	2.6×10^{-6}
12	General Transient	Operators fail to maintain stable long-term heat removal and inventory control. All other systems available.	None.	2.4×10^{-6}
13	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators. Operators start PD charging pump to maintain RCP seal cooling. PD charging pump and turbine-driven AFW pump remain available. Pressurizer PORV opens and fails to reclose after RCS pressure relief. Operators fail to recover offsite power.	Small LOCA through stuck-open PORV, ECCS injection, and containment heat removal.	2.1×10^{-6}
14	General Transient	Failure of both normally running trains of EAB ventilation fans. Operators start standby train, open EAB room doors, and transfer loads. Third train of ventilation fans fails. Operators start PD charging pump to maintain RCP seal cooling. PD charging pump and turbine-driven AFW pump remain available. Pressurizer PORV opens and fails to reclose after RCS pressure relief.	EAB ventilation, AC power, small LOCA through stuck-open PORV, ECCS injection, and containment heat removal.	1.9×10^{-6}

TABLE 2 (continued)

Sheet 4 of 4

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
15	Small LOCA	Failure of all three trains of high head safety injection pumps.	None.	$1.9x10^{-6}$
16	Small LOCA	Failure of standby and "off" trains of ECW and failure of containment fan cooler train supplied from available ECW train. Successful injection and switchover to high pressure recirculation.	Core recirculation cooling.	$1.8x10^{-6}$
All other sequences with individual frequencies less than $1.6x10^{-6}$ event per reactor year				$9.6x10^{-5}$
Total				$2.4x10^{-4}$

ATTACHMENT
ST-HL-AE-1606
PAGE 11 OF 17

0131H013186

TABLE 3. SEQUENCES CONTRIBUTING TO ASSUMPTION SET S2
ASSUMPTION SET PROBABILITY: 0.78

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
1	Small LOCA	ECCS switchover to core recirculation cooling attempted but sump recirculation valves fail. All other systems available.	Core recirculation cooling.	1.4×10^{-5}
2	General Transient	Failure of all four AFW trains. Operators reset AFW turbine and manually open motor-operated stop check valve in turbine-driven pump train. Turbine-driven AFW pump fails to restart. Operators fail to initiate bleed and feed cooling. All other systems available.	None.	1.1×10^{-5}
3	Loss of All Three ECW Trains	Operators start EAB smoke purge, open inverter room doors, and start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling, and containment heat removal.	6.0×10^{-6}
4	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators and failure of turbine-driven AFW pump. Operators start PD charging pump to maintain RCP seal cooling. Operators reset AFW turbine, but turbine fails to restart. Operators fail to recover offsite power.	None.	5.3×10^{-6}
5	General Transient	Failure of both normally running trains of EAB ventilation fans. Operators start standby train, open EAB room doors, and transfer loads. Third train of ventilation fans fails. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. Turbine-driven AFW pump remains available.	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, and containment heat removal.	3.6×10^{-6}

ATTACHMENT
ST-HL-AE-1606
PAGE 12 OF 17

TABLE 3 (continued)

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
6	Small LOCA	Successful injection and switchover to high pressure recirculation. Failure of all three trains of containment fan coolers.	Core recirculation cooling.	3.5×10^{-6}
7	General Transient	Operators fail to maintain stable long-term heat removal and inventory control. All other systems available.	None.	2.4×10^{-6}
8	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators. Operators start PD charging pump to maintain RCP seal cooling. TSC diesel generator fails. Operators fail to recover offsite power before batteries depleted. Turbine-driven AFW pump remains available.	RCP seal LOCA, ECCS injection, and containment heat removal.	2.3×10^{-6}
9	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators. Operators start PD charging pump to maintain RCP seal cooling. PD charging pump and turbine-driven AFW pump remain available. Pressurizer PORV opens and fails to reclose after RCS pressure relief. Operators fail to recover offsite power.	Small LOCA through stuck-open PORV, ECCS injection, and containment heat removal.	2.1×10^{-6}
10	General Transient	Failure of both normally running trains of EAB ventilation fans. Operators start standby train, open EAB room doors, and transfer loads. Third train of ventilation fans fails. Operators start PD charging pump to maintain RCP seal cooling. PD charging pump and turbine-driven AFW pump remain available. Pressurizer PORV opens and fails to reclose after RCS pressure relief.	EAB ventilation, AC power, small LOCA through stuck-open PORV, ECCS injection, and containment heat removal.	1.9×10^{-6}

