GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

GE-NE-T23007400-2
DRF T23-00740
CLASS II
DECEMBER 1996

Dresden Nuclear Power Station
Units 2 and 3
Containment Analyses of the DBA-LOCA
Based on Long-Term
LPCI/Containment Cooling System Configuration of
One LPCI/Containment Cooling System Pump and 2 CCSW Pumps

Additional Sensitivity Analyses

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IMPORTANT INFORMATION REGARDING

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ABSTRACT

This report provides the results from an evaluation of the Dresden containment response during the limiting design basis loss-of-coolant accident (DBA-LOCA). The analyses in this report assume that for vessel liquid makeup two low pressure coolant injection (LPCI) pumps and one core spray (CS) pump are available during the time period prior to initiation of long-term containment cooling. One CS pump is available for vessel makeup after containment cooling is initiated. The analyses further assume that to initiate containment cooling, operation of two LPCI pumps is switched to containment cooling mode by operating one LPCI/Containment Cooling pump and two containment cooling service water (CCSW) pumps. The analysis results presented in this report can be used by ComEd to evaluate available NPSH for pumps taking suction from the suppression pool. This report also provides an evaluation of the LPCI/Containment Cooling System heat exchanger performance for the containment cooling configuration analyzed in this report.

1.0 INTRODUCTION

References 1 and 2 provided the long-term containment response to the DBA-LOCA for Dresden Units 2 and 3. Analyses described in these two references assumed two long-term containment cooling configurations: a) one LPCI/Containment Cooling pump and one containment cooling service water (CCSW) pump, b) two LPCI/Containment cooling pumps and two CCSW pumps.

Additional analyses were provided in References 3, 4 and 5 which assumed the following ECCS and containment cooling configuration.

2 LPCI/Containment Cooling Pump and 1 core spray (CS) pump up to 600 seconds following the DBA-LOCA.

1 LPCI/Containment Cooling Pump, 2 CCSW pumps and 1 CS pump after 600 seconds.

Per Reference 6, the tasks described in Section 1.1 are performed to provide additional analyses of the suppression pool temperature and suppression chamber pressure response for a long-term containment cooling configuration of one LPCI/Containment Cooling pump and two CCSW pumps. This report presents the results of this evaluation.

1.1 SCOPE OF WORK

The work scope consists of two tasks, as described below.

Task 1 - Heat Exchanger Performance Evaluation

An evaluation is performed of the heat exchanger performance for a long-term containment cooling configuration consisting of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and one LPCI/Containment Cooling heat exchanger. The evaluation is based on a below rated LPCI/Containment Cooling pump flow rate of 4611 gpm and a combined 2 CCSW pump flow of 5400 gpm.

The evaluation of the heat exchanger performance utilizes the results from the heat exchanger performance work performed in 1992 (Reference 7), which determined a heat exchanger heat transfer rate of 98.6 MBTU/hr based on a tube side flow of 7000 gpm and a shell side flow of

10,700 gpm, and a shell side inlet temperature of 165 °F and a tube side inlet temperature of 95 °F.

Task 2 - Evaluation of DBA-LOCA Containment Response

In Task 2, analyses are performed to evaluate the containment short-term and long-term pressure and temperature response following the DBA-LOCA. "Short-term" is defined for this report as the time period from the beginning of the DBA-LOCA to the time at which operator actions can be credited to initiate containment cooling or to control pump flows. For both the short-term and long-term analyses, the SHEX computer code is used.

A total of eight (8) cases are performed with the GE computer model SHEX to determine the short-term (prior to initiation of containment cooling) and long-term (after initiation of containment cooling) suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA.

For all cases it is assumed that during the time period prior to initiation of containment cooling (10 minutes or 30 minutes) 2 LPCI/Containment Cooling pumps and 1 CS pump are used for vessel makeup purposes. It is assumed that during this time period the pump flow for the 2 LPCI/Containment Cooling pumps is at the above nominal flow rate of 5800 per pump and that the CS pump flow is at the above nominal flow rate of 5800 per pump. It is assumed that when containment cooling is initiated (10 minutes or 30 minutes) the operator shuts down 1 LPCI/Containment Cooling pump and aligns 1 LPCI/Containment Cooling pumps from vessel injection mode to containment cooling mode. At this time the operator reduces the LPCI/Containment Cooling pump flow to the nominal flow of 5000 gpm per pump (except for Cases S-4a and S-4b which assume a flow rate of 4611 gpm) and the CS pump flow to the nominal pump flow of 4500 gpm. At the same time two CCSW pumps and one LPCI/Containment Cooling System heat exchanger are lined up for long-term containment cooling. The resulting long-term containment cooling configuration consists of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and 1 LPCI/Containment Cooling heat exchanger.

