

LIMERICK GENERATING STATION UNITS 1 & 2

DESIGN ASSESSMENT REPORT

REVISION 7 PAGE CHANGES

The attached pages and tables are considered part of a controlled copy of the Limerick Generating Station DAR. This material should be incorporated into the DAR by following the instructions below.

After the revised pages have been inserted, place the page that follows these instructions in the front of Volume 1.

REMOVE

INSERT

VOLUME 2

Pages I-i thru -iv
Pages I.1-1 thru -4
Figure I.1-1
Pages I.2-3 & -4
Pages I.2-11 & -12
Figures I.2-1 thru -6

Pages I-i thru -iv
Pages I.1-1 thru -12
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Pages I.2-3 & -4
Pages I.2-11 & -12
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THIS DAR SET HAS BEEN UPDATED TO
INCLUDE REVISIONS THROUGH 7
DATED 01/84.

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APPENDIX I

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I.1 SUPPRESSION POOL TEMPERATURE MONITORING SYSTEM (SPTMS) |

I.1.1 SUPPRESSION POOL TEMPERATURE MONITORING SYSTEM DESIGN CRITERIA

The suppression pool temperature monitoring system (SPTMS) monitors the suppression pool temperature during normal plant operations and after transients or accidents. Operator monitoring of pool temperature is required to ensure that the suppression pool is operated within the allowable temperature limits set forth in the Limerick technical specifications. Operation of the pool within these technical specifications will provide assurance that the suppression pool temperature will be maintained within the limits specified in NUREG-0783. Section I.1.1.4 describes the Limerick technical specification temperature alarm setpoints for pool operation.

The SPTMS is designed in conformance with the acceptance criteria specified in NUREG-0487 (Ref. I.2-2) and NUREG-0783 (Ref. I.2-4).

I.1.1.1 SENSOR LOCATIONS

The suppression pool temperature is redundantly monitored by two divisionalized systems. Eight dual element RTDs are provided for each system and are evenly distributed around the pool to provide a reasonable measure of the bulk water temperature. The eight monitoring locations and individual RTD identifications are shown in Figure I.1-1.

The sensors are located at a depth of two feet below the minimum pool water level. This depth ensures a conservative measurement of bulk temperature because the hottest water will rise to the pool surface. This depth also provides adequate sensor submergence to preclude the possibility of sensor uncover during an accident or transient.

I.1.1.2 SAFETY EVALUATION

The indication of suppression pool temperature in the control room is required to ensure that the plant is always operating within the technical specification limits. Manual operator action is required to maintain the plant within the specifications. Suppression pool temperature is also required for post accident monitoring. These functions are safety related.

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The system design conforms to all applicable criteria for physical separation, redundancy and divisionalization. Physical and electrical separation is provided for the safety related instrumentation. The safety related instrumentation is powered from divisionalized Class 1E power sources.

The suppression pool temperature sensors are qualified to seismic Category I and Class 1E criteria and are energized from onsite emergency power supplies.

The hardcopy timeplot of suppression pool temperature is for operating history only and is not safety related.

I.1.1.3 EQUIPMENT DESIGN

The signals from the redundant sensors are processed by two independent divisionalized microprocessors located on a main control room cabinet. The microprocessors convert the RTD signals into degrees Fahrenheit and compute the average of the eight temperatures. The average value is displayed by digital indicators provided on the microprocessors and on remote indicators located at the main control board. Keyboards located on the microprocessor and on the remote indicator allow the operator to display any individual temperature input.

The SPTMS trouble alarm located in the main control room is generated if the calculated average temperature exceeds any of the four distinct high temperature setpoints that are permanently stored in the microprocessors. (Section I.1.1.4 provides details on the temperature alarm setpoints.) Also, appropriate high temperature status lights are initiated on the associated microprocessor and remote indicator. Electrically isolated outputs interface with the SPTMS trouble alarm located in the main control room.

The SPTMS trouble alarm is also initiated if one of the RTDs fails or if non-1E power to the cabinet cooling fans is lost. Keyboards allow the operator to remove a failed RTD from the calculated average.

Both elements of each dual element RTD are wired out through containment penetrations. One element of each RTD is connected

to a microprocessor loop. This design provides the capability to easily connect the backup RTD elements in case of a failure.

A digital printer located on the microprocessor periodically prints the average temperature, the individual temperature, and the current date and time. Trending information may also be printed at the operator's request. Alarm conditions are printed along with the temperature.

Electrically isolated digital and analog signals are provided to interface with other plant information systems including a signal to the emergency response facility data system (ERFDS) computer. The microprocessor has a self checking diagnostic system that provides an error alarm if a failure is detected in any part of the system.

I.1.1.4 ALARM SETPOINTS

The SPTMS provides alarm at four pool temperature setpoints (95, 105, 110, and 120°F) to provide assurance that the suppression pool will be maintained within the temperature limits defined in NUREG-0783. Appendix I.2 describes these pool temperature limits and provides Limerick's analysis for suppression pool temperature response to SRV discharge. This analysis demonstrates the adequacy of these alarm setpoints with regard to alerting the operator to maintain the pool temperature below the NUREG-0783 limit. The alarm setpoints are based on Ref. I.1-1 and are defined as follows:

- a. 95°F: maximum allowable pool temperature for continuous power operation without suppression pool cooling
- b. 105°F: maximum allowable pool temperature during testing at power which adds heat to the pool.
- c. 110°F: manual reactor scram setpoint
- d. 120°F: manual reactor depressurization setpoint.

I.1.2 SPTMS ADEQUACY ASSESSMENT

As mentioned in Section I.1.1, the selection of the SPTMS sensor locations conforms with the acceptance criteria specified in NUREG-0487 (Ref. I.2-2) and NUREG-0783 (Ref. I.2-4). Section I.1.2 provides data for confirming the adequacy of the SPTMS sensor locations, shown on Figure I.1-1, in predicting the bulk pool temperature.

In lieu of conducting Limerick-unique confirmatory in-plant tests of safety relief valve discharges, analyses were performed using the KFIXTM computer code. KFIXTM is a three-dimensional thermal-hydraulic computer code which was developed to provide an analytical tool for predicting the thermal mixing and temperature response in the Limerick pressure suppression pool resulting from SRV actuation. The calculated results from the KFIXTM code have been verified against LaSalle and Caorso SRV extended blowdown in-plant test data. The KFIXTM code verification and methodology have been provided to the NRC (Ref. I.1-2).

Section I.1.2.1 describes the scenarios that were analyzed for assessment of the Limerick SPTMS. These scenarios are also used in Section I.3 to assess the adequacy of the suppression pool local-to-bulk temperature difference (ΔT). Sections I.1.2.1.1 and I.1.2.1.2 describe the initial/operating conditions and KFIXTM modeling, respectively. The calculated temperature time histories for the individual SPTMS sensors are discussed in Section I.1.2.2. The arithmetic average values among these sensors are presented in Section I.1.2.3. Conclusions of the SPTMS adequacy assessment are provided in Section I.1.2.4.

I.1.2.1 STUCK-OPEN RELIEF VALVE (SORV) SCENARIOS

The KFIXTM code is employed for the simulation of three stuck-open relief valve (SORV) scenarios to predict the Limerick suppression pool thermal mixing and temperature response.

To parallel the scenarios chosen in the LaSalle in-plant tests, two single SORV blowdown scenarios under conditions of high reactor pressure and relatively low pool temperature were selected. This analysis quantifies the thermal mixing effectiveness in the pool due to the large momentum associated with the heated fluid jet induced by high reactor pressure steam discharges through the quencher.

The third scenario considers a single SORV blowdown scenario under conditions of low reactor pressure and high pool temperature. This analysis quantifies the thermal mixing effectiveness in the pool even under conditions of reduced fluid jet momentum associated with steam discharges under low reactor pressure.

The Limerick SRV set pressures are provided in Table 1.4-1. The associated quencher orientations are shown in Figure 1.4-3. Among the 14 SRVs, the two with designations of L and H, which are located along the outer and inner quencher circles, respectively, were selected for the high reactor pressure analyses because these valves have the lowest set pressure values among those on the corresponding quencher circles. SRV-H was chosen for the low reactor pressure analysis. Quenchers H and L have off-radial orientations of 30 and 10 degrees in the counter-clockwise direction, respectively. Discharge associated with the end gap of Quencher H is towards the containment wall, while discharge associated with the end cap of Quencher L is towards the pedestal. Figures I.1-2 and I.1-5 show these quencher configurations in the KFIXTM models.

In the KFIXTM code, the Limerick pressure suppression pool is subdivided into a large number of computational cells which is on the order of 5500. Among these computational cells, the containment walls, major submerged structures, and boundaries are treated as obstruction (or fictitious) cells while the remainder are called fluid cells. The governing conservation equations are solved with respect to the fluid cells. Fluid cells which contain the quencher discharge arms are called special cells. Additional source terms are included in the conservation equations in these special cells to account for the steam blowdown process. The source terms are derived from various operating conditions, i.e., the reactor pressure, the SRV steam flow rate, the geometrical data of the quencher, and the quencher orientation. Geometrical data of the Mark II T-quencher is provided in Section 4.1.

I.1.2.1.1 Initial and Operating Conditions

The initial and operating conditions pertinent to the high and low reactor pressure SORV scenarios are tabulated below:

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Parameter	High Reactor Pressure Analysis	Low Reactor Pressure Analysis
Reactor vessel pressure	1025 psia	90 psia
SRV steam flow rate	239.6 lbm/sec	21 lbm/sec
Suppression pool initial water depth	22 ft	23 ft
Initial pool temperature	95°F	199°F
Duration of blowdown	10 minutes or longer	20 minutes or longer

The 1025 psia reactor pressure corresponds to the nominal pressure in the RPV steam dome at 105% of nuclear boiler rated steam flow. The 90 psia reactor pressure corresponds to the lowest pressure just prior to clearing the shutdown cooling pressure interlock. The SRV flow rates correspond to the nominal flow rates adjusted to the specified reactor pressures.

The high pressure analysis initial pool water depth (22 feet) corresponds to the low pool level (Figure 1.4-2). The initial pool temperature (95°F) corresponds to the maximum operating temperature without suppression pool cooling.

The low pressure analysis initial pool water depth (23 feet) corresponds to the normal pool level. The normal water level was chosen in lieu of the low level to account for the additional water condensed from the incoming SRV steam during reactor depressurization to 90 psia.

The low pressure analysis initial pool temperature corresponds to the highest temperature at a reactor pressure of 90 psia. From Limerick's analysis of suppression pool temperature response to SRV discharge presented in Section I.2, a pool temperature of 199°F exists at 90 psia and 10^4 seconds into the transient (Figure I.2-5, Case 3.a).

The blowdown durations selected for the high and low pressure SORV scenarios allow the pool temperature to reach a quasi-steady rate of increase.

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In addition to the above initial and operating conditions, several conservative assumptions are made in the high and low reactor pressure analyses. For example, the water in the pedestal is neglected, no RHR operation is considered, the initial pool motion is assumed to be stagnant, and containment wall boundaries are treated adiabatically.

I.1.2.1.2 Geometrical Modeling

The plan and section views of the mesh systems used in the KFIXTM model to simulate the SRV-H and SRV-L blowdown scenarios are shown in Figures I.1-2 through I.1-6. The mesh compositions associated with each scenario are summarized as follows:

Parameter	SRV-H Blowdown (High Reactor Pressure)	SRV-L Blowdown (High Reactor Pressure)	SRV-H Blowdown (Low Reactor Pressure)
Total Cell Number	11x12x39=5148	12x12x40=5760	11x12x39=5148
Grid size variation along radial direction (ΔR)	2 to 4.076 ft	2 to 3.5 ft	2 to 4.076 ft
Grid size variation along circumferential direction ($\Delta \theta$)	7 to 11.5°	5.5 to 11.5°	7 to 11.5°
Grid size variation along vertical direction (ΔZ)	2.333 to 2.695 ft	2.333 to 2.695 ft	2.333 to 2.841 ft

The following KFIXTM geometrical modeling aspects apply to the mesh system summarized above and shown in Figures I.1-2 through I.1-6:

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- Variable grid sizes are used in the mesh systems. Note that finer mesh sizes in the vicinity of the quencher allow KFIXTM to more accurately predict the pool response in the local region.
- Because the pool normal water level (23 ft) was used in analyzing the SRV-H scenario under the low reactor pressure condition in comparison with the minimum level (22 ft) associated with the high pressure case, the grid sizes along the vertical direction for the low pressure case have to be slightly expanded to account for the additional one foot of water.
- The free surface at the top of the suppression pool is calculated by tracing the surface waves kinematically.
- Because the SPTMS sensors are not located at cell centers, the calculated SPTMS temperatures are interpolated or extrapolated from the temperature values defined at the neighboring cell centers in the code calculations.
- The suppression chamber columns are modeled as stacks of obstruction cells which conservatively approximate the circular cross section of the actual columns.
- The two T-quencher arms are modeled by means of two special cells separated by an obstruction cell representing the quencher hub/assembly.
- The size of the special cells (i.e., fluid cells which contain the quencher discharge arms) are chosen to be comparable with those used in the LaSalle simulation runs for verifying the KFIXTM code (Reference I.1-2).
- A greater number of fluid cells are needed to model the SRV-L blowdown scenario than that needed for the SRV-H blowdown scenario. This is due to the fact that a better resolution with respect to the outer quencher (e.g., Quencher L) generally requires more cells in the cylindrical coordinates (compare Figures I.1-2 and I.1-5).

- The obstruction effects of the downcomers are neglected to simplify the geometrical modeling. The downcomers have negligible obstruction effects on SPTMS sensor predictions because of their relative distance from the sensor locations.

I.1.2.2 INDIVIDUAL SPTMS SENSOR PREDICTIONS

The SPTMS sensor identifications and locations are shown in Figure I.1-1. The SPTMS sensor locations can be classified into two categories: 1) four dual element sensors mounted on columns with approximate azimuthal locations of 0, 90, 180, and 270 degrees, (i.e., TE 101/103-B, D, F & H); and 2) four dual element sensors mounted on the containment wall with approximate azimuthal locations of 45, 135, 225 and 315 degrees (i.e., TE 101/103-A, C, E & G).

The calculated sensor predictions for each SRV blowdown scenario are shown in Figures I.1-7 through I.1-12 and are discussed in the following sections. The four temperature traces associated with each SPTMS sensor category (as defined above) are shown on the same figure. Sensor temperature traces may vary among each other because of the relative distances between the active quenchers and the various sensor locations. Only Division TE 101 predictions are provided. Temperature traces of redundant Division TE 103 are not presented because they are nearly identical. Also shown on these figures is the analytical bulk pool temperature trace which provides a measure of how close the individual sensor predicts the bulk temperature. The bulk pool temperature is calculated by KFIXTM and is based on a mass-energy balance assuming that the pool is a uniform heat sink.

I.1.2.2.1 SRV-H Blowdown Under High Reactor Pressure

Figures I.1-7 and I.1-8 show the KFIXTM calculated temperature time histories of the SPTMS sensors mounted on the columns and the containment wall, respectively, resulting from the SRV-H blowdown under the high reactor pressure condition.

Time delays, or response times, exist before the SPTMS sensors start sensing the heat-up process in the suppression pool. These time delays result from the considerable vertical elevation difference between the sensors and the active quencher (i.e., 16.5 feet). However, within this short time delay period, the pool will experience only minor bulk heat-up. Figures I.1-7 and

I.1-8 show a bulk pool heat-up on the order of 3°F during a response time ranging from 1 to 1.5 minutes.

I.1.2.2.2 SRV-L Blowdown Under High Reactor Pressure

Figures I.1-9 and I.1-10 show the KFIXTM calculated temperature time histories of the SPTMS sensors mounted on the columns and the containment wall, respectively, resulting from the SRV-L blowdown under the high reactor pressure condition. The response times range from about 0.5 to 1 minute.

I.1.2.2.3 SRV-H Blowdown Under Low Reactor Pressure

Figures I.1-11 and I.1-12 show the KFIXTM calculated temperature traces of the SPTMS sensors mounted on the columns and the containment wall, respectively, resulting from the SRV-H blowdown under the low reactor pressure condition. The response times range from 1.5 to 3 minutes.

Note that Figures I.1-11 and I.1-12 show that the time scale (abscissa) is compressed in comparison to the high pressure cases to accommodate the longer transient (approximately 25 minutes). The temperature scale (ordinate) is stretched to suit the milder temperature variation resulting from a smaller SRV steam flow rate associated with the low reactor pressure condition. Note also that the elevated pool temperature reflects the assumption of RHR system inoperation (i.e., no pool cooling or shutdown cooling) during the SORV transient analysis.