TABLE 3 (continued)

Frequency Rank	Initiating Event	Plant Failures or Operator Actions Contributing to Sequence Frequency and Damage State	Functionally Dependent Failures Resulting from Preceding Events	Point Estimate Frequency (event per reactor year)
11	Small LOCA	Failure of all three trains of high head safety injection pumps.	None.	1.9×10^{-6}
12	Small LOCA	Failure of standby and "off" trains of ECW and failure of containment fan cooler train supplied from available ECW train. Successful injection and switchover to high pressure recirculation.	Core recirculation cooling.	1.8×10^{-6}
All other sequences with individual frequencies less than 1.6×10^{-6} event per reactor year.				8.7×10^{-5}
Total				1.4×10^{-4}

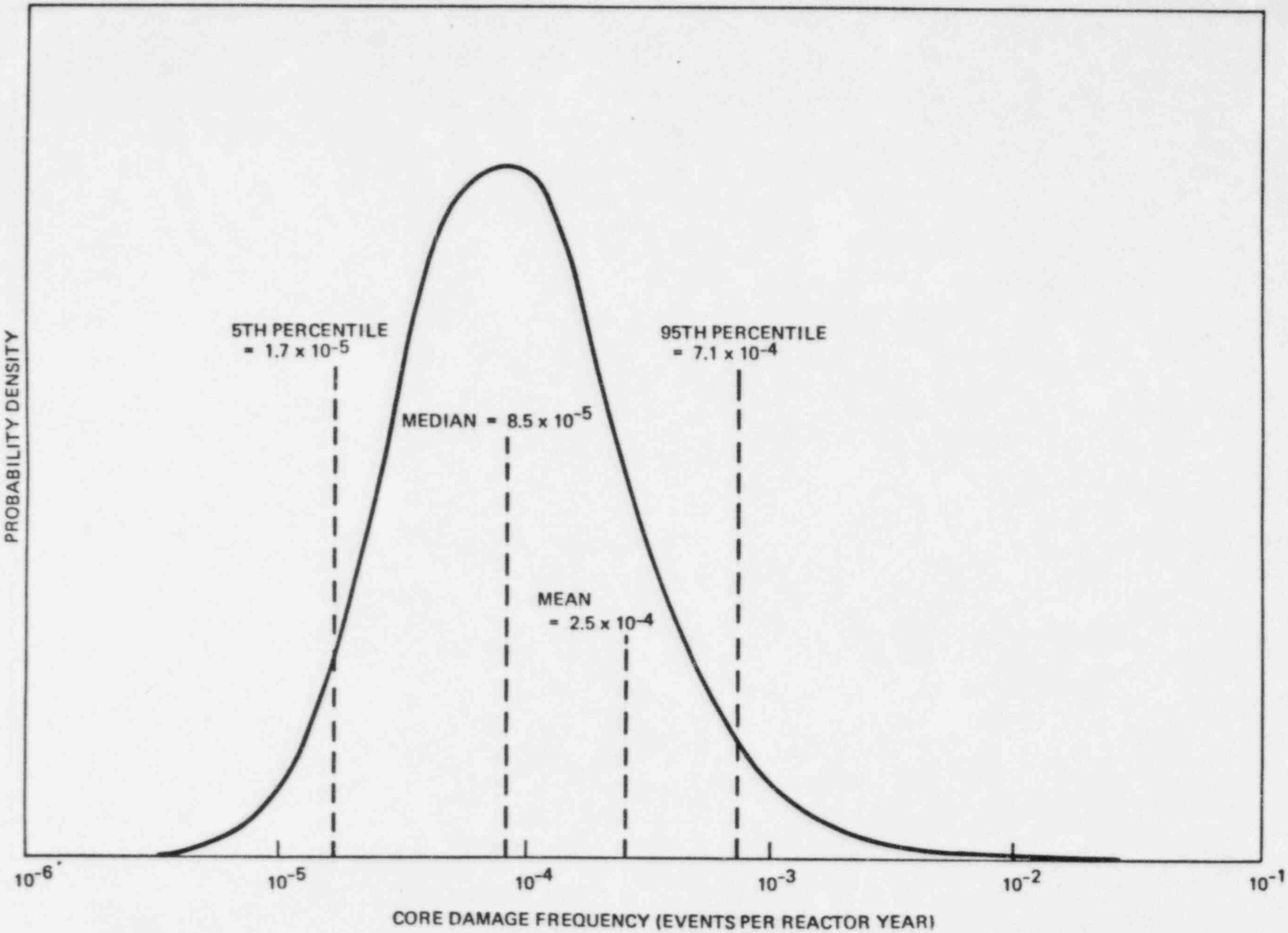