The 307.4 BTU/°F-sec K value (see Section 7 for a definition of K) is used for a rated LPCI/Containment Cooling pump flow rate of 5000 gpm and a combined 2 CCSW pump flow of 7000 gpm (Reference 3). The 288.0 BTU/°F-sec K value is used for a rated LPCI/Containment

Cooling pump flow rate of 5000 gpm and a combined 2 CCSW pump flow of 5400 gpm (Reference 5).

The analysis uses the heat exchanger K value obtained from Task 1 for the below rated LPCI/Containment Cooling pump flow rate of 4611 gpm and a combined 2 CCSW pump flow of 5400 gpm

All cases use heat sinks to minimize containment pressure.

In Task 2, various cases as described in Section 7 were analyzed, assuming various combinations of pump flow rates and different heat exchanger performance values. Cases have also been analyzed using different assumptions on thermal mixing efficiency between the break liquid and drywell atmosphere to determine the effect of this parameter on the suppression chamber pressure response. One case was analyzed to determine the effect of applying a 10% adder to the ANS 5.1 -1979 decay heat. See Section 7 for a description of all cases.

2.0 RESULTS

The results for each of the two tasks described in Sections 1 and 7 are presented in the following paragraphs.

Task 1 Calculation of Heat Exchanger Performance (K Value Calculation)

The calculated heat exchanger K value is given in Table 1 for a one LPCI/Containment Cooling pump flow of 4611 gpm. (See Section 7 for the definition of K-value.) A combined two CCSW pump flow of 5400 gpm is assumed, with a shell side inlet temperature of 165°F and a tube side inlet temperature of 95°F.

Task 2 - Calculation of Suppression Pool Temperature and Suppression Chamber Pressure

Table 3 contains a summary of the results of the containment analyses performed for the various cases performed for Task 2. (See Section 7 for a description of the cases analyzed.) This table shows:

Suppression pool temperature and suppression chamber pressure at initiation of operator actions (10 minutes or 30 minutes)

Minimum suppression chamber pressure following initiation of containment (drywell and suppression chamber) sprays

Suppression pool temperature and suppression chamber pressure at the time of the peak suppression pool temperature

Figures 1-16 show the suppression pool temperature and suppression chamber pressure responses.

The analyses for Cases S-1 and S-2 assumed 0% for the thermal mixing efficiency between the break flow and drywell atmosphere. A comparison was made between Case S-1 and Case 2a1 (20% mixing efficiency) of Reference 4 which is identical to Case S-1 except for the thermal mixing efficiency. This comparison shows that the reduction in the thermal mixing efficiency from 20% to 0% produces reduction of a 0.7 psi in the minimum suppression chamber pressure following initiation of containment sprays and a reduction of 0.6 psi at the time of the peak suppression pool temperature. This occurs since the break fluid is hotter than the drywell atmosphere temperature following initiation of containment sprays. Therefore, a reduction in the mixing efficiency results in a cooler drywell temperature which reduces both drywell and wetwell pressure.

The effect of a delay in the operator action initiation time to 30 minutes is obtained from a comparison of Cases S-4a and S-4b. The additional 20 minute delay in initiation of operator actions produces an increase of approximately 13°F in the pool temperature at the time operator actions are initiated. This is due to the additional decay and vessel energy which is transferred to the suppression pool during the additional 20 minute delay period. In addition, the containment pressure for Case S-4b at the initiation of operator action is 8 psi lower than the value obtained for Case S-4a. This is attributed to the additional time available for mixing of the drywell atmosphere with the relatively colder vessel break liquid prior to initiation of operator actions. This additional time for mixing results in a colder drywell temperature and lower drywell and suppression chamber pressures when operator actions are initiated.