I.1.2.3 AVERAGE SPTMS SENSOR PREDICTION

The arithmetic average values of the eight traces for the three blowdown cases are presented in Figures I.1-13, I.1-14 and I.1-15. Also shown on these figures are the corresponding analytical bulk pool temperatures (based on a pool mass-energy balance) and code predicted overall average temperatures. The KFIXTM predicted overall average temperature is defined as the average of the entire set of computational fluid cells in the Limerick pool model.

In principle, the predicted overall average temperature should adhere closely to the bulk pool temperature to warrant a global energy balance in the pressure suppression pool in the calculation. However, due to the accumulated errors in the numerical computation spanning a large number of

computational cycles (on the order of 10,000 for the present calculations), the overall average temperature may deviate slightly from the bulk pool temperature.

Figure I.1-13 provides the average SPTMS sensor prediction resulting from SRV-H blowdown under high reactor pressure. The response time is approximately 45 seconds. The SPTMS over-predicts the bulk pool temperature by approximately 1.7°F. The bulk pool temperature and overall average temperature traces are nearly identical, reflecting the adequacy of the overall energy conservation equations in the suppression pool model.

Figure I.1-14 provides the average SPTMS sensor prediction resulting from SRV-L blowdown under high reactor pressure. The response time is about 25 seconds. The SPTMS over-predicts the bulk pool temperature by approximately 2°F. The bulk pool temperature and the overall average temperature traces are nearly identical.

Figure I.1-15 provides the average SPTMS sensor prediction resulting from SRV-H blowdown at low reactor pressure. The response time is about 60 seconds. Both the SPTMS and overall average temperature predictions diverge from and under-predict (by about 1°F) the analytical bulk pool temperature. The apparent inaccuracy in the overall average and SPTMS temperature predictions are due to inherent interpolation errors associated with the large variations in subcooled water properties at elevated pool temperatures amplified by the large number of computational cycles in the code. Regardless of these apparent inaccuracies, the fact that the SPTMS adheres closely to the overall average temperature implies that the in-plant SPTMS sensor average reading will closely follow the actual suppression pool bulk temperature.

Note that the elevated pool temperature shown in Figure I.1-15 reflects the assumption of RHR system inoperation (i.e., no pool cooling or shutdown cooling) during the SORV transient analysis.

I.1.2.4 CONCLUSION

In light of the code results presented in the preceding sections, it can be concluded that the SPTMS sensor locations are adequate in predicting the bulk pool temperature. The temperature traces indicate that short response times exist for the heated fluid, induced by the quencher discharges at the low pool elevation, to rise near the top of the suppression pool where the SPTMS sensors

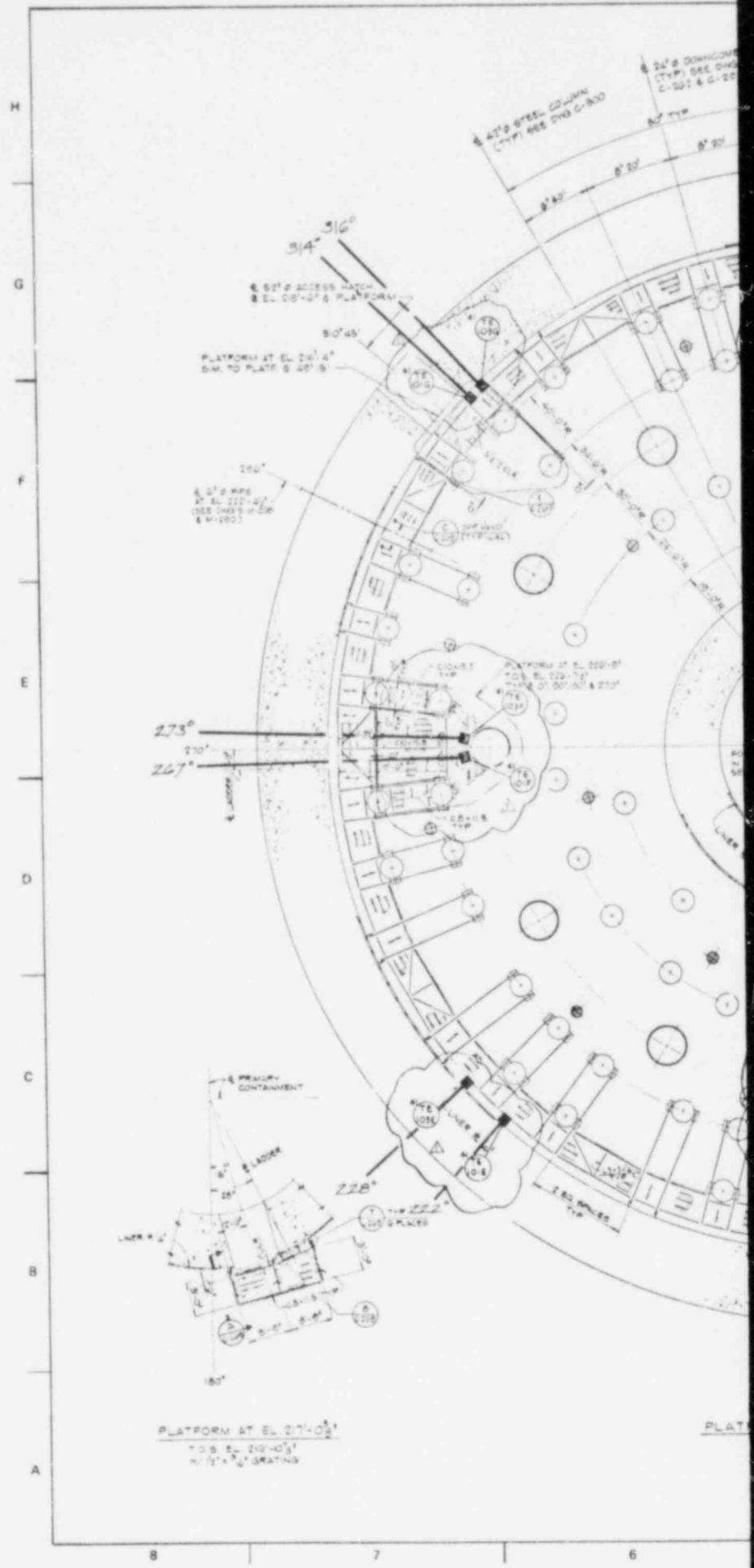
are located. The SPTMS sensor average conservatively over-predicts the pool bulk temperature by 1.7 to 2°F for the high reactor pressure blowdown scenario.

For the low pressure blowdown scenario, the calculated results for the SPTMS adequately predict the calculated overall average temperature. Because the calculated overall average temperature slightly deviates from the bulk temperature by about 1°F, it is concluded that the code calculated results for the SPTMS predict the bulk pool temperature with an accuracy of 1°F for the low reactor pressure/high pool temperature scenario.

The SPTMS will adequately monitor the suppression pool bulk temperature in accordance with the requirements of NUREG-0487 (Ref. I.2-2) and NUREG-0783 (Ref. I.2-4).

I.1.3 REFERENCES

- I.1-1 General Electric Service Information Letter (SIL) No. 106, October 25, 1974.
- I.1-2 Letter, N.W. Curtis, Pennsylvania Power & Light Company, to A. Schwencer, NRC, "Evaluation of NUREG-0783 Local Pool Temperature Limits for the Susquehanna Steam Electric Station," dated November 28, 1983.

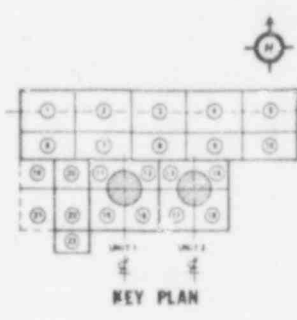
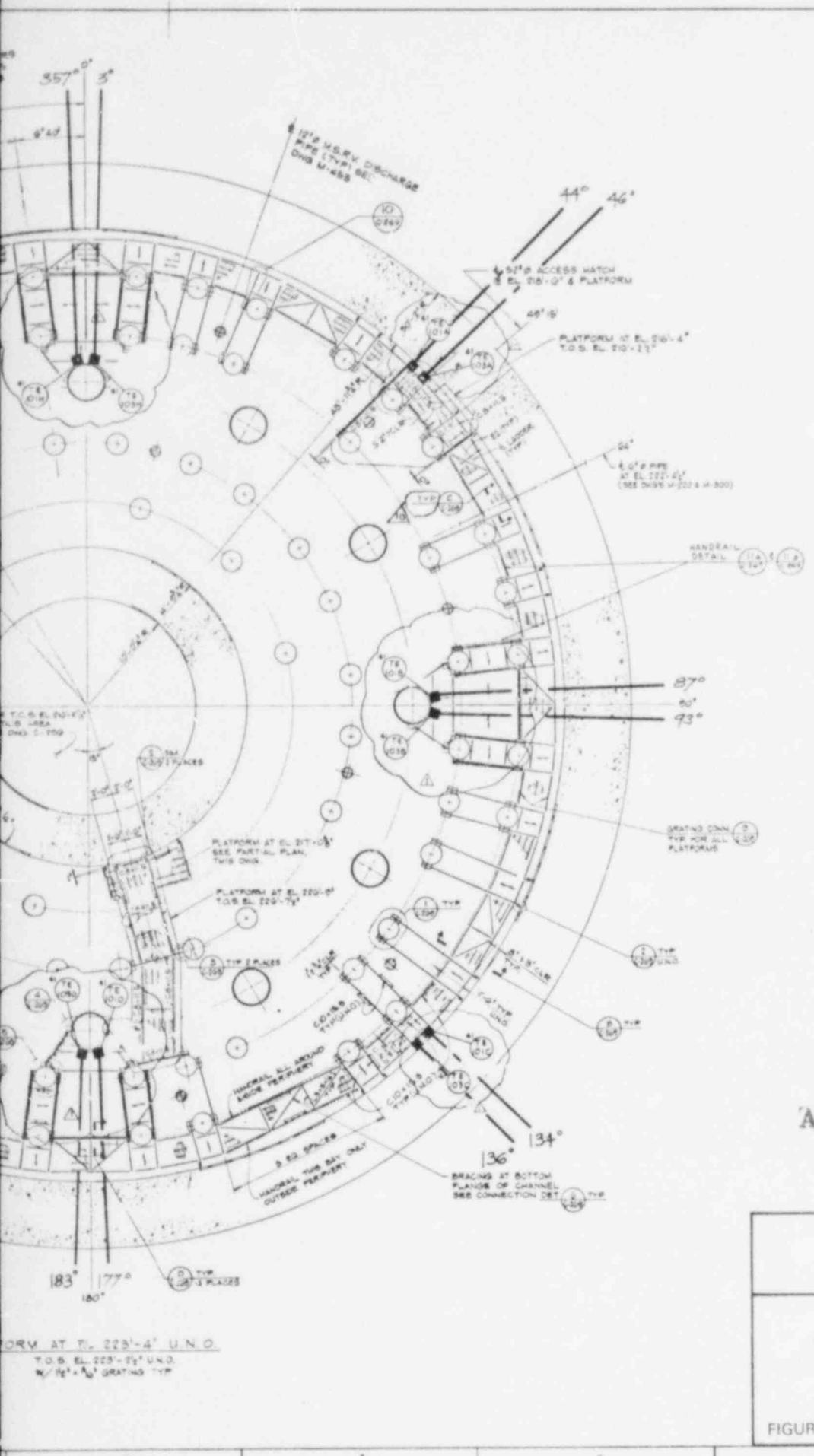


H
G
F
E
D
C
B
A

PLATFORM AT EL 217-0.1
T.O.S. EL 216-0.1
14' 0" x 8' 0" GRATING

PLAT

8 | 7 | 6



- NOTES:
1. FOR LEGEND AND GENERAL NOTES SEE SHEET W-105
 2. DISTANCE BETWEEN TWO REDUNDANT SENSORS (E.G. TE-A-1034 & TE-A-1034A) SHOULD BE AT LEAST 10' OR MORE
 3. APPROX. ELEV. OF SUPPRESSION POOL. TEM. SENS. CENTER LINE IS 228'-0" FOR EXACT ELEV. SEE REGULATION DETAIL. REF. W-430-100A

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 APERTURE
 CARD

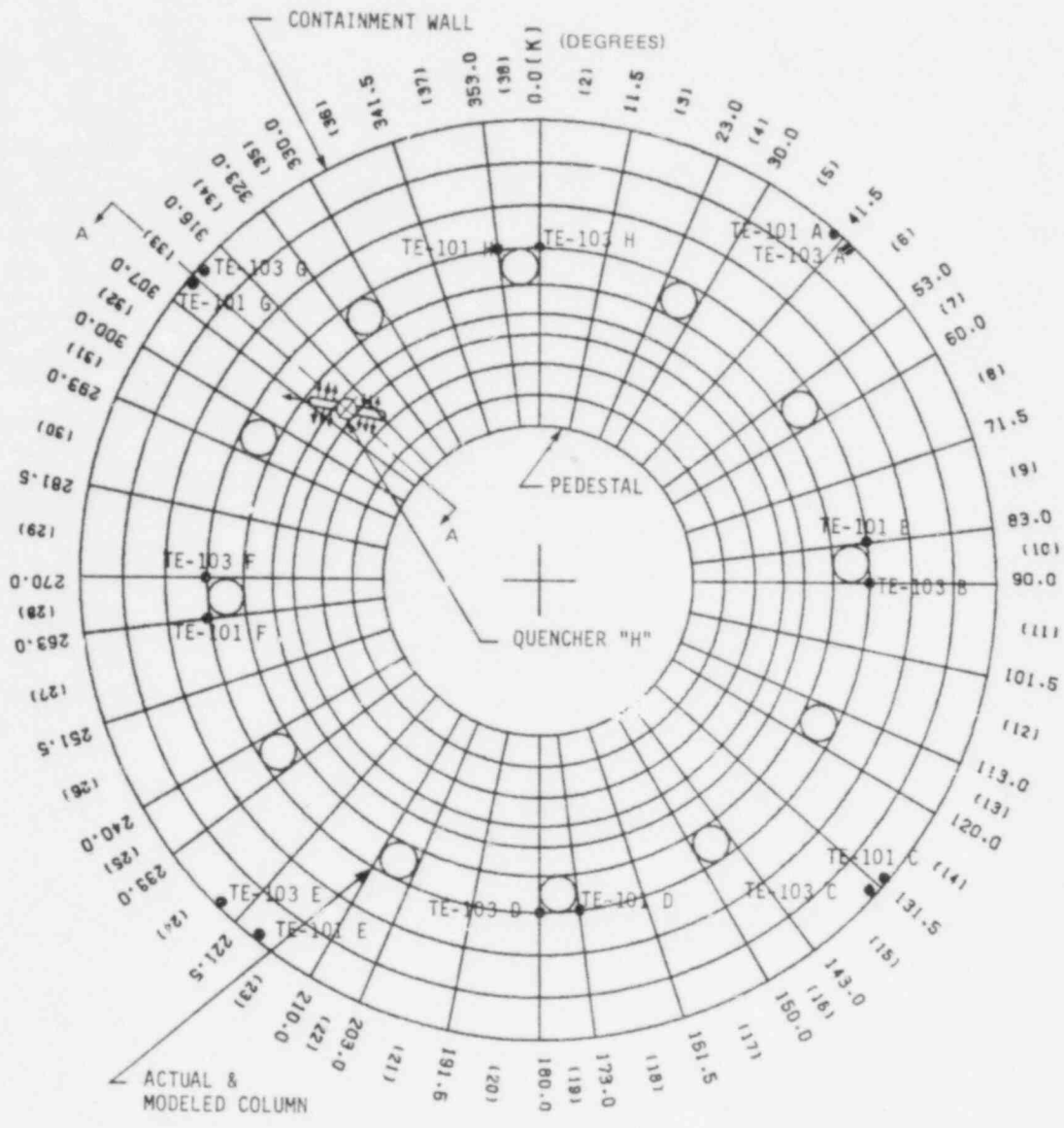
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LIMERICK GENERATING STATION
UNITS 1 AND 2
DESIGN ASSESSMENT REPORT