FIGURE 1. PROBABILITY DISTRIBUTION FOR TOTAL CORE DAMAGE FREQUENCY

ATTACHMENT
ST-HL-AE-1606
PAGE 15 OF 17

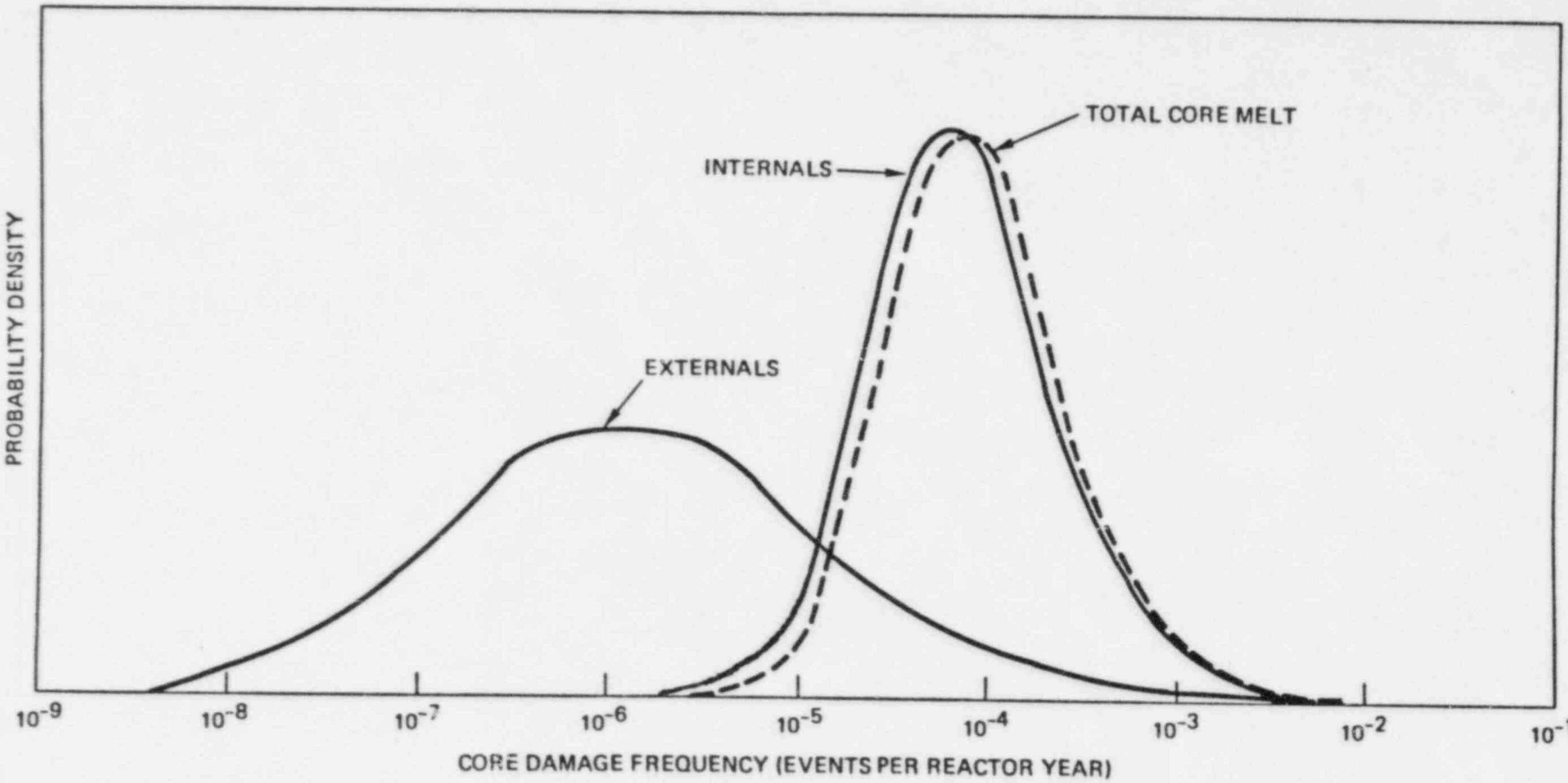

FIGURE 2. PROBABILITY DISTRIBUTIONS FOR INTERNAL AND EXTERNAL EVENTS

ATTACHMENT
ST-HL-AE-1606
PAGE 16 OF 17

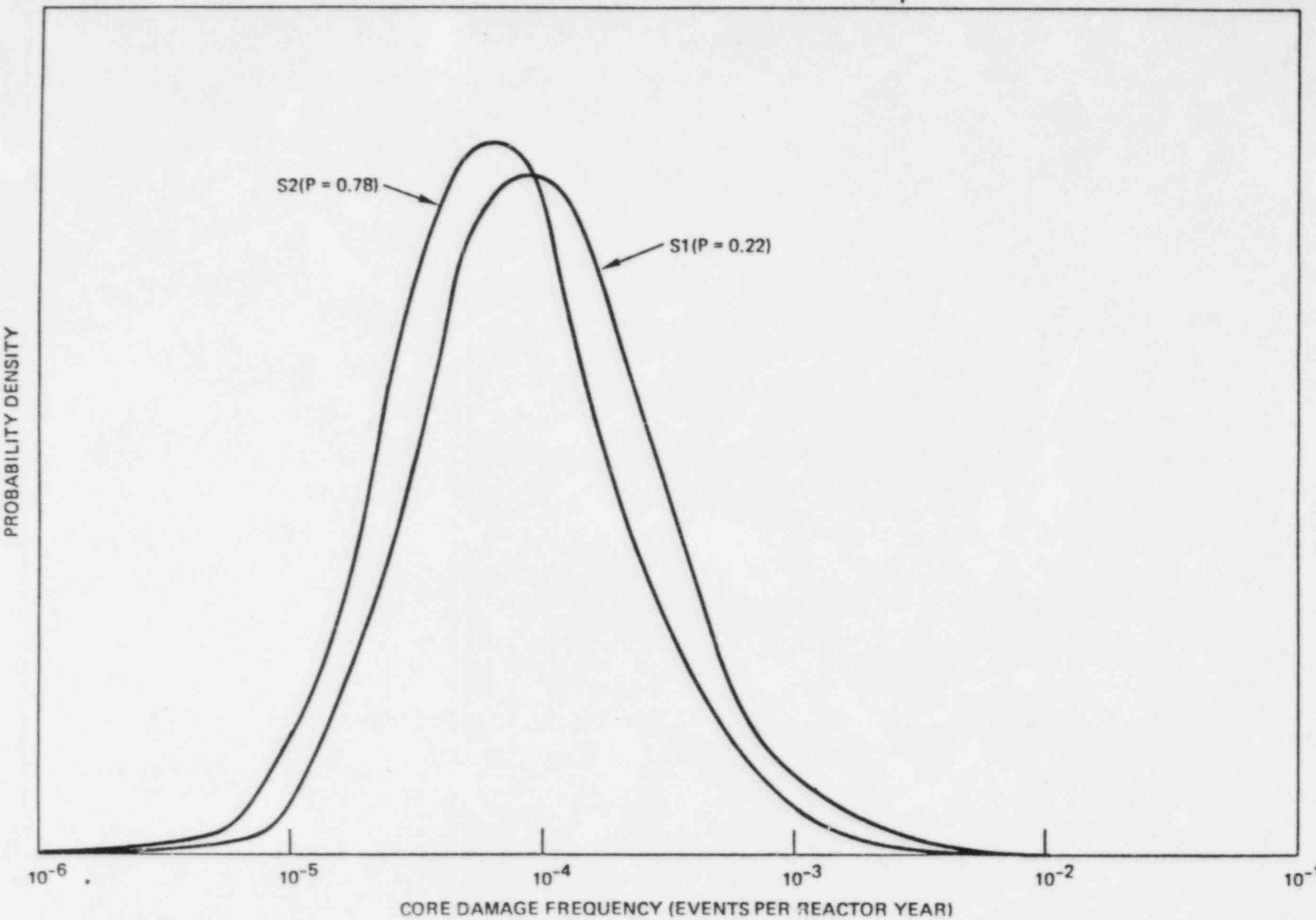

FIGURE 3. PROBABILITY DISTRIBUTIONS FOR INTERNAL EVENTS ASSUMPTION SETS S1 AND S2