A comparison of Cases S-3a (20% thermal mixing) and S-3b (100% thermal mixing) shows that with a 30 minute operator delay time an increase in the thermal mixing efficiency from 20% to 100% will have a small (0.1 psi) effect on the suppression chamber pressure at the time operator action is initiated. This is explained by the fact that with a longer delay there is sufficient time for the drywell pressure to be reduced to its minimum value (prior to initiation of sprays) with either thermal mixing efficiency assumption. A comparison of the peak suppression pool temperature between Cases S-4a and S-4b shows that the 20 minute additional delay in containment cooling produces a 1°F increase in the peak suppression pool temperature.

A comparison of Case S-6 (1.1* ANS 5.1-1979) with Case 4a1 (ANS 5.1- 1979) of Reference 5 which is the same as Case S-6 except for the decay heat, shows that a 10% adder to the ANS 5.1-1979 decay heat results in an increase of 4°F in the peak suppression pool temperature.

3.0 DESIGN ASSUMPTIONS AND ENGINEERING JUDGMENTS

Input assumptions are used which maintain the overall conservatism in the evaluation by maximizing the suppression pool temperature. Additionally, the input assumptions are chosen to conservatively minimize the suppression chamber pressure and, therefore, minimize the available NPSH. The key input assumptions which are used in performing the Dresden containment DBA-LOCA pressure and temperature response analysis are described below. Table 4 provides values of key containment parameters common to all cases, while Table 5 and Table 6 provide case-specific inputs.

1. The reactor is assumed to be operating at 102% of the rated thermal power, per Reg. Guide 1.49.

2. Vessel blowdown flow rates are based on the Homogeneous Equilibrium Model (Reference 5).

3. The core decay heat is based on ANSI/ANS-5.1-1979 decay heat (Reference 9) without adders. For Case S-6, a multiplication factor of 1.1 is applied to this decay heat.

4. Feedwater flow into the RPV continues until all the feedwater above 180°F is injected into the vessel.

5. Thermodynamic equilibrium exists between the liquids and gases in the drywell.

6. The held-up liquid in the drywell airspace from the liquid break flow which does not flash is assumed to be negligible (0%), partial (20%) or full (100%), depending upon cases to minimize the containment pressure. Thermal

equilibrium conditions are imposed between the held-up liquid and the fluids in the drywell as described in Assumption No. 5 above. The liquid not held up is assumed to flow directly to the suppression pool without heat transfer to the drywell fluids.

7. The vent system flow to the suppression pool consists of a homogeneous mixture of the fluid in the drywell.

8. The initial suppression pool volume is at the minimum Technical Specification (T/S) limit to maximize the calculated suppression pool temperature.

9. The initial drywell and suppression chamber pressure are at the minimum expected operating values to minimize the containment pressure.

10. The maximum operating value of the drywell temperature of 150°F and a relative humidity of 100% are used to minimize the initial non-condensible gas mass and minimize the long-term containment pressure for the NPSH evaluation.

11. The initial suppression pool temperature is at the maximum T/S value (95°F) to maximize the calculated suppression pool temperature.

12. Consistent with the UFSAR analyses, containment sprays are available to cool the containment. Once initiated, it is assumed that containment sprays are operated continuously with no throttling of the LPCI/Containment Cooling pumps below the initial spray flow rate.

13. Heat sinks are used in the analyses to minimize containment pressure. Heat sink inputs were developed based on the Dresden drywell and torus geometry parameters which were compiled and used during the Mark I Containment Long Term Program and which are documented in Reference 13. The drywell and torus shell condensation heat transfer coefficient is based on the Uchida correlation with a 1.2 multiplier.

14. All Core Spray and LPCI/Containment Cooling system pumps have 100% of their horsepower rating converted to a pump heat input which is added either to the RPV liquid or suppression pool water.

15. Heat transfer from the primary containment to the reactor building is neglected.

16. Although a containment atmospheric leakage rate of 5% per day is used to determine the available NPSH in UFSAR Section 6.3, containment leakage is not included in the analyses in Task 2. Including containment leakage has no impact on the peak suppression pool temperature, but will slightly reduce the calculated containment pressure. A leakage rate of 5% per day is considered to be unrealistically large since the Dresden T/S limits the allowable leakage to 1.6 % per day. Use of the leakage rate of 1.6 % per day would result in less than a 0.1 psi reduction in the containment pressures calculated in the analysis. This effect is neglected in the analysis considering that conservative input assumptions are used to minimize containment pressure

4.0 INPUT DOCUMENTATION

4.1 Inputs

The initial conditions and key input parameters used in the long-term containment pressure and temperature analysis are provided in Tables 3, 4, 5 and 6. These are based on the current Dresden containment data which was confirmed by ComEd in Reference 10.