SUPPRESSION POOL TEMPERATURE
MONITORING SYSTEM
SENSOR LOCATIONS

FIGURE I.1-1 Rev. 7, 01/84

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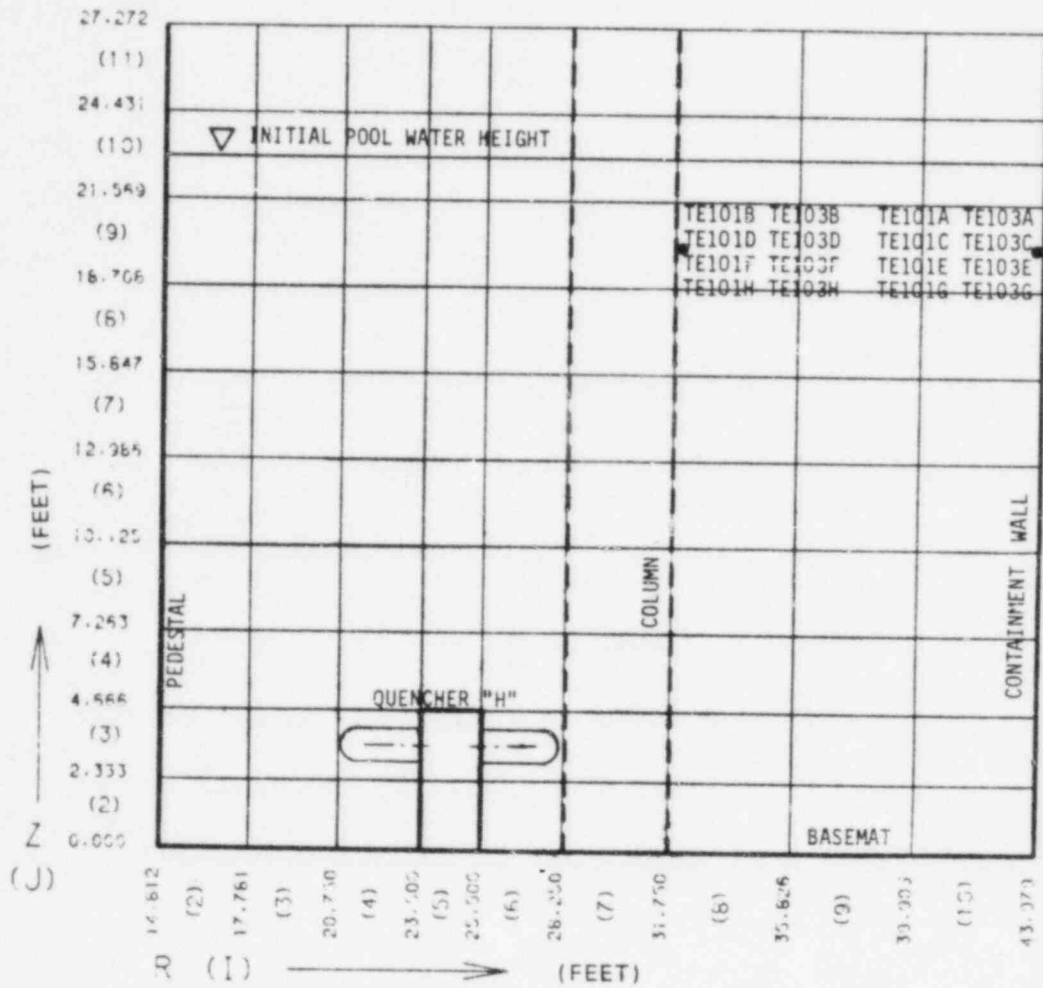


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PLAN VIEW OF MESH
 SYSTEM MODELING OF SUPPRESSION
 POOL FOR SRV-H HIGH AND LOW
 REACTOR PRESSURE BLOWDOWN (WITH
 SPTMS SENSOR LOCATIONS)

FIGURE I.1-2 REV. 7, 01/84

VIEW A-A OF FIGURE I.1-2

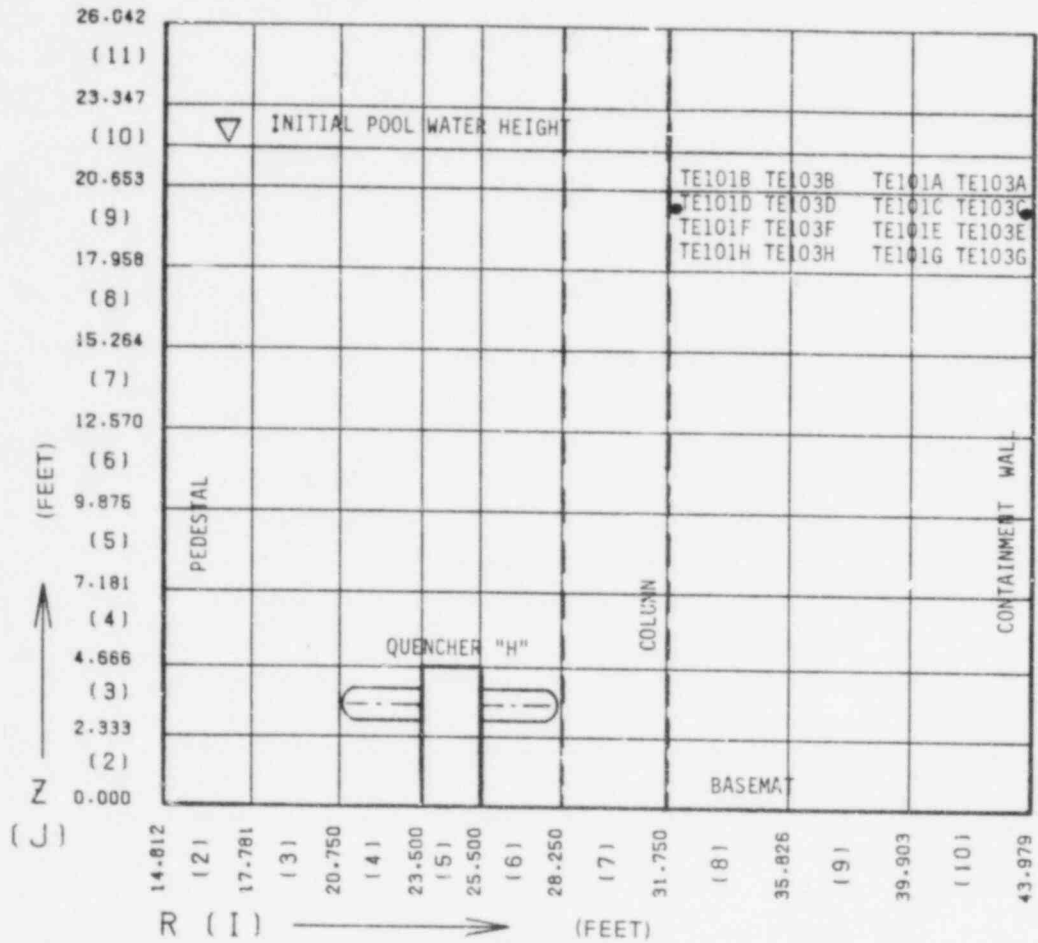


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SECTION VIEW OF MESH
 SYSTEM MODELING OF SUPPRESSION
 POOL FOR SRV-H HIGH REACTOR
 PRESSURE BLOWDOWN (WITH SPTMS
 SENSOR LOCATIONS)

FIGURE I.1-3
 REV. 7, 01/84

VIEW A-A OF FIGURE I.1-2

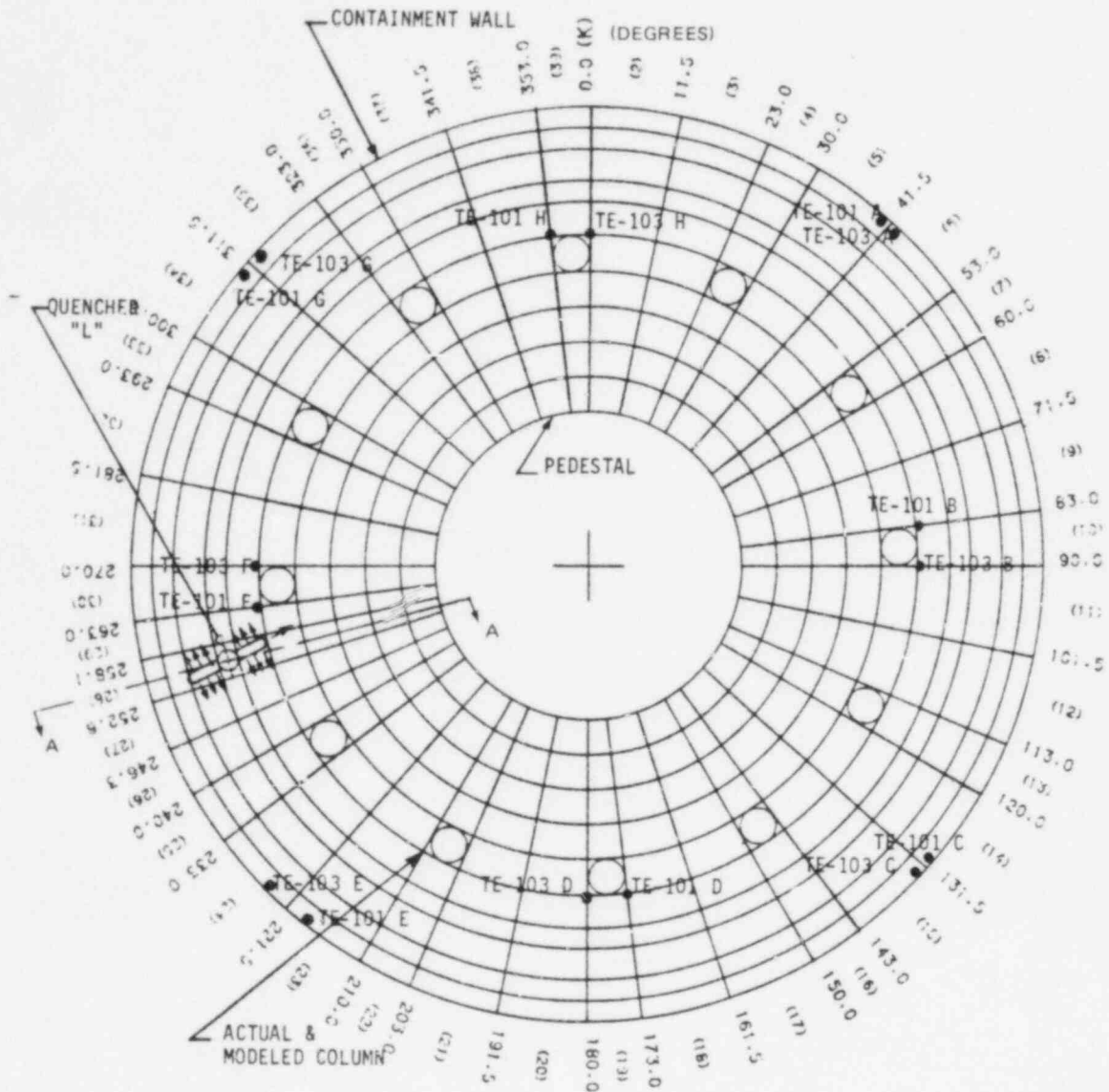


LIMERICK GENERATING STATION
 UNITS 1 AND 2
 DESIGN ASSESSMENT REPORT

SECTION VIEW OF MESH
 SYSTEM MODELING OF SUPPRESSION
 POOL FOR SRV-H LOW REACTOR
 PRESSURE BLOWDOWN (WITH SPTMS
 SENSOR LOCATIONS)

FIGURE I.1-4

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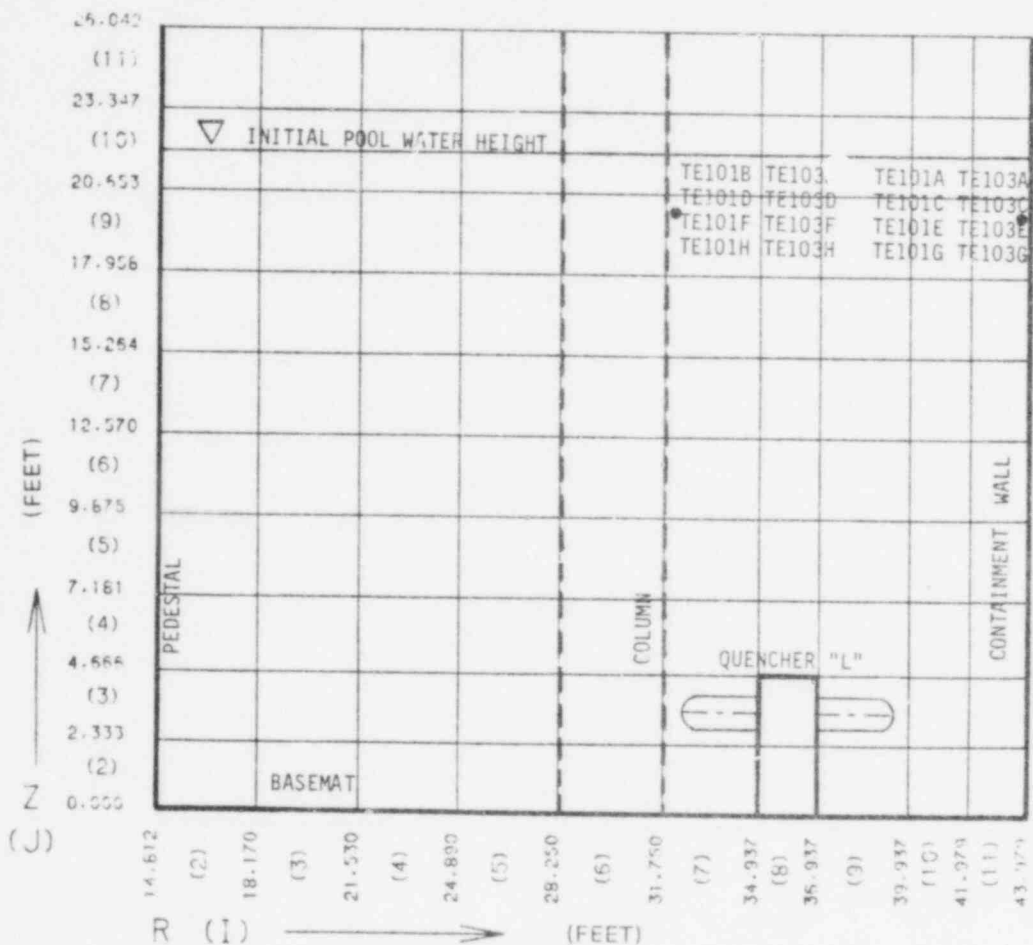
LIMERICK GENERATING STATION
 UNITS 1 AND 2
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PLAN VIEW OF MESH
 SYSTEM MODELING OF SUPPRESSION
 POOL FOR SRV-L HIGH REACTOR
 PRESSURE BLOWDOWN (WITH SPTMS
 SENSOR LOCATIONS)

FIGURE I.15

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VIEW A-A OF FIGURE I.1-5

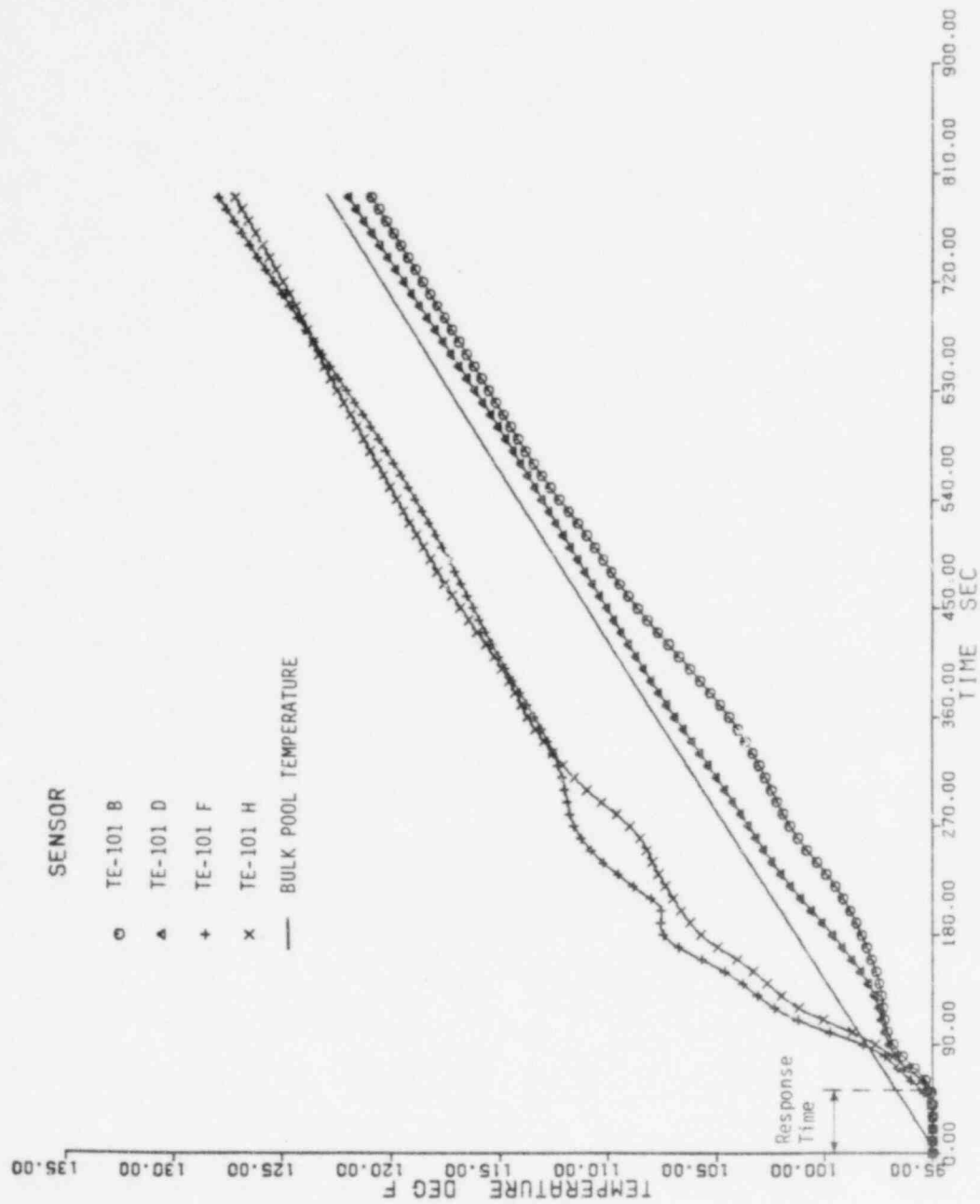


LIMERICK GENERATING STATION
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SECTION VIEW OF MESH
 SYSTEM MODELING OF SUPPRESSION
 POOL FOR SRV-L HIGH REACTOR
 BLOWDOWN (WITH SPTMS SENSOR
 LOCATIONS)