Appendix A provides the core decay heat values used in the analysis, based on the ANSI/ANS-5.1-1979 model.

Reference 7 provided by ComEd, contains the LPCI/Containment Cooling pump CS pump and CCSW pump flow rates used for the analyses performed for this report.

4.2 Industry Codes and Standards

The core decay heat used for the containment analysis is based on the ANSI/ANS-5.1-1979 decay heat model (Reference 9).

5.0 REGULATORY REQUIREMENTS

The analysis are performed with an initial reactor thermal power level of 102% of the rated reactor thermal power, per Regulatory Guide 1.49.

Pertinent sections of the UFSAR which are affected by the results of this report are UFSAR Sections 6.2 and 6.3.

6.0 LIMITATIONS OF APPLICABILITY

The results of the analysis described in this report are based on the inputs identified in Section 4.0. Any changes to these inputs should be reviewed to determine the impact on the results and conclusions reported here.

7.0 CALCULATIONS AND COMPUTER CODES

7.1 Calculation Record

The calculations used for this report are documented in the GE Design Record File DRF T23-00740.

7.2 Model Description

The GE computer code SHEX is used to perform the analysis of the containment pressure and temperature response. The SHEX code has been validated in conformance with the requirements of the GE Engineering Operating Procedures (EOPs). In addition, Reference 2 provided a benchmark analysis to validate the code for a plant-specific application to Dresden was performed.

SHEX uses a coupled reactor pressure vessel and containment model, based on the Reference 11 and Reference 12 models which have been reviewed and approved by the NRC, to calculate the transient response of the containment during the LOCA. This model performs fluid mass and energy balances on the reactor primary system and the suppression pool, and calculates the reactor vessel water level, the reactor vessel pressure, the pressure and temperature in the drywell and suppression chamber airspace and the bulk suppression pool temperature. The various modes of operation of all important auxiliary systems, such as SRVs, the MSIVs, the ECCS, the RHR system (the LPCI/Containment Cooling System when applied to Dresden) and feedwater, are modeled. The model can simulate actions based on system setpoints, automatic actions and operator-initiated actions.

7.3 Analysis Approach

Task 1 - Evaluation of LPCI/Containment Cooling Heat Exchanger Heat Transfer Rate

The heat exchanger heat transfer rate as defined by K is used in the analyses performed with the GE SHEX code. The definition of K is given below:

$K = Q/[(T_{si}-T_{ti})*3600]$

Where

K - heat exchanger heat transfer rate (BTU/sec-°F)
Q = heat exchanger heat transfer rate (BTU/hr)
$T_{si}-T_{ti}$ = Temperature difference between the shell side and tube side inlet temperatures (°F).

The heat exchanger performance (K) for a long-term containment cooling configuration consisting of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and one LPCI/Containment Cooling heat exchanger was evaluated assuming a LPCI/Containment Cooling pump flow of 4611 gpm and a combined flow of 5400 gpm from two CCSW pumps

The evaluation of the heat exchanger performance was based on the heat exchanger performance work performed in 1992 (Reference 7), which determined a heat exchanger heat transfer rate of 98.6 MBTU/hr based on a tube side flow of 7000 gpm with a tube side inlet temperature of 95°F and a shell side flow of 10,700 gpm with a shell side inlet temperature of 165°F.

The overall heat transfer rate (U) with the new LPCI/Containment Cooling pump flow (4611 gpm) and new CCSW pump flow (5400 gpm) was revised by adjusting the tube side and shell side heat transfer coefficients based on the new pump flows. New values of K were then calculated with the NTU-effectiveness method for a shell and tube heat exchanger geometry.

This method was validated by a calculation of the K value with tube side flow of 3500 gpm with a tube side inlet temperature of 95°F and a shell side flow of 5000 gpm with a shell side inlet temperature of 165°F. The resultant value of 249.5 BTU/sec-°F closely matches the K value of 249.6 BTU/sec-°F previously calculated by GE for this configuration.

Appendix B provides a detailed discussion of the method used to determine the heat exchanger performance for off-rated pump flows.

The calculated K value for a LPCI/Containment Cooling pump flow of 4611 gpm and a combined flow of 5400 gpm from two CCSW pumps is given in Table 1.

Task 2 - Calculation of Suppression Pool Temperature and Suppression Chamber Pressure

The objective of this task is to determine the short-term (prior to initiation of operator actions) and long-term (following initiation of operator actions) suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA. The GE computer model SHEX-04 (References 8 and 9) with decay heat based on the ANS 5.1 1979 decay heat model (without adders) was used in the analyses. Analyses performed to benchmark analyses with the SHEX-04 code to the Dresden FSAR analyses were documented in Reference 2. The bench-marking analyses in Reference 2 included sensitivity studies to quantify the effect on peak suppression pool temperature due to differences between the updated analysis and the FSAR original analysis.

Key input assumptions for the present analyses are consistent with the general containment parameters used in the analyses of References 1 through 5, as confirmed in Reference 10.

<u>Operator Actions</u>

For all cases it is assumed that during the time period prior to initiation of containment cooling (10 minutes or 30 minutes) 2 LPCI/Containment Cooling pumps and 1 CS pump are used for vessel makeup purposes. It is assumed that during this time period the pump flow for the 2 LPCI/Containment Cooling pumps is at the above nominal flow rate of 5800 per pump and that the CS pump flow is at the above nominal flow rate of 5800 per pump. It is assumed that when containment cooling is initiated (10 minutes or 30 minutes) the operator shuts down 1 LPCI/Containment Cooling pump and aligns 1 LPCI/Containment Cooling pumps from vessel injection mode to containment cooling mode. At this time the operator reduces the LPCI/Containment Cooling pump flow to the nominal flow of 5000 gpm per pump (except for Cases S-4a and S-4b which use a flow rate of 4611 gpm) and the CS pump flow to the nominal pump flow of 4500 gpm. At the same time two CCSW pumps and one LPCI/Containment Cooling System heat exchanger are lined up for long-term containment cooling. The resulting long-term containment cooling configuration consists of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and 1 LPCI/Containment Cooling heat exchanger.

Heat Exchanger Performance

The 307.4 BTU/°F-sec K value is used for a rated 1 LPCI/Containment Cooling pump flow rate of 5000 gpm and a combined 2 CCSW pump flow of 7000 gpm (Reference 3). The 288.0 BTU/°F-sec K value is used for a rated 1 LPCI/Containment Cooling pump flow rate of 5000 gpm and a combined 2 CCSW pump flow of 5400 gpm (Reference 5).

The analysis uses the heat exchanger performance value obtained from Task 1 for the below rated LPCI/Containment Cooling pump flow rate of 4611 gpm and a combined 2 CCSW pump flow of 5400 gpm

Thermal Mixing Efficiency

All cases assume either 20% or 100% thermal mixing efficiency. However, for Cases S-1 and S-2 a thermal mixing efficiency of 0% between the break liquid and drywell atmosphere is assumed to evaluate this parameter. Previous GE analyses have used a thermal mixing efficiency of 20% to minimize containment pressure for analyses which are used to evaluate NPSH. The basis for the value of 20% is based on model-test data comparisons which are described in Reference 14. According to Reference 14 a thermal mixing efficiency of approximately 40% produces analysis results with the SHEX code which best matches test data with respect to drywell pressure. Higher values produce higher drywell pressures than predicted and lower values produce lower drywell pressures than predicted. Therefore 20% was chosen as a conservatively low value to minimize drywell and consequently minimize suppression chamber pressure. While a value of 20% is considered to be a conservative low value, a thermal mixing efficiency of 0% is considered non-realistic and is therefore not used for design application

Initial Conditions

Table 3 identifies input values used to minimize the suppression chamber pressure response. Initial conditions for all cases are used to minimize the suppression chamber pressure response.

Heat Sinks

For all cases the drywell shell, vent system and torus shell are modeled as heat sinks. Heat sinks used were developed based on the Dresden drywell and torus geometry parameters which were compiled during the Mark I Containment Long Term Program and which are documented in Reference 13.