FIGURE I.1-6

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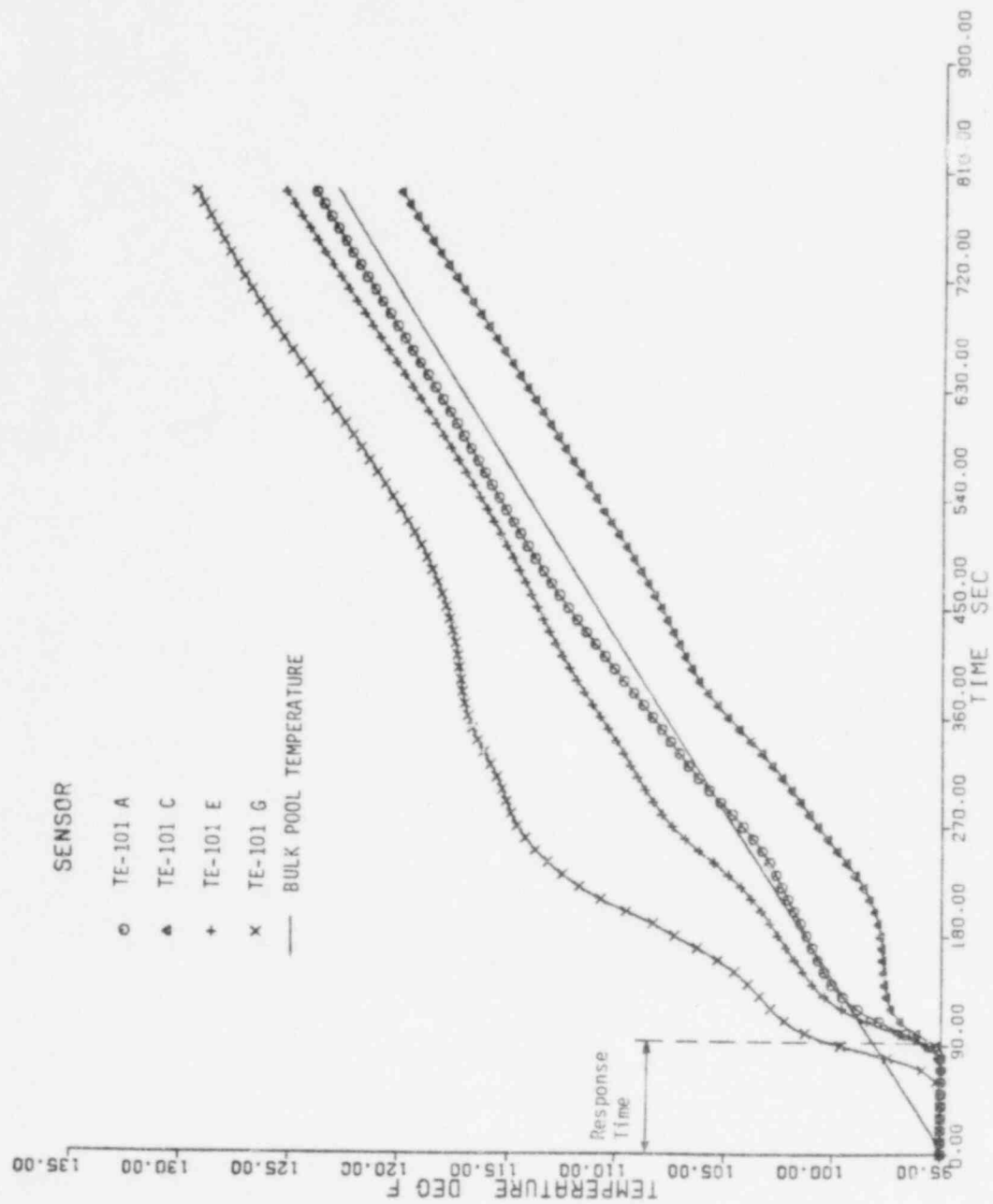


LIMERICK GENERATING STATION
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TEMPERATURE TIME
 HISTORIES OF COLUMN MOUNTED
 SPTMS SENSORS (TE-101 B, D, F & H)
 FOR SRV-H HIGH REACTOR
 PRESSURE BLOWDOWN

FIGURE I.1-7

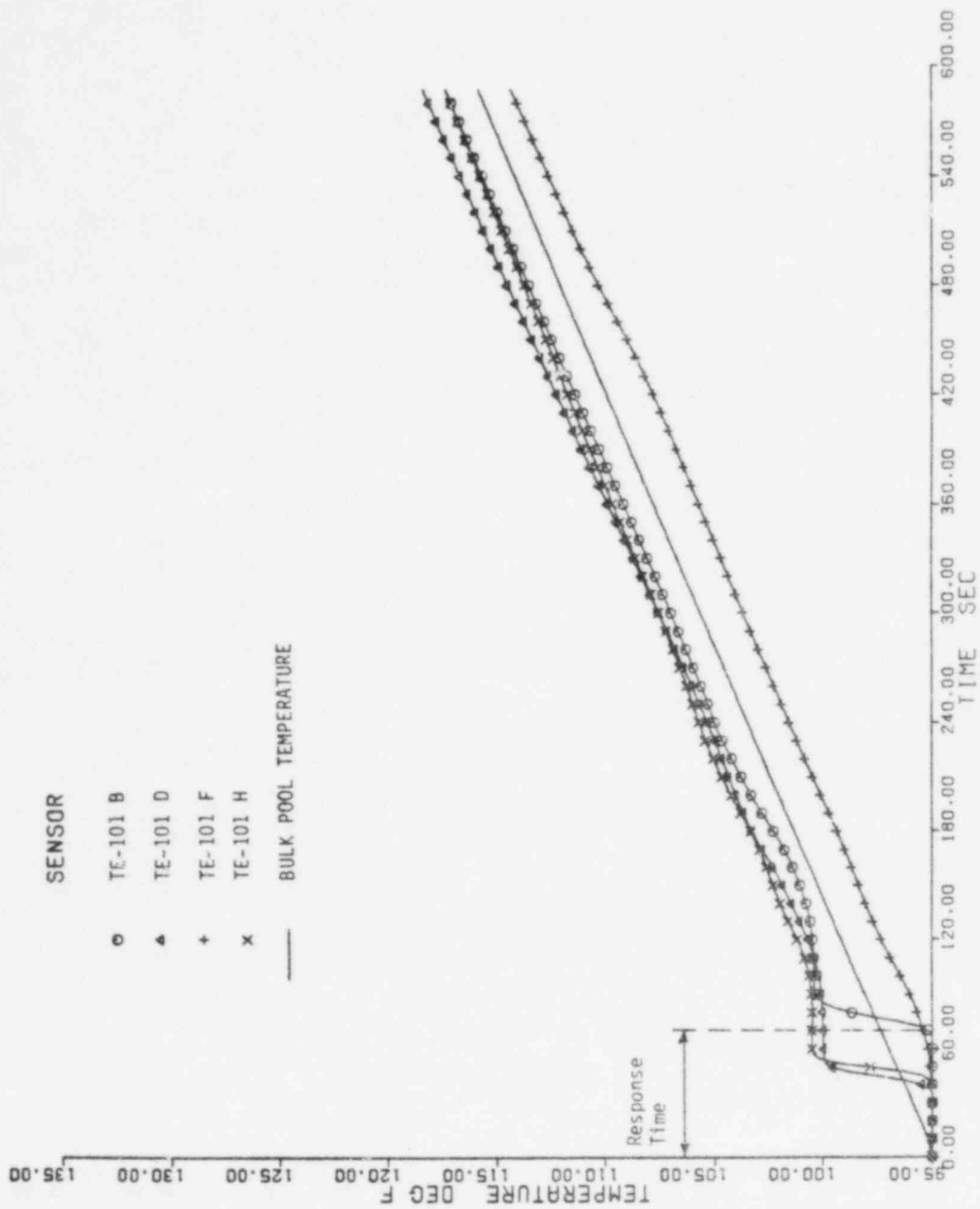
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LIMERICK GENERATING STATION
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TEMPERATURE TIME
 HISTORIES OF CONTAINMENT WALL
 MOUNTED SPTMS SENSORS (TE-101 A,
 C, E & G) FOR SRV-H HIGH REACTOR
 PRESSURE BLOWDOWN

FIGURE I.1-8
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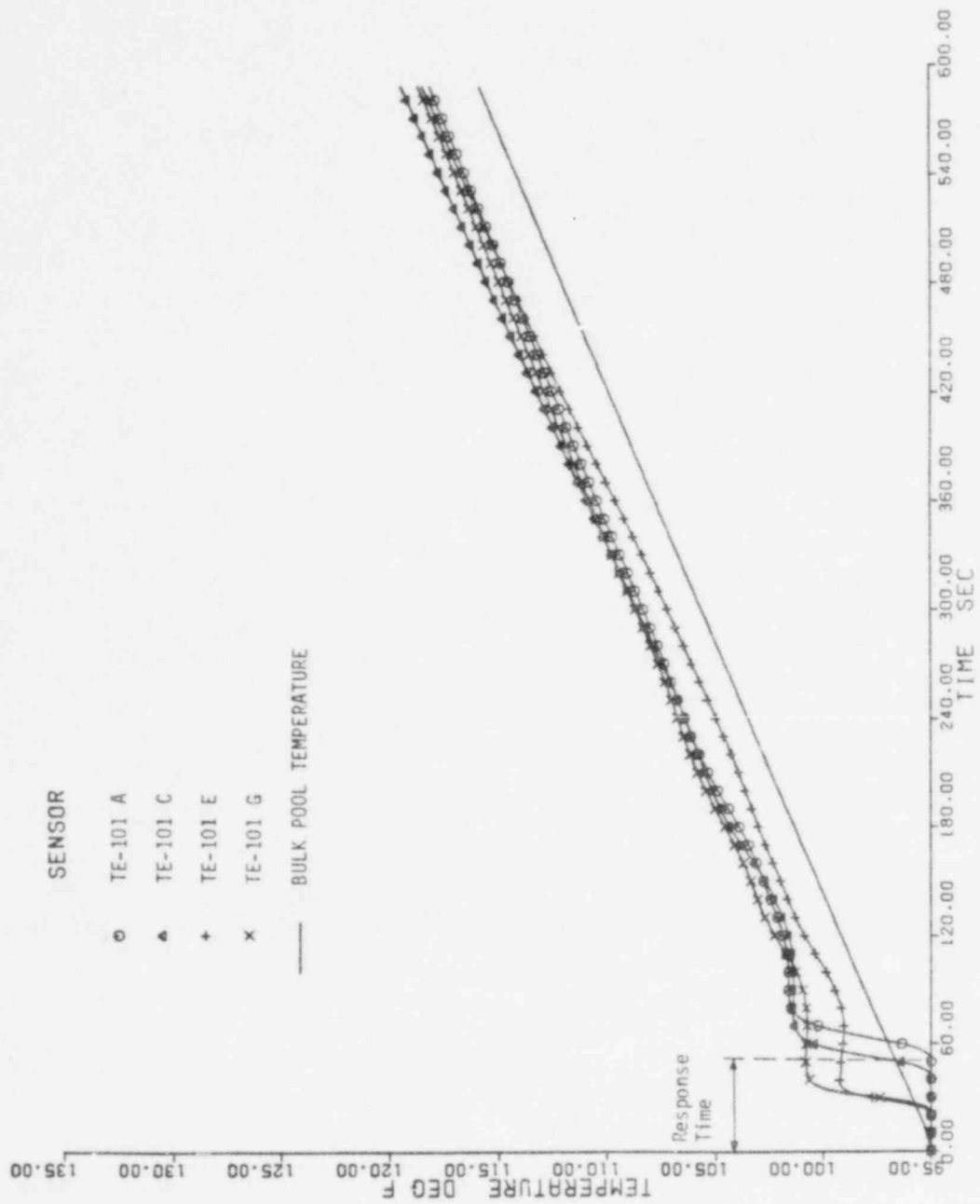


LIMERICK GENERATING STATION
 UNITS 1 AND 2
 DESIGN ASSESSMENT REPORT

TEMPERATURE TIME
 HISTORIES OF COLUMN MOUNTED
 SPTMS SENSORS (TE-101 B, D, F & H)
 FOR SRV-L HIGH REACTOR
 PRESSURE BLOWDOWN

FIGURE T.1-9

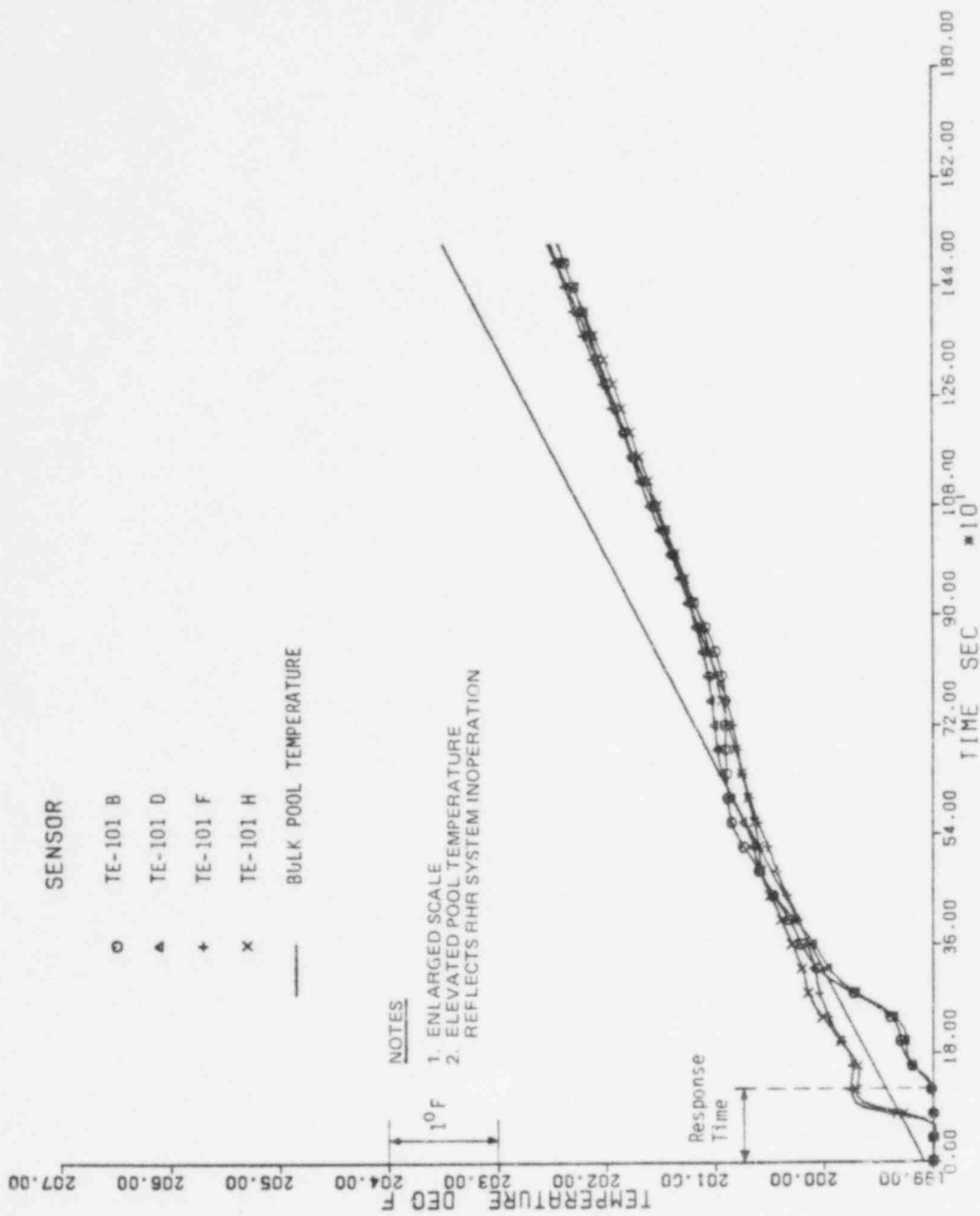
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LIMERICK GENERATING STATION
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TEMPERATURE TIME
 HISTORIES OF CONTAINMENT WALL
 MOUNTED SPTMS SENSORS (TE-101 A,
 C, E & G) FOR SRV-L HIGH REACTOR
 PRESSURE BLOWDOWN