Case Specific Assumptions

Case-specific containment input parameters for the different cases are summarized in Tables 5 and 6. Except as identified below and in Tables 5 and 6, the input values used in the analyses for this report are the same as previously used in the analysis described in References 1 through 5.

A description of assumptions for the 8 containment analysis cases is provided below including containment cooling initiation times and pump flow rate.

The cases are labeled Case S-1 through S-6 per Reference 6.

Short-Term Pump Flow Configuration

The short-term is defined as the time prior to initiation of containment cooling (10 minutes or 30 minutes). The pump flow configuration during the short-term is the same for all cases:

> 2 LPCI/Containment Cooling Pump (10600 gpm) and 1 core spray (CS) pump (5800 gpm) up to 600 seconds following the DBA-LOCA.

Long-term Pump Flow Configuration

Long-term is defined as the time period following initiation of containment cooling. The long-term pump flow configuration and the containment cooling initiation times are given below.

Case S-1

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (7000 gpm) and 1 CS pump (4500 gpm) after 10 minutes. 0 % thermal mixing efficiency of break liquid. Containment cooling initiated at 10 minutes.

Case S-2

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (5400 gpm) and 1 CS pump (4500 gpm) after minutes. 0 % thermal mixing efficiency of break liquid. Containment cooling initiated at 10 minutes.

Case S-3a

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (7000 gpm) and 1 CS pump (4500 gpm) after 30 minutes. 20 % thermal mixing efficiency of break liquid. Containment cooling initiated at 30 minutes.

Case S-3b

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (7000 gpm) and 1 CS pump (4500 gpm) after 30 minutes. 100 % thermal mixing efficiency of break liquid. Containment cooling initiated at 30 minutes.

Case S-4a

1 LPCI/Containment Cooling Pump (4611 gpm), 2 CCSW pumps (5400 gpm) and 1 CS pump (4500 gpm) after 10 minutes. 20 % thermal mixing efficiency of break liquid. Containment cooling initiated at 10 minutes.

Case S-4b

1 LPCI/Containment Cooling Pump (4611 gpm), 2 CCSW pumps (5400 gpm) and 1 CS pump after 30 minutes. 20 % thermal mixing efficiency of break liquid. Containment cooling initiated at 30 minutes.

Case S-5

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (5400 gpm) and 1 CS pump (4500 gpm) after 30 minutes. 20 % thermal mixing efficiency of break liquid. Containment cooling initiated at 30 minutes

Case S-6

1 LPCI/Containment Cooling Pump (5000 gpm), 2 CCSW pumps (5400 gpm) and 1 CS pump after 10 minutes. 20 % thermal mixing efficiency of break liquid. Containment cooling initiated at 10 minutes. ANS 5.1-1979 decay heat will be used with a 1.1 multiplier on decay heat.

8.0 Q/A RECORDS

All work performed to produce this document and supporting background information is contained in the GE Design Record File DRF T23-00740.

9.0 REFERENCES

1) GENE-770-26-1092, "Dresden Nuclear Power Station, Units 2 and 3, LPCI/Containment Cooling System Evaluation," November 1992.

2) GENE-637-042-1193, "Dresden Nuclear Power Station, Units 2 and 3, Containment Analyses of the DBA-LOCA to Update the Design Basis for the LPCI/Containment Cooling System, February 1994.

3) Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for Limiting DBA-LOCA," October 23, 1996

4) Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for Limiting DBA-LOCA," October 31, 1996

5) Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for the Limiting DBA-LOCA, " November 18, 1996.

6) Letter, K. Dias to S. Konrad, "Dresden Nuclear Station, Change Order Request for Purchase Order 118064, Proposal for Analysis of HX Performance and Suppression Pool Temperature and Chamber Pressure, GE #523-1GY5D-EB0, Revision," November 28, 1996.

7) Letter, S. Mintz to S. L. Eldridge/B. M. Viehl, "Dresden LPCI/Containment Cooling System - Comparison of Heat Exchanger Heat Transfer Rates, December 28, 1992.

8) NEDO-21052, "Maximum Discharge Rate of Liquid-Vapor Mixtures from Vessels," General Electric Company, September 1975.

9) "Decay Heat Power in Light Water Reactors," ANSI/ANS - 5.1 - 1979, Approved by American National Standards Institute, August 29, 1979.

10) Letter, J. W. Dingler (ComEd) to J. Nash (GE), "Inputs Parameter for Suppression Pool Pressure and Temperature Analysis," October 1996.

11) NEDM-10320, "The GE Pressure Suppression Containment System Analytical Model," March 1971.

12) NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," June 1974.

13) GE Document 22A5743 and GE Document 22A5744, Containment Data, September 1982. (Customer Interface Data Documents for Dresden 2 and Dresden 3 respectively).

14) NEDE-30911, "SHEX-04 User's Manual," August 1985.

TABLE 1 - Heat Exchanger Heat Transfer Rate

Shell Side Flow Rate (LPCI/Containment Cooling Pump) (GPM)	Tube Side Pump Flow Rate (CCSW Pump) (GPM)	K-Value (BTU/SEC-°F.)	Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature) (Million BTU/hr.)
4611	5400	279.1	70.3

TABLE 2 SUMMARY OF DRESDEN CONTAINMENT ANALYSIS RESULTS

CASE	S-1	S-2	S-3a	S-3b
Containment Cooling Initiated (minutes)	10	10	30	30
Heat Exchanger K Value (Btu/°F-sec)	307.4	288.0	307.4	307.4
Thermal Mixing Efficiency (%)	0	0	20	100
Heat Sinks considered (y/n)	y	y	y	y
Suppression Pool Temperature (°F) at initiation of operator actions	148	148	161	161
Suppression Chamber Airspace Pressure at initiation of operator actions (psig)	20.5	20.5	4.4	4.4
Minimum Suppression Chamber Pressure Following Initiation of Containment Spray (psig)	1.2	1.3	1.7	3.1
Peak Long-term Suppression Pool Temperature (°F)	172	175	174	174
Suppression Chamber Airspace Pressure at of Peak Suppression Pool Temperature (psig)	2.3	2.5	3.1	5.0

TABLE 2 - SUMMARY OF DRESDEN CONTAINMENT ANALYSIS RESULTS
(continued)

CASE	S-4a	S-4b	S-5	S-6
Containment Cooling Initiated (minutes)	10	30	30	10
Heat Exchanger K Value (Btu/°F-sec)	279.1	279.1	288.0	288.0
Thermal Mixing Efficiency (%)	20	20	20	20
Heat Sinks considered (y/n)	y	y	y	y
Suppression Pool Temperature (°F) at initiation of operator actions	149	161	161	149
Suppression Chamber Airspace Pressure at initiation of operator actions (psig)	11.3	4.4	4.4	11.3
Minimum Suppression Chamber Pressure Following Initiation of Containment Spray (psig)	2.0	1.8	1.8	2.3
Peak Long-term Suppression Pool Temperature (°F)	176	177	176	180
Suppression Chamber Airspace Pressure at of Peak Suppression Pool Temperature (psig)	3.4	3.5	3.5	3.8

TABLE 3 - Initial Conditions used to Minimize the Suppression Chamber Pressure

Initial Conditions	Value
Initial Drywell Temperature (°F)	150
Initial Drywell Relative Humidity (%)	100
Initial Drywell Pressure (psig)	1.0
Initial Wetwell Pressure (psig)	0.0

TABLE 4- Input Parameters for Containment Analysis

Parameter	Units	Value Used In Analysis
Core Thermal Power	MWt	2578
Vessel Dome Pressure	psia	1020
Drywell Free (Airspace) Volume (including vent system)	ft^3	158236
Initial Suppression Chamber Free (Airspace) Volume at Low Water Level (LWL)	ft^3	120097
Initial Suppression Pool Volume at LWL	ft^3	112000
No. of Downcomers		96
Total Downcomer Flow Area	ft^2	301.6
Initial Downcomer Submergence	ft	3.67
Downcomer I.D.	ft	2.00
Vent System Flow Path Loss Coefficient (includes exit loss)		5.17
Supp. Chamber (Torus) Major Radius	ft	54.50
Supp. Chamber (Torus) Minor Radius	ft	15.00
Suppression Pool Surface Area (in contact with suppression chamber airspace)	ft^2	9971.4

Table 4 - Input Parameters for Containment Analysis (continued)