FIGURE I.1-10 REV. 7, 01/84

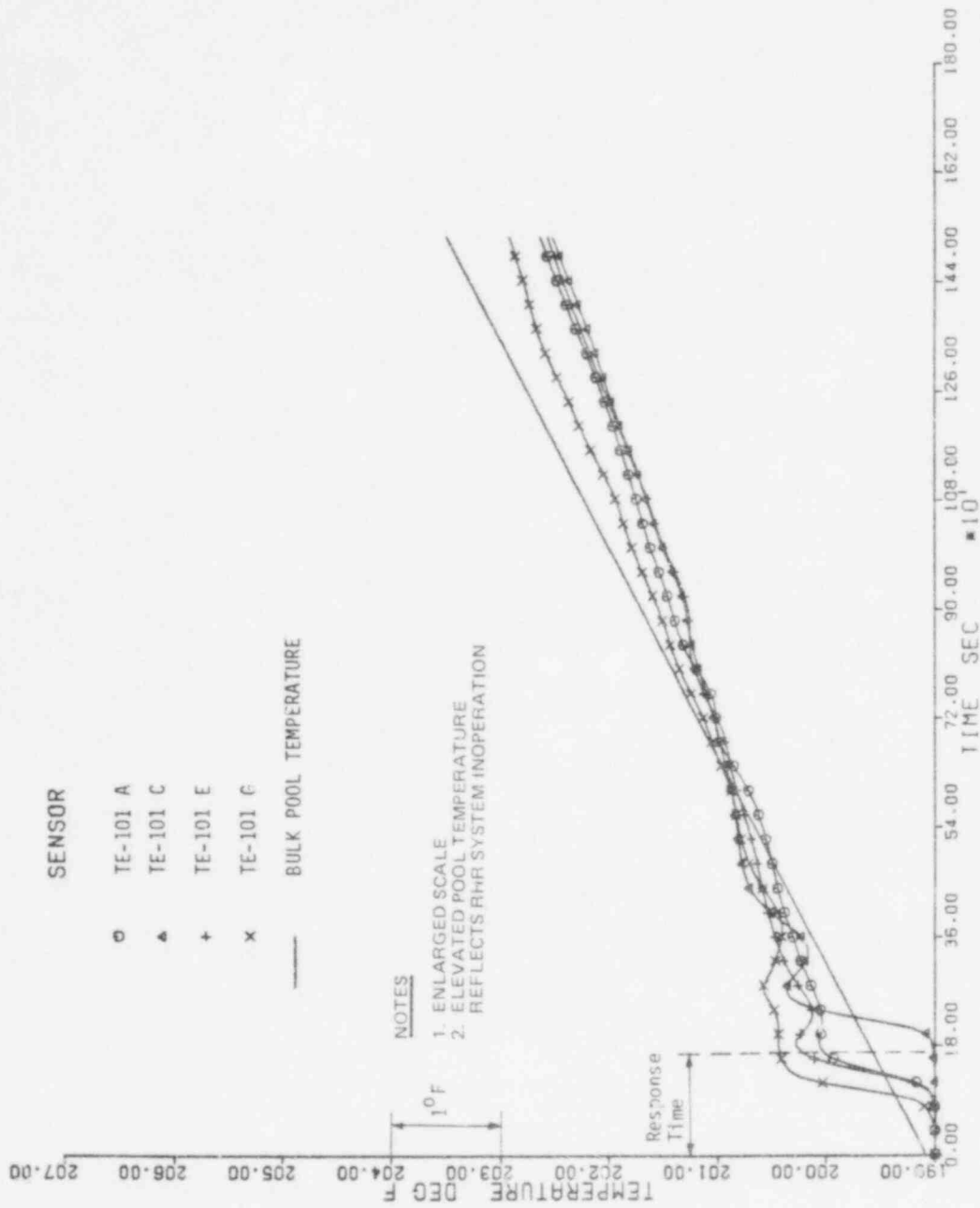


LIMERICK GENERATING STATION
UNITS 1 AND 2
DESIGN ASSESSMENT REPORT

TEMPERATURE TIME
HISTORIES OF COLUMN MOUNTED
SPTMS SENSORS (TE-101 B, D, F & H)
FOR SRV-H LOW REACTOR
PRESSURE BLOWDOWN

FIGURE I.1-11

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SENSOR

- o TE-101 A
- ▲ TE-101 C
- + TE-101 E
- x TE-101 G
- BULK POOL TEMPERATURE

NOTES

1. ENLARGED SCALE
2. ELEVATED POOL TEMPERATURE REFLECTS RHR SYSTEM INOPERATION

10F

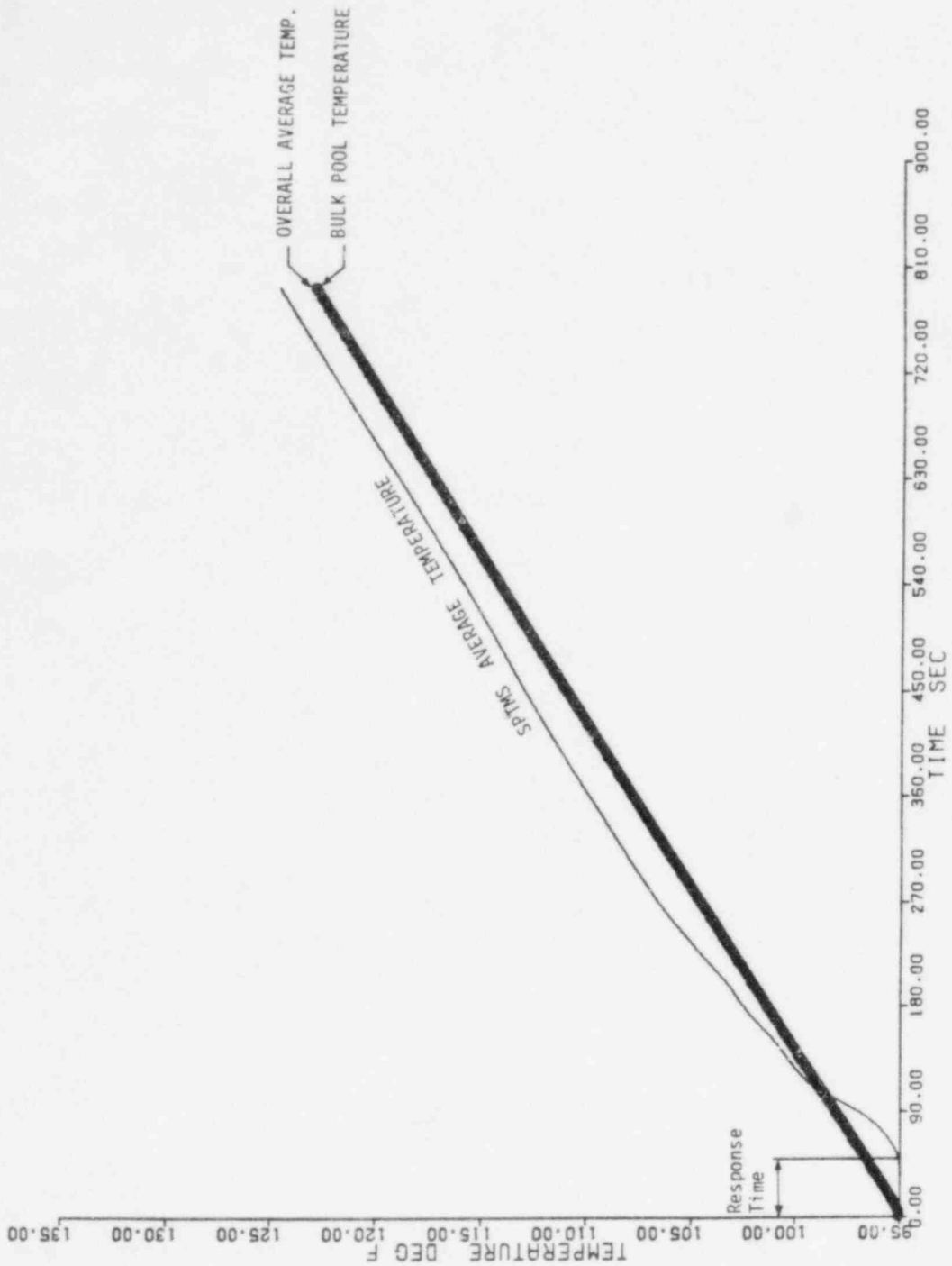
Response Time

LIMERICK GENERATING STATION
 UNITS 1 AND 2
 DESIGN ASSESSMENT REPORT

TEMPERATURE TIME
 HISTORIES OF CONTAINMENT WALL
 MOUNTED SPTMS SENSORS (TE-101 A,
 C, E & G) FOR SRV-H LOW REACTOR
 PRESSURE BLOWDOWN

FIGURE I.1-12

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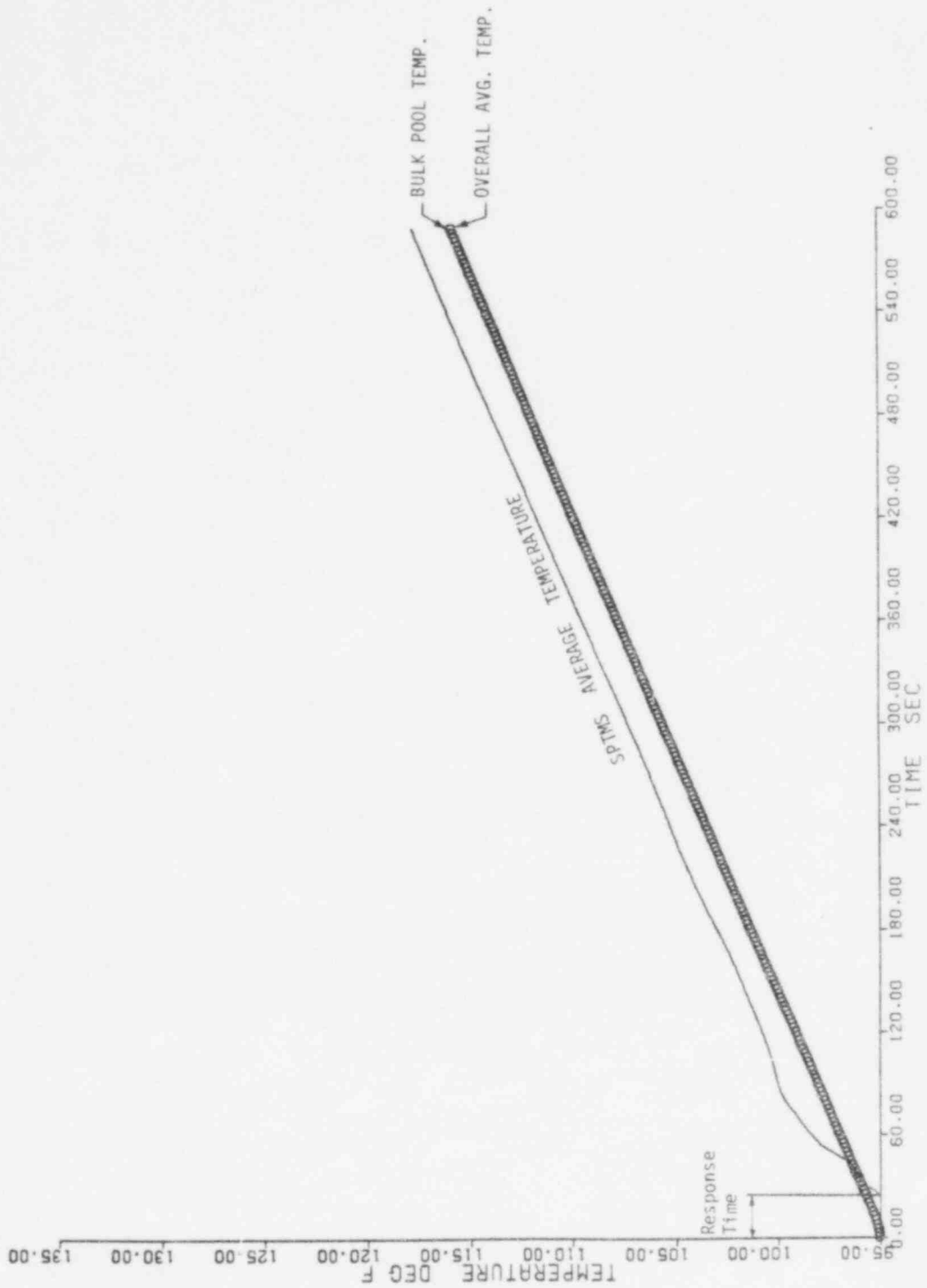


LIMERICK GENERATING STATION
 UNITS 1 AND 2
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BULK TEMP. VS. AVG.
 TEMP. FROM SPTMS DIVISION 1
 (TE-101A...TE-101H) FOR SRV-H HIGH
 REACTOR PRESSURE BLOWDOWN

FIGURE I.1-13

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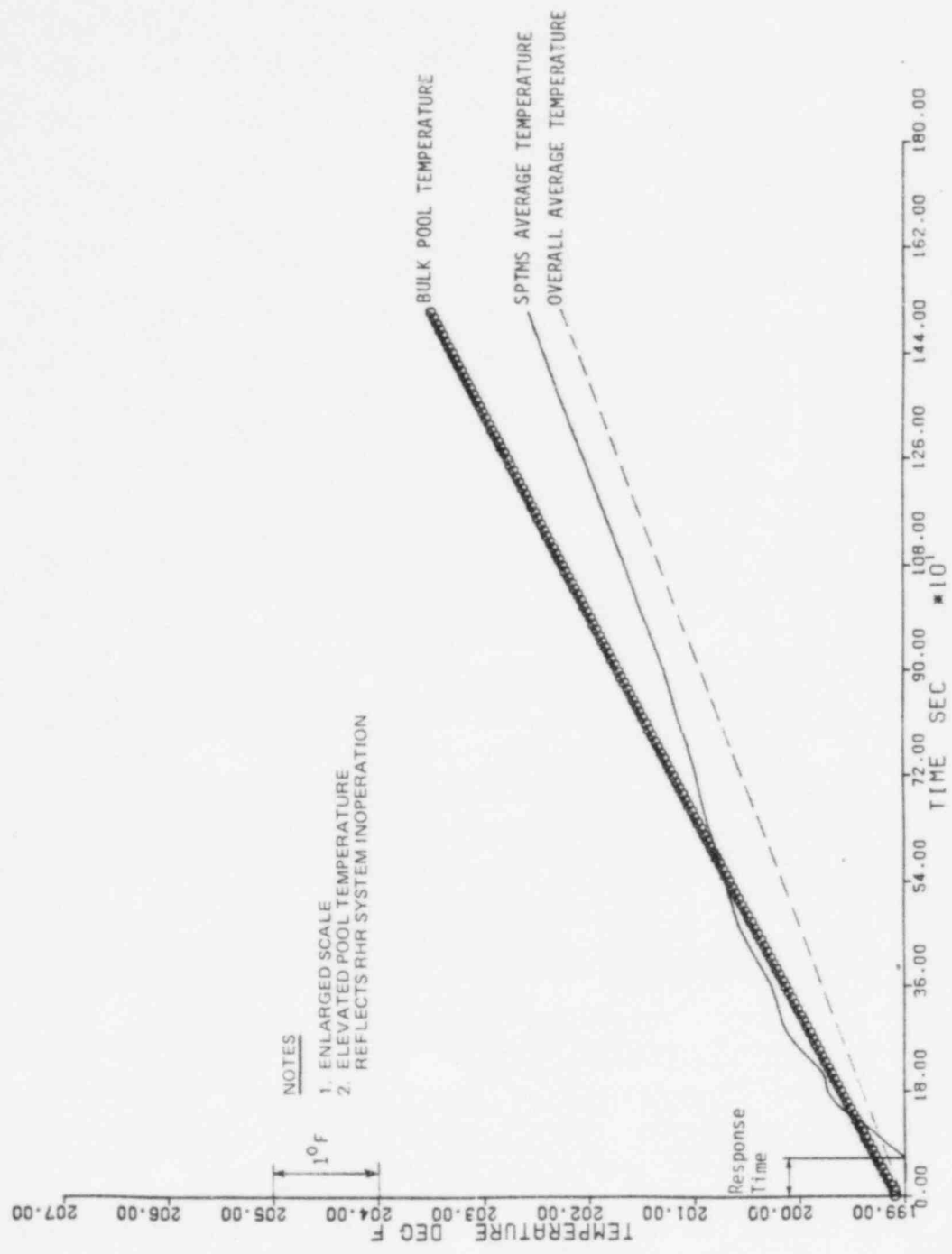


LIMERICK GENERATING STATION
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BULK TEMP. VS. AVG.
 TEMP. FROM SPTMS DIVISION 1
 (TE-101A . . . TE-101H) FOR SRV-L
 HIGH REACTOR PRESSURE BLOWDOWN

FIGURE I.1-14

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NOTES
 1. ENLARGED SCALE
 2. ELEVATED POOL TEMPERATURE
 REFLECTS RHR SYSTEM INOPERATION

LIMERICK GENERATING STATION
 UNITS 1 AND 2
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BULK TEMP. VS. AVG.
 TEMP. FROM SPTMS DIVISION 1
 (TE-101A . . . TE-101H) FOR SRV-H LOW
 REACTOR PRESSURE BLOWDOWN

FIGURE I.1-15 REV. 7, 01/84

Two single failures are considered separately:

Case 2.a: Single failure of one RHR heat exchanger

Case 2.b: Failure of an SRV to reclose (SORV)
(Note: Case 2.b is not required by NUREG-0783 but is presented to maintain consistency with the "White Paper" cases.)

I.2.2.3 Event 3: SRV Discharge Following a Small Break Accident

SBA cases are analyzed to demonstrate that SRV discharge required to depressurize the reactor coolant system following a small break will not result in high pool temperatures. As a result of continued flow through the break, peak pool temperature is not reached until after SRV discharge has terminated.

Two cases of SBA are considered separately:

Case 3.a: Single failure of one RHR heat exchanger

Case 3.b: Loss of shutdown cooling
(Note: Case 3.b is not required by NUREG-0783 but is presented to maintain consistency with the "White Paper" cases.)

I.2.3 ASSUMPTIONS USED IN THE ANALYSIS

I.2.3.1 General Assumptions

The following general assumptions and initial conditions have been used for all transients. Table I.2-1 summarizes the values for important system characteristics and input parameters listed below.

- a. Power level, decay heat standard, RHR heat exchanger capability (considering design fouling factors), and suppression pool initial temperature (maximum technical specification temperature for continuous power operation without pool cooling) are consistent with those used for the analysis of containment pressure and temperature

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response to a loss-of-coolant accident specified in the FSAR.

- b. The service water temperature is characterized as a transient starting at 88°F (technical specification limit for average spray pond temperature).
- c. The initial water level of the suppression pool is at the minimum level in the technical specification.
- d. MSIV closure is complete 3.5 seconds after the isolation signal ($t=0$) for transients where isolation occurs.
- e. The water volume within the reactor vessel pedestal is not included in the calculation of pool temperature response.
- f. To maximize heat addition to the pool, feedwater at the temperature in excess of instantaneous pool temperature is assumed to maintain RPV level rather than condensate storage tank inventory via RCIC and HPCI. Feedwater injection is terminated when additional feedwater will ultimately result in cooling the pool. (Note: This requirement is more conservative than the NUREG-0783 assumption that "feedwater pumps supply feedwater to the reactor until the feedpumps trip on an automatic signal.") HPCI (from the suppression pool) and CRD (from the condensate storage tank) systems provide vessel makeup after all the hot feedwater is expended. CRD flow was used for all cases except small break accidents with one RHR.
- g. Offsite power is not available for isolation/scram and SBA events or where MSIV closure is assumed, except SBA Case 3.b. Offsite power is available for Case 3.b; however, Case 3.b is conservative due to the conservatism associated with feedwater addition (see assumption "f" above) and the unavailability of the main condenser. Also, Case 3.b is not the controlling event for calculation of peak pool temperature (Table I.2-2).
- h. High pressure coolant injection (HPCI) system is terminated at or before a pool temperature of 170°F.

temperature reaches 120°F at approximately 1000 seconds. The time available for manual operator action after $t=1000$ seconds without the pool exceeding the peak calculated temperature is limited to the same point in time in Case 3.a where shutdown cooling was initiated (89.7 psia), i.e., approximately 10,000 seconds. Therefore, the total time available based on limiting Case 3.a is approximately 9,000 seconds or 2-1/2 hours.

A study of required manual operator actions has concluded that a second RHR heat exchanger could be available in the pool cooling mode in less than 2-1/2 hours (the time when Case 3.a peak pool temperature is reached). The pool temperature will decrease following the initiation of the second RHR loop in the pool cooling mode because the heat removal rate of both RHR exchangers will exceed the heat addition rate to the pool at this time in the event.

Because the RHR shutdown cooling mode is not initiated, the operator will ultimately reach cold shutdown by establishing the alternate shutdown cooling path as outlined in FSAR Section 15.2.9. The heat addition rate to the pool resulting from this alternate path of shutdown cooling will be controlled to preclude the possibility of additional pool heatup.

If manual operator actions are required in case of a worst case single electrical division failure, the plant operator could actually reduce the blowdown rate to extend the time before the peak pool temperature is reached. This scenario allows additional time for operator actions and would result in a peak pool temperature which is lower than Case 3.a.

I.2.4 ANALYSIS RESULTS AND CONCLUSIONS

Table I.2-2 lists the peak bulk suppression pool temperatures that were calculated using the General Electric computer code HEX for the scenarios described in Sections I.2.2 and I.2.3. Figures I.2-1 through I.2-6 provide plots of the suppression pool temperature and the respective reactor pressure versus time.

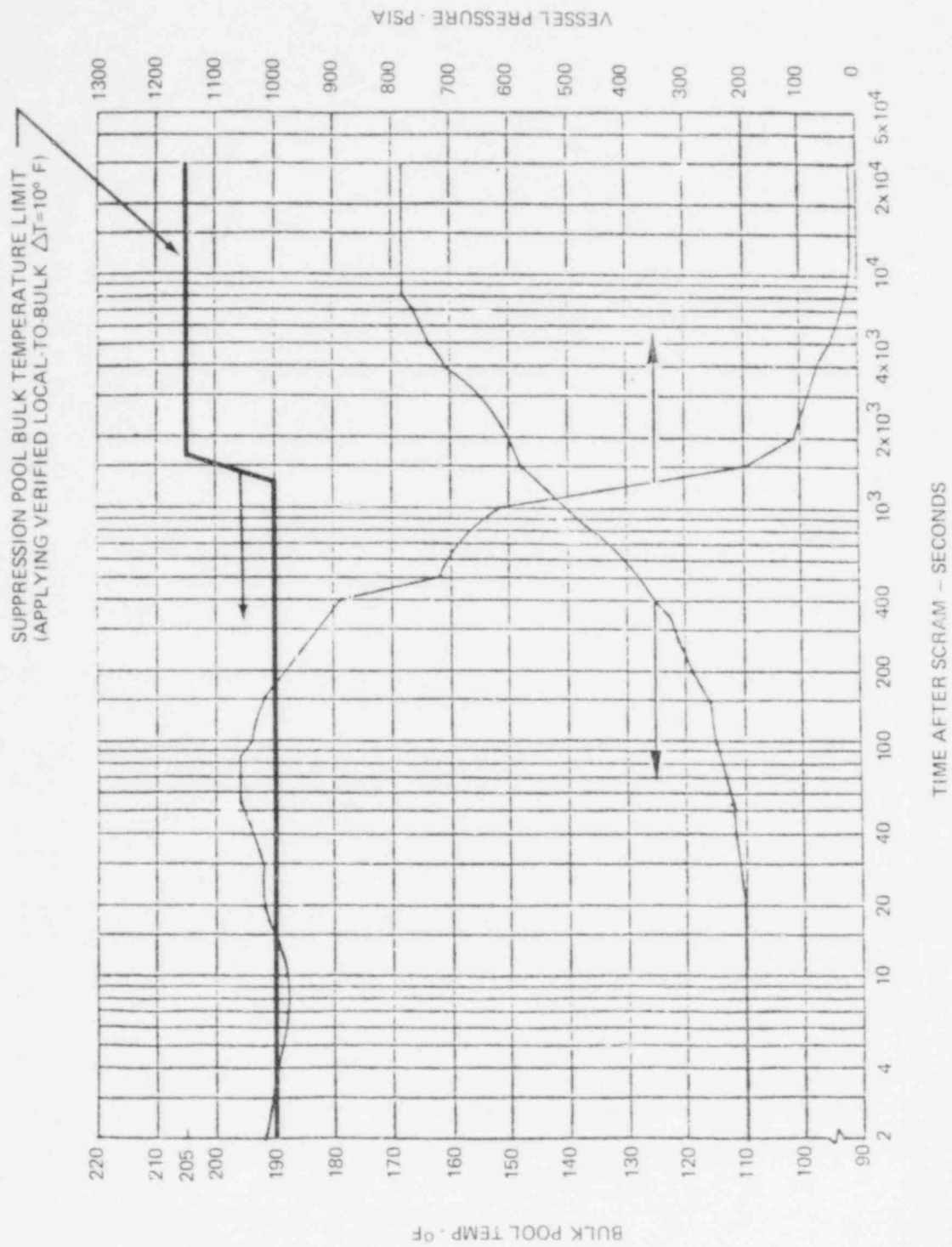
As stated earlier, the pool temperatures summarized in Table I.2-2 represent "bulk" temperatures, i.e., they were calculated assuming a homogeneously mixed suppression pool. In reality, pool mixing will not be perfect and differences will exist between the "local" temperature of the water in the immediate vicinity of the quencher and the calculated "bulk" temperature. However, because of the special design features of quenchers and their predominantly radial orientation in the

suppression pool to optimize pool thermal mixing (Figure 1.4-3), the local-to-bulk ΔT is expected to be small and not exceed the value that was previously derived for ramshead discharge devices in Mark I plants (10°F, Ref. I.2-2). This number has been verified to be conservative for Limerick using in-plant tests and analysis (Appendix I.3).

The suppression pool temperature limits defined in NUREG-0783 and listed in Section I.2.1 are specified in terms of "local" pool temperature and quencher mass flux criteria. Because Figures I.2-1 through I.2-6 specify the Limerick time histories in terms of "bulk" pool temperature and reactor pressure, it is necessary to convert the NUREG-0783 local pool temperature limit criteria to bulk pool temperature and reactor pressure criteria. Applying a local-to-bulk ΔT of 10°F as described above and calculating the Limerick reactor pressures corresponding to steam fluxes of 42 and 94 lbm/ft² sec, respectively, a bulk suppression pool temperature limit curve is developed. These curves are shown on Figures I.2-1 through I.2-6 and demonstrate that the Limerick suppression pool temperatures due to SRV discharge comply with the temperature limits defined in NUREG-0783.

I.2.5 REFERENCES

- I.2-1 RO Bulletin 74-14, "BWR Relief Valve Discharge to Suppression Pool," November 15, 1974.
- I.2-2 NUREG-0487, "Mark II Containment Lead Plant Program - Load Evaluation and Acceptance Criteria," October 1978.
- I.2-3 Mark II Owners Group, "Assumptions for Use in Analyzing Mark II BWR Suppression Pool Temperature Response to Plant Transients Involving Safety/Relief Valve Discharge," March 24, 1980.
- I.2-4 NUREG-0783, "Suppression Pool Temperature Limits for BWR Containments," November 1981.
- I.2-5 Letter report, R. H. Bucholz to Karl Kniel dated March 12, 1981, "Mark II Containment Program Method for Calculating Mass and Energy Release for Suppression Pool Temperature Response to Safety Relief Valve Discharges."

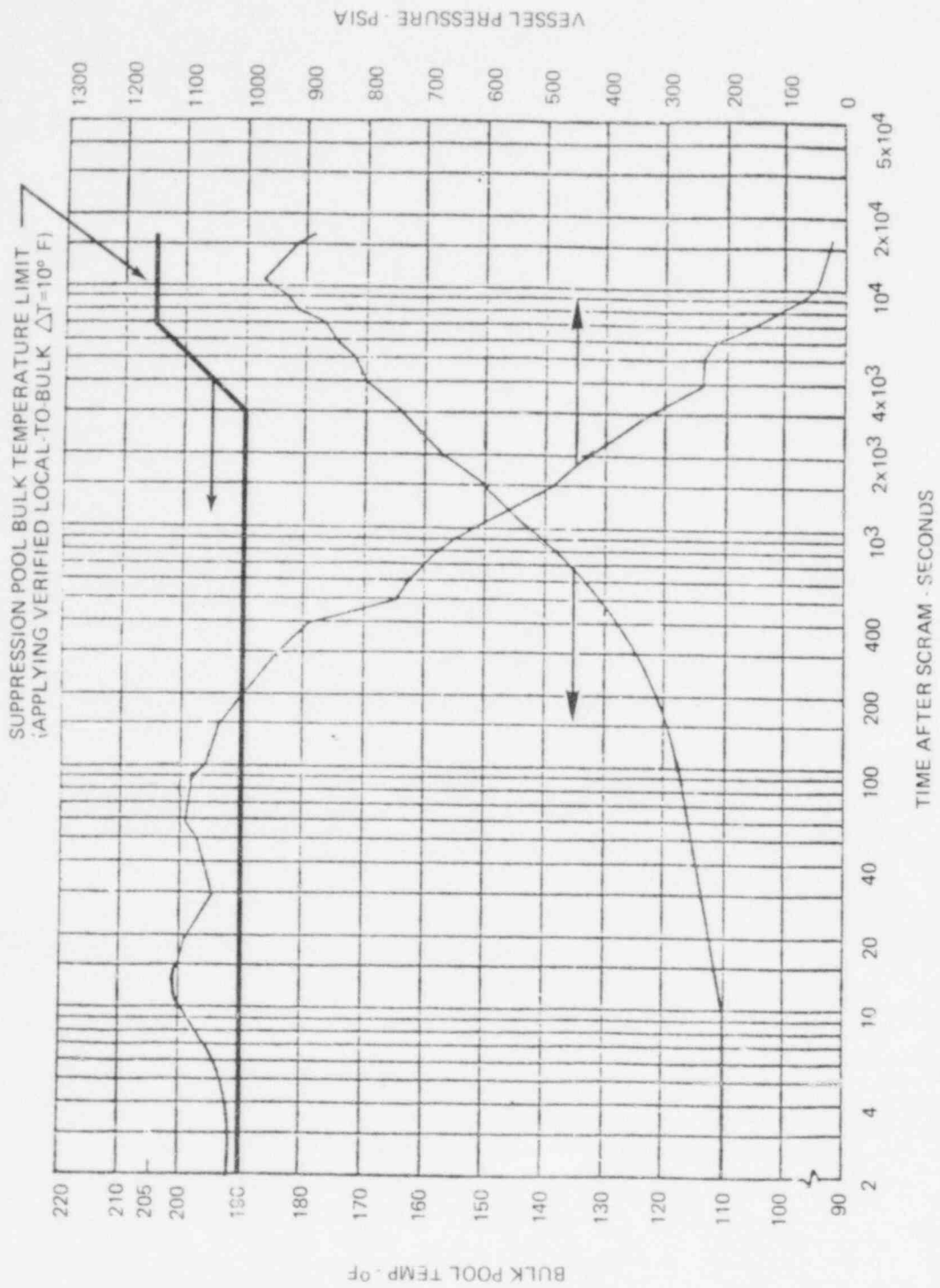


LIMERICK GENERATING STATION
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SUPPRESSION POOL
 TEMPERATURE TRANSIENT
 CASE 1.a

FIGURE I.2-1

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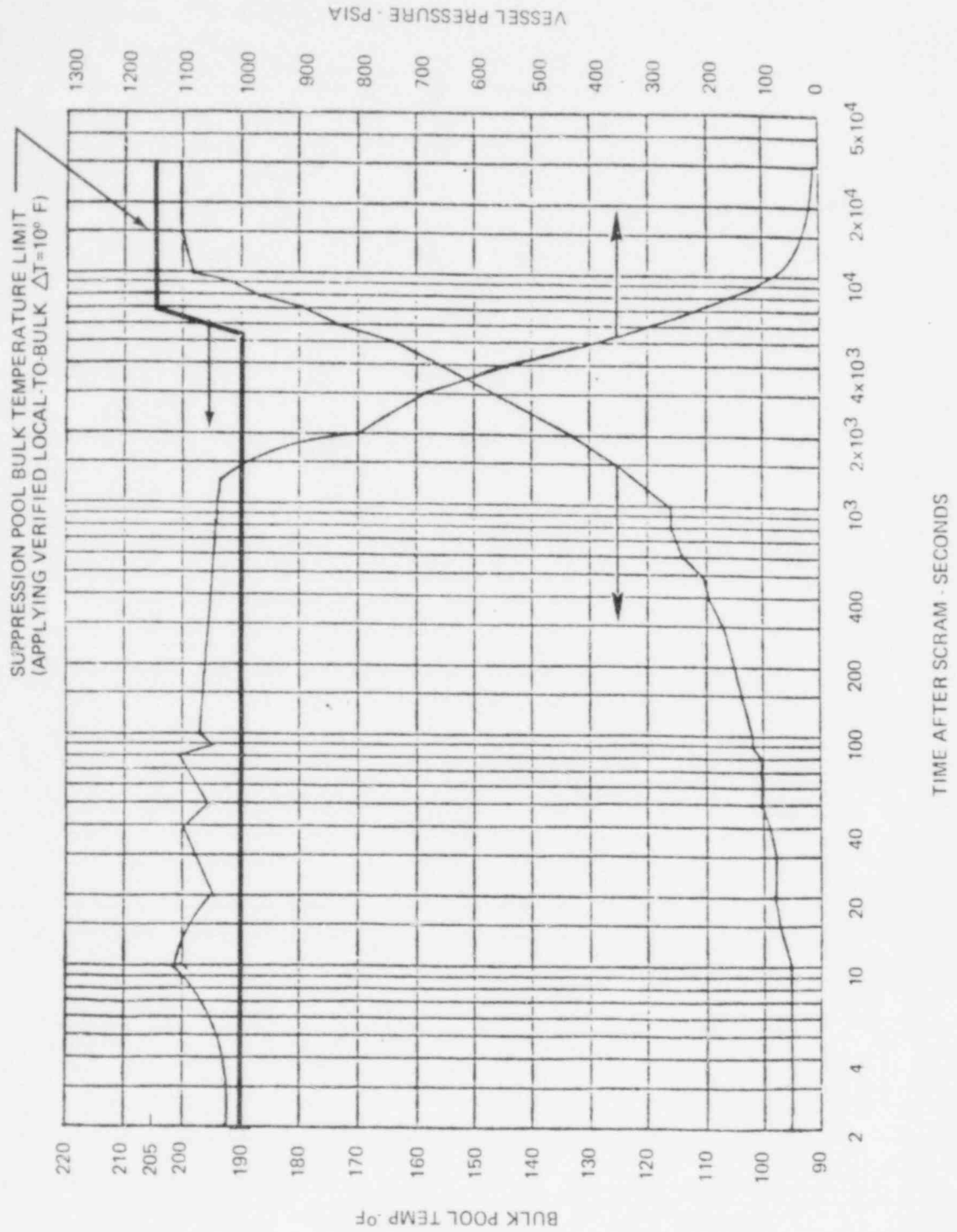


LIMERICK GENERATING STATION
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SUPPRESSION POOL
 TEMPERATURE TRANSIENT
 CASE 1.b

FIGURE I.2-2

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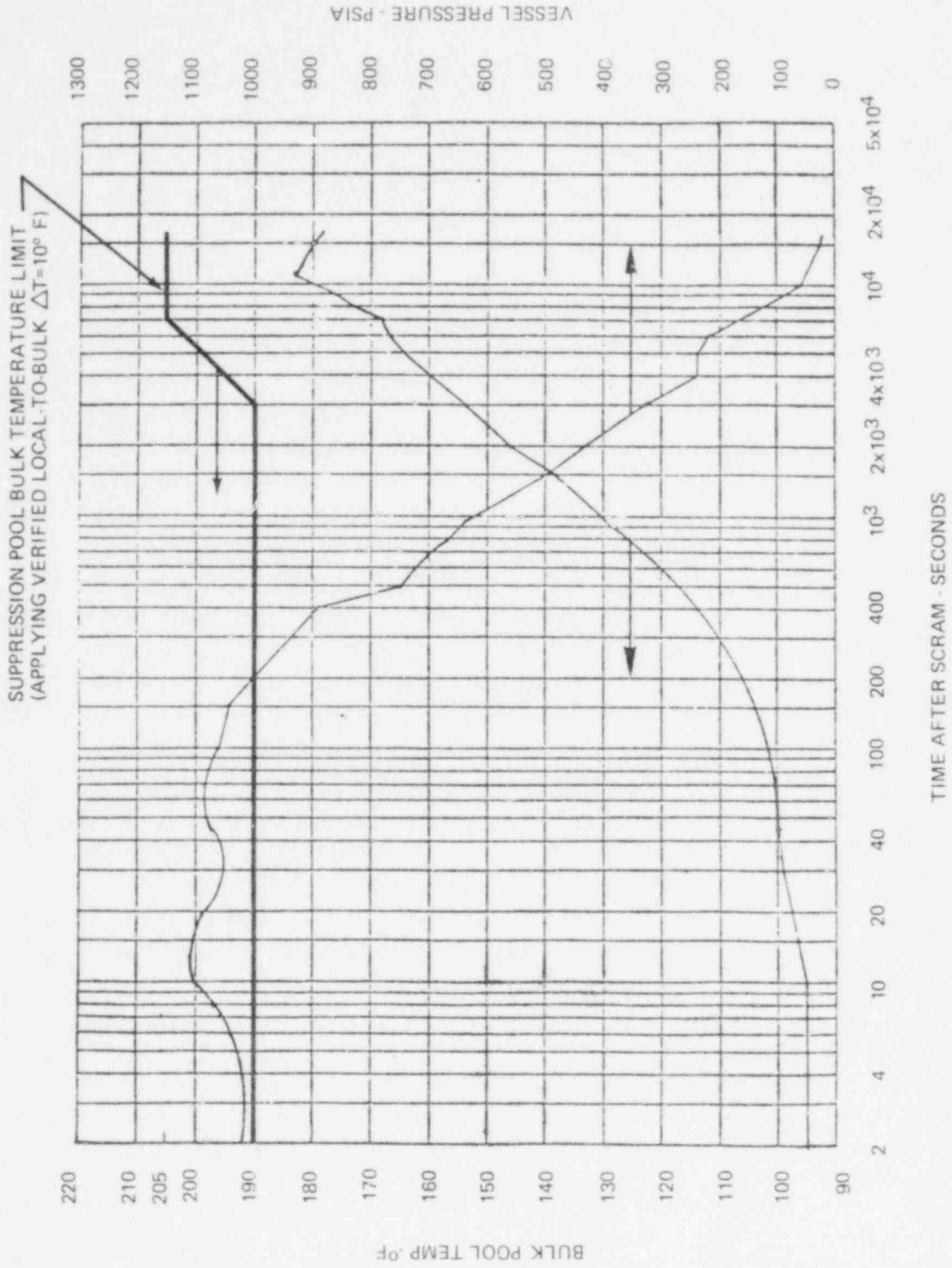


LIMERICK GENERATING STATION
 UNITS 1 AND 2
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SUPPRESSION POOL
 TEMPERATURE TRANSIENT
 CASE 2.a

FIGURE I.2-3

REV. 7, 01/84

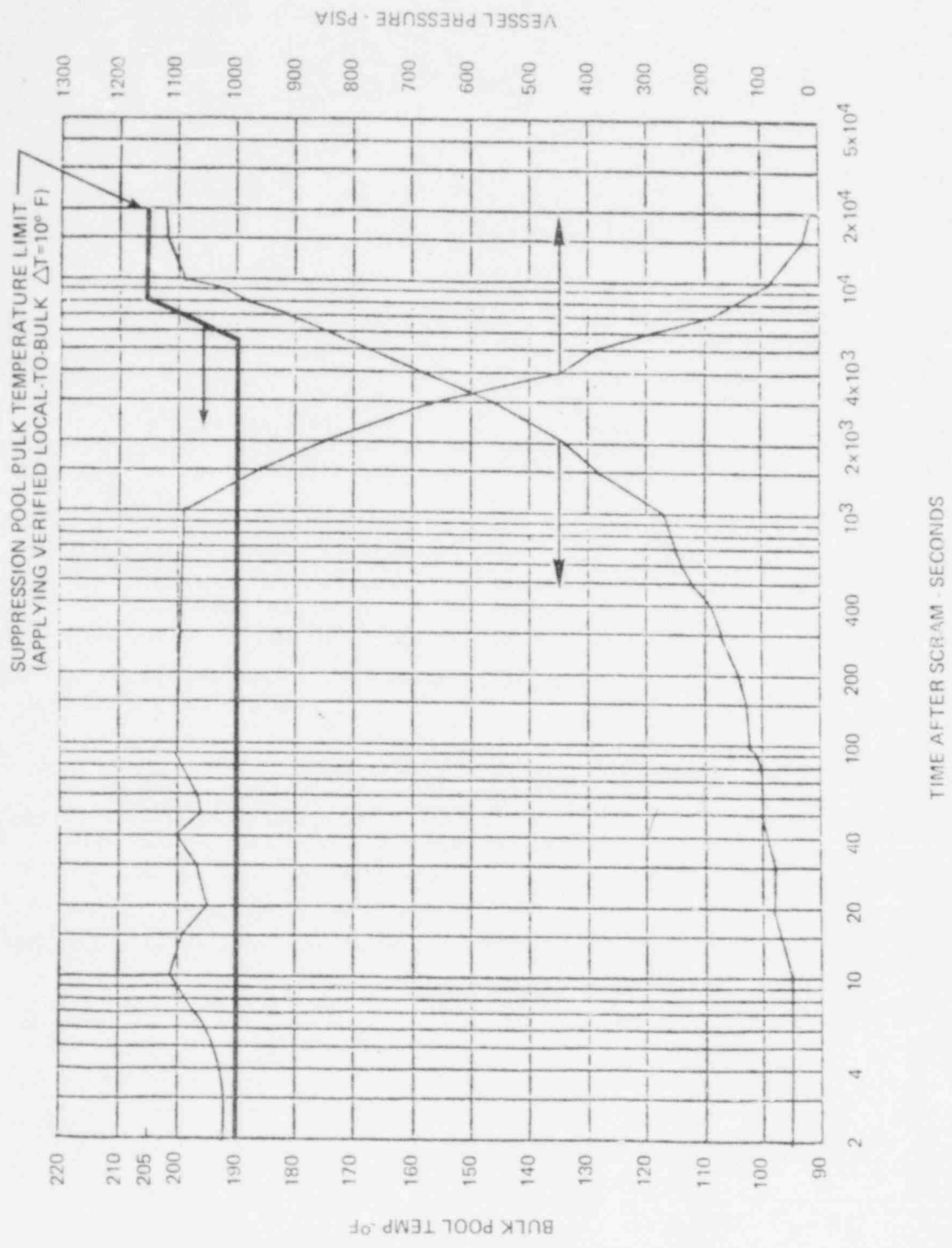


LIMERICK GENERATING STATION
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 DESIGN ASSESSMENT REPORT

SUPPRESSION POOL
 TEMPERATURE TRANSIENT
 Case 2.b

FIGURE I.2-4

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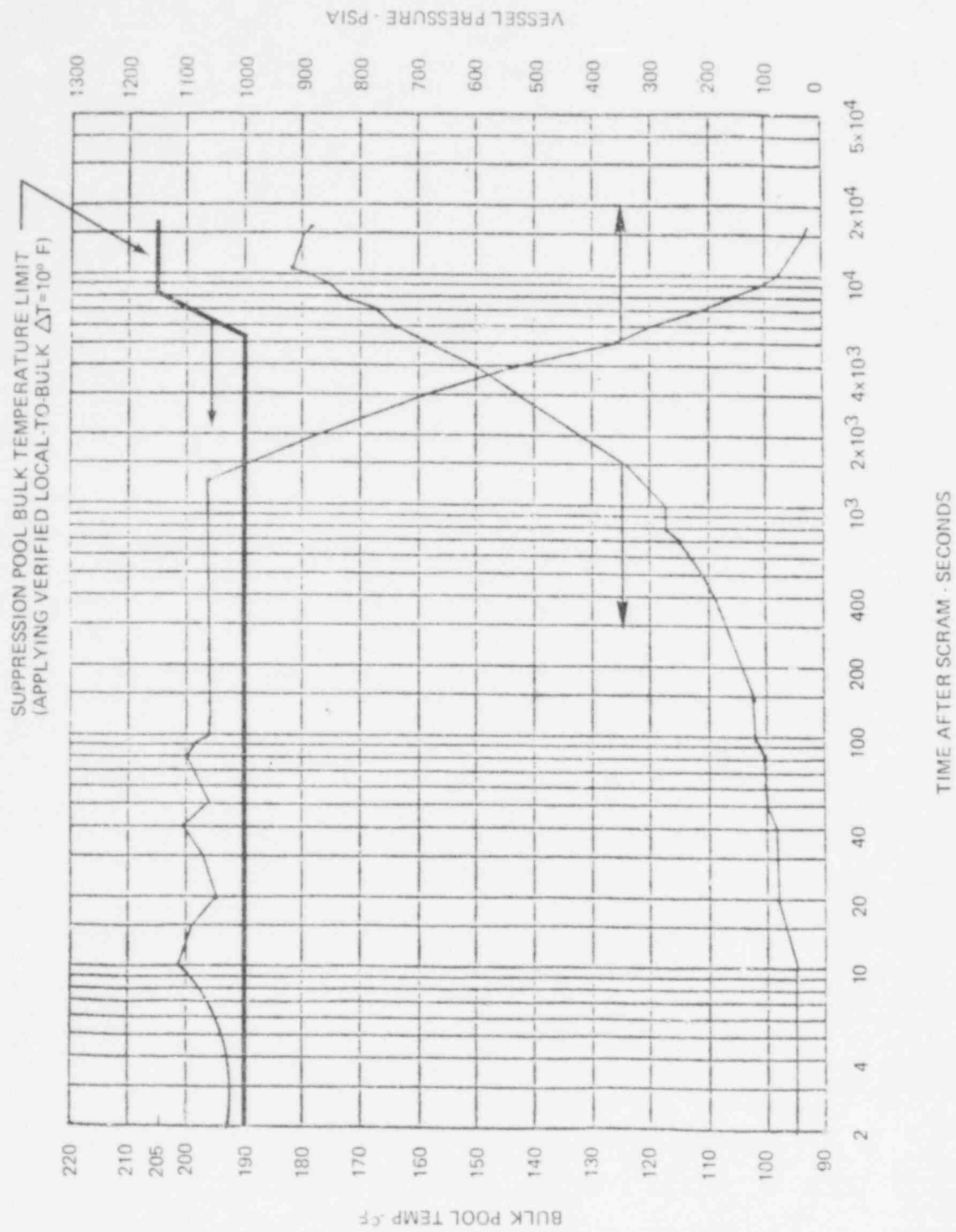


LIMERICK GENERATING STATION
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DESIGN ASSESSMENT REPORT

SUPPRESSION POOL
TEMPERATURE TRANSIENT
CASE 3.a

FIGURE I-2-5

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LIMERICK GENERATING STATION
UNITS 1 AND 2
DESIGN ASSESSMENT REPORT

SUPPRESSION POOL
TEMPERATURE TRANSIENT
CASE 3.b

FIGURE I2-6

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I.3 SUPPRESSION POOL LOCAL-TO-BULK TEMPERATURE DIFFERENCE (ΔT) ADEQUACY ASSESSMENT

I.3.1 INTRODUCTION

NUREG-0783 (Ref. I.2-4) defines the suppression pool temperature limits for steam discharges through the Mark II T-quenchers (e.g., those used in the Limerick suppression pool). These limits stem from the NRC's concern that, for certain combinations of pool temperatures and quencher mass fluxes, the steam condensation in the vicinity of the quencher exit may lead to higher vibratory loads on the submerged structures within the suppression pool. These pool temperature limits depend on the quencher steam mass flux and the saturation temperature at the quencher centerline submergence. The NUREG-0783 local pool temperature limits are expressed in terms of a local pool temperature. According to NUREG-0783, the local pool temperature is defined as the average water temperature in the vicinity of the quencher discharge device and represents the relevant temperature which controls the condensation process occurring at the quencher exit.

To confirm that Limerick will not exceed the pool temperature limits stipulated in NUREG-0783 for all design basis scenarios which involve T-quencher operation, the Limerick mass and energy analysis has been performed as reported in Section I.2. The analysis calculates a bulk pool temperature, defined as the pool temperature obtained by an energy sink balance on the pool assuming the pool acts as a uniform heat sink (i.e., no thermal stratification)

If ideal pool mixing would occur during steam discharges through the quenchers, the bulk temperature calculated by the mass and energy analysis would become the local pool temperature, and could be used directly to confirm that the Limerick suppression pool will not exceed the NUREG-0783 temperature limits. In reality, thermal stratification occurs in the suppression pool, resulting in higher values of local pool temperature in comparison with the bulk pool temperature. The difference between these two temperatures is the local-to-bulk pool temperature difference (ΔT). Therefore, once the Limerick-unique local-to-bulk ΔT is determined, it can be used with the results of the mass and energy analysis (Section I.2) to confirm that the Limerick suppression pool conforms to the local pool temperature criteria provided in NUREG-0783.

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In conjunction with the SPTMS adequacy assessment provided in Section I.1.2, the KFIXTM code is used to calculate the local-to-bulk ΔT in the Limerick suppression pool for the SORV blowdown scenarios described in Section I.1.2.1. Sections I.1.2.1.1 and I.1.2.1.2 provide the initial/operating conditions and KFIXTM geometrical models associated with these scenarios, respectively. Summarizing, these scenarios consist of two single SORV blowdowns under the high reactor pressure condition (SRV-H and L) and one single SORV blowdown under the low reactor pressure condition (SRV-H).

The two conditions of high and low reactor pressures correspond to the early and late stages of the SORV transient, respectively. The magnitude of the local-to-bulk ΔT gains significance at the later stages of the transient due to the smaller margin between the elevated bulk pool temperature and NUREG-0783 pool temperature limits. The results from the KFIXTM analysis, to be delineated in the following sections, indicate that the low reactor pressure analysis yields a lower local-to-bulk ΔT than that associated with the high pressure analysis.

NUREG-0783 provides a specific definition of local pool temperature stated as follows:

"To define the local pool temperature, a qualitative picture of the flow pattern during quencher discharge can be evolved by a combination of physical reasoning and experimental evidence...., it is apparent that the temperature which controls the condensation process (that is, the "local" temperature) is best characterized by that which would occur at a point directly above and below the quencher arms (perhaps one or two arms diameters distant), with the former providing a more conservative measure of this parameter."

Based on this definition, the local pool temperature can be calculated for both the high and low reactor pressure cases by mass averaging the temperature traces from the four fluid cells located directly above and below the two special cells representing the quencher arms. From Figures I.1-3, I.1-4, and I.1-6, the distances from the centers of these four cells to the centerline of the quencher arm varies from 2.333 to 2.47 ft, or approximately twice the quencher arm diameter. The distances from the centers of these four cells to the top or bottom surface of the quencher arm is about 1.5 times the quencher arm diameter. Thus, the methodology for calculating the local temperature conforms to the NUREG-0783 criteria.

Sections I.3.2, I.3.3, and I.3.4 discuss the KFIXTM calculated local and bulk pool temperature traces and corresponding local-to-bulk ΔT 's for the SRV scenarios. Concluding remarks regarding the Limerick local pool temperature and the related NUREG-0783 pool temperature limits are presented in Section I.3.5.

I.3.2 SRV-H BLOWDOWN UNDER HIGH REACTOR PRESSURE

Figure I.3-1 shows that the quasi-steady state local-to-bulk ΔT is about 8.6°F for SRV-H blowdown under high reactor pressure. The calculation of the local temperature is described in Section I.3.1. The bulk pool temperature is calculated by KFIXTM and is based on a mass-energy balance assuming that the pool is a uniform heat sink.

I.3.3 SRV-L BLOWDOWN UNDER HIGH REACTOR PRESSURE

Figure I.3-4 illustrates that the predicted local pool temperature follows the bulk pool temperature closely for SRV-L blowdown under high reactor pressure (i.e., local-to-bulk ΔT is minimal). The favorable thermal mixing characteristics associated with this analysis result from the combination of the quencher location (outer ring) and its orientation.

I.3.4 SRV-H BLOWDOWN UNDER LOW REACTOR PRESSURE

Section I.3.2 shows that a peak local-to-bulk ΔT of approximately 8.6°F is calculated for the high reactor pressure and relatively low pool temperature conditions. At this time in the transient, the steam flux through the active quencher is greater than 94 lbm/ft² sec. As discussed in Section I.2.1, the NUREG-0783 local pool temperature limit at this flux is 200°F. Because the bulk pool temperature is much lower than 200°F at high reactor pressures (Figures I.2-1 through I.2-6), the local-to-bulk ΔT is relatively unimportant at these conditions.

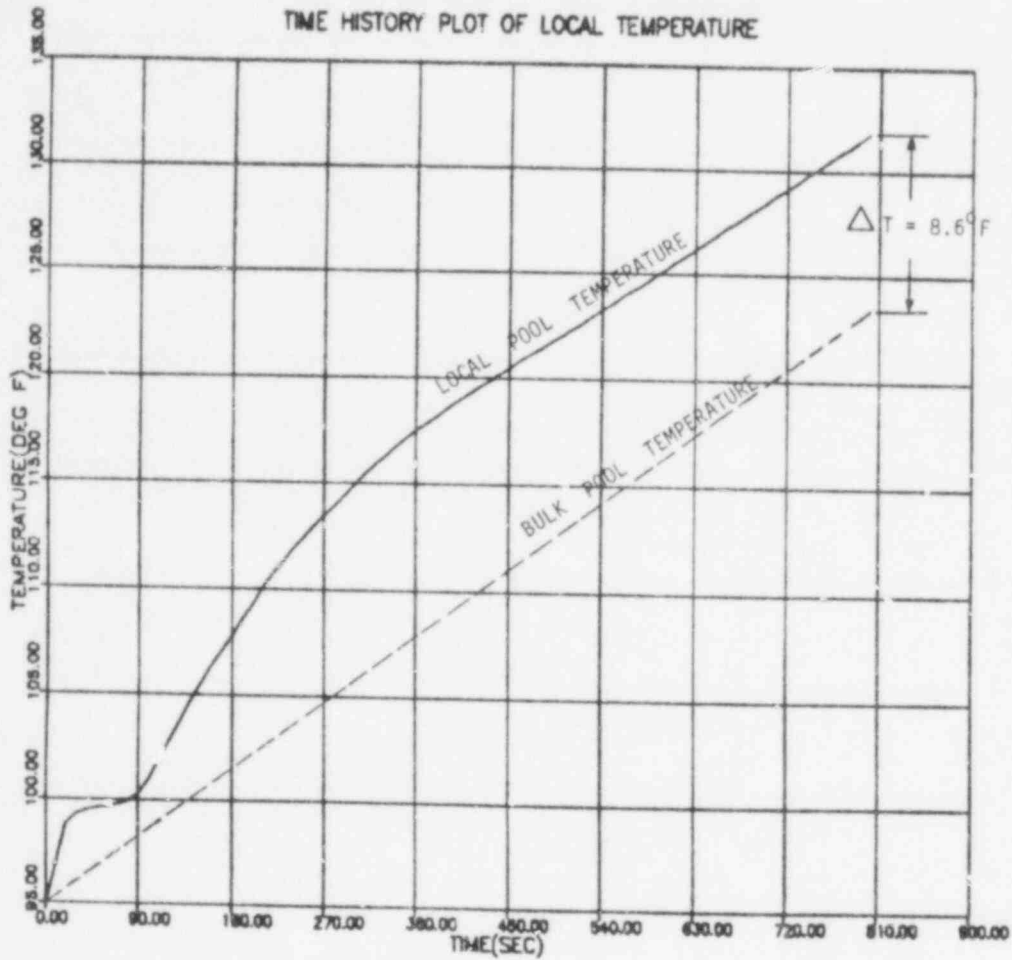
As the reactor depressurizes and SRV flow rate decreases, the momentum transfer to the pool (i.e., pool mixing) decreases. The bulk pool temperature continues to increase and the local-to-bulk ΔT gains significance. Therefore, the KFIXTM code is used to quantify the local-to-bulk ΔT at low reactor pressure and to verify that the high reactor pressure ΔT calculated earlier is conservative with respect to the low reactor pressure ΔT .

Figure I.3-7 shows the bulk temperature trace along with the code predicted local temperature trace and overall average temperature trace (of all fluid cells) for SRV-H blowdown under low reactor pressure. The slight deviations between the bulk pool temperature and the KFIXTM predicted overall average temperature are due to the minor inaccuracies of KFIXTM temperature predictions under low reactor pressure and elevated pool temperature conditions (Section I.1.2.3). Regardless of the apparent inaccuracy, the local pool temperature adheres closely to the overall average temperature and the local-to-bulk ΔT for the low pressure scenario is both minimal and bounded by the ΔT for the high pressure scenario.

I.3.5 CONCLUSION

The local pool temperature limits stipulated in NUREG-0783 have been restated in Section I.2.1. Figures I.2-1 to I.2-6 plot these pool temperature limits relative to the bulk temperature time histories for the six mass and energy cases described in Section I.2.2. The local temperature limits have been converted to bulk limits by applying a local-to-bulk ΔT equal to 10°F. A local-to-bulk ΔT of 10°F was previously derived for ramshead discharge devices in Mark I plants (Ref. I.2-2). Figures I.2-1 to I.2-6 indicate that adequate margin exists between the NUREG-0783 local limits (converted to bulk limits by 10°F ΔT) and the calculated bulk temperatures from the mass and energy analyses. The minimum margin occurs for Case 3.a near the end of the transient at low reactor pressure when the maximum bulk temperature peaks at 202°F (Figure I.2-5).

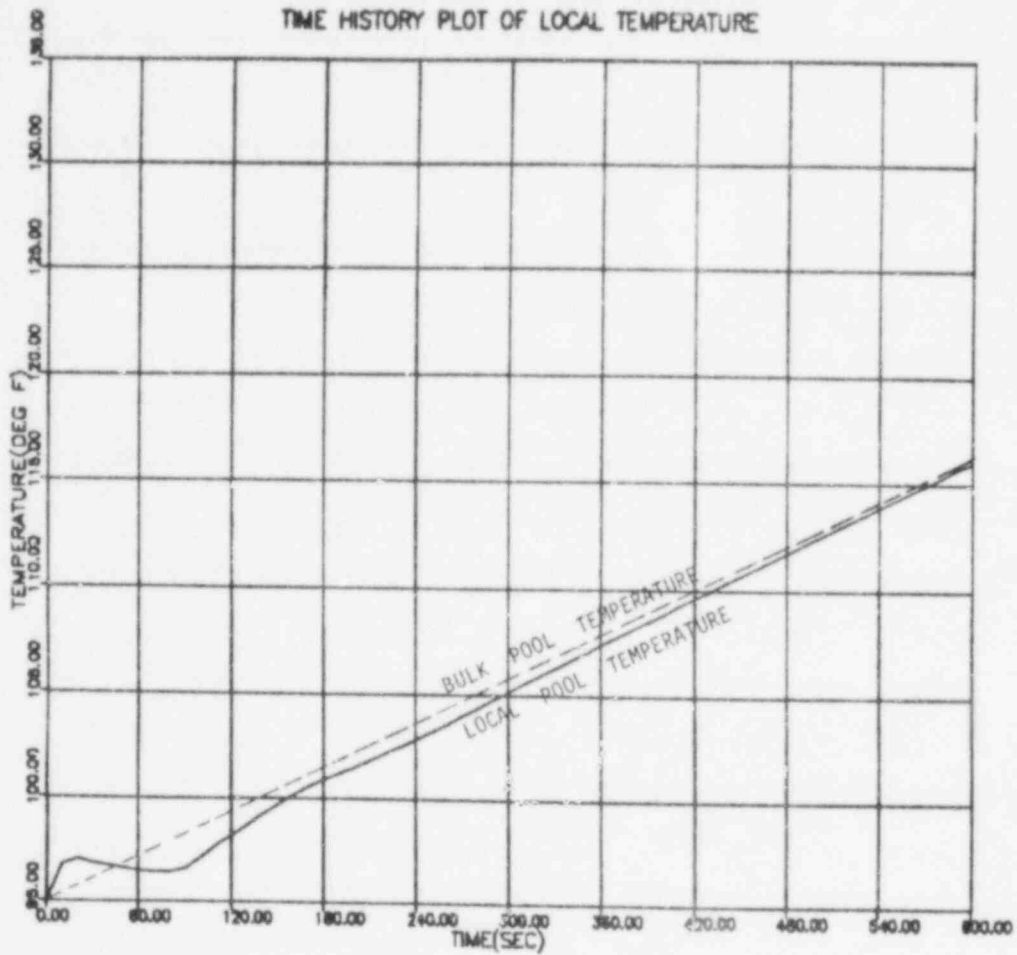
The peak calculated local-to-bulk ΔT has been established to be 8.6°F for SRV-H blowdown under high reactor pressure (Section I.3.2) and is adequately bounded by 10°F ΔT . In addition, the results of the low reactor pressure analysis (Section I.3.4) confirm that the low reactor pressure ΔT is much lower than the high pressure ΔT . Therefore, Limerick has demonstrated that the NUREG-0783 maximum local pool temperature specification will not be exceeded.



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LOCAL-TO-BULK
TEMPERATURE DIFFERENCE (ΔT)
TRACE FOR SRV-H BLOWDOWN UNDER
HIGH REACTOR PRESSURE

FIGURE I.3-1
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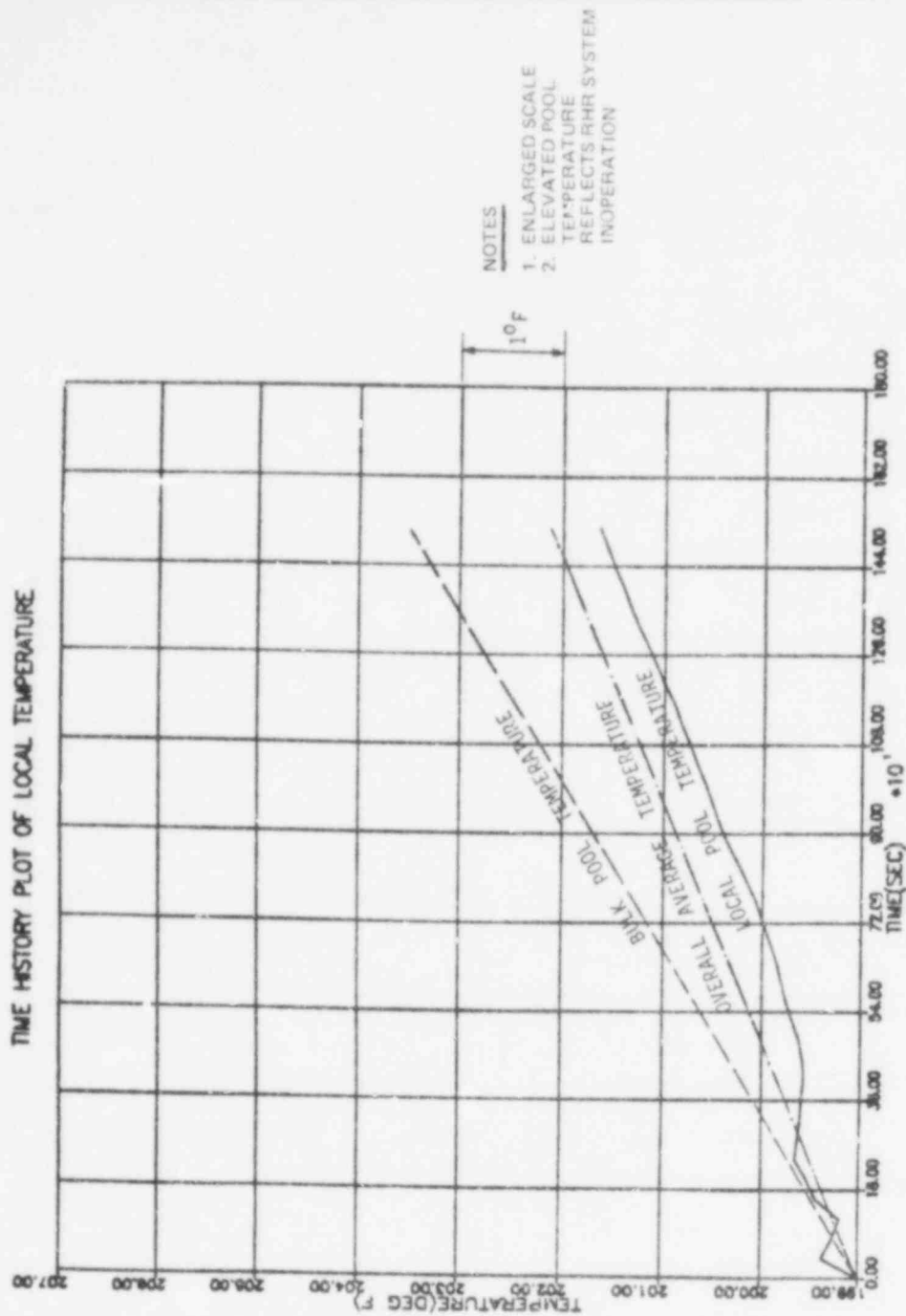


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LOCAL-TO-BULK
 TEMPERATURE DIFFERENCE (ΔT)
 TRACE FOR SRV-L BLOWDOWN
 UNDER HIGH REACTOR PRESSURE

FIGURE I.3-2

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LOCAL-TO-BULK
 TEMPERATURE DIFFERENCE (ΔT)
 TRACE FOR SRV-H BLOWDOWN UNDER
 LOW REACTOR PRESSURE

FIGURE I.3-3 REV. 7, 01/84