Parameter	Units	Value Used in Analysis
Suppression Chamber-to-Drywell Vacuum Breaker Opening Diff. Press.		
- start	psid	0.15
- full open	psid	0.5
Supp. Chamber-to-Drywell Vacuum Breaker Valve Opening Time	sec	1.0
Supp. Chamber-to-Drywell Vacuum Breaker Flow Area (per valve assembly)	ft^2	3.14
Supp. Chamber-to-Drywell Vacuum Breaker Flow Loss Coefficient (including exit loss)		3.47
No. of Supp. Chamber-to-Drywell Vacuum Breaker Valve Assemblies (2 valves per assembly)		6
LPCI/Containment Cooling Heat Exchanger K in Containment Cooling Mode	Btu/sec-°F	See Table 6
LPCI/Containment Cooling Service Water Temperature	°F	95
LPCI/Containment Cooling Pump Heat (per pump)	hp	700
Core Spray Pump Heat (per pump)	hp	800
Time for Operator to Turn On LPCI/Containment Cooling System in Containment Cooling Mode (after LOCA signal)	sec	See Table 5

Table 4 - Input Parameters for Containment Analysis (continued)

Feedwater Addition (to RPV after start of event; mass and energy)

Feedwater Node **	Mass (lbm)	Enthalpy * (Btu/lbm)
1	34658	308.0
2	96419	289.2
3	145651	268.7
4	91600	219.8
5	65072	188.4

* Includes sensible heat from the feedwater system piping metal.
** Feedwater mass and energy data combined to fit into 5 nodes for use in the analysis.

TABLE 5- PUMP FLOWS FOR DBA-LOCA CONTAINMENT ANALYSIS

	CASE S-1	CASE S-2	CASE S-3A S-3B	CASE S-4A S-4B	CASE 5	CASE 6
CONTAINMENT COOLING INITIATION TIME (Minutes) This time is denoted as "T" in this Table.	10	10	30	10 - S-4A 30 - S-4B	30	10
CORE SPRAY PUMP FLOW** (GPM)						
$0 < t \leq T$	5800	5800	5800	5800	5800	5800
$t > T$	4500	4500	4500	4500	5800	5800
LPCI/CONTAINMENT COOLING PUMP FLOW (GPM)						
$0 < t \leq T$ (2 Pumps, LPCI vessel injection mode*)	11,600	11,600	11,600	11,600	11,600	11,600
$t > T$ (1 Pump, Containment Cooling Mode with Drywell and Suppression Chamber Spray)	5000	5000	5000	4611	5000	5000
CCSW PUMP FLOW (GPM)	7000	5400	7000	5400	5400	5400

*LPCI/Containment Cooling pump flow in vessel injection mode shown in Table 5 is equal to maximum pump flow for a vessel to drywell pressure difference of 20 psid or less. Pump flow rates at higher pressure differentials are modeled based on the LPCI/Containment Cooling pump flow curve. LPCI/Containment Cooling pump flows in containment cooling mode are assumed to be constant at the flows shown in Table 5.

**CS pump flow shown in Table 5 is equal to maximum pump flow for a vessel to drywell pressure differe of 90 psid or less. Pump flow rates at higher pressure differentials are modeled based on the LPCI/Containm Cooling pump flow curve.

TABLE 6 - KEY PARAMETERS FOR CONTAINMENT ANALYSIS

CASE	S-1	S-2	S-3a	S-3b	S-4a	S-4b	S-5	S-6
Decay Heat Model	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	1.1 * ANS 5.1
Heat Sinks	YES	YES	YES	YES	YES	YES	YES	YES
Feedwater Added	YES	YES	YES	YES	YES	YES	YES	YES
Pump Heat Added	YES	YES	YES	YES	YES	YES	YES	YES
Heat Exchanger K Value (BTU/Sec-°F)	307.4	288.0	307.4	307.4	279.1	279.1	288.0	288.0
Initial Drywell Pressure (PSIA)	15.70	15.70	15.70	15.70	15.70	15.70	15.70	15.70
Initial Suppression Chamber Pressure (PSIA)	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Initial Drywell Temperature (°F)	150	150	150	150	150	150	150	150
Initial Drywell Relative Humidity (%)	100	100	100	100	100	100	100	100
Initial Suppression Chamber Relative Humidity (%)	100	100	100	100	100	100	100	100
Mixing Efficiency betwee Break Liquid and Drywell Atmosphere (%)	0	0	20	100	20	20	20	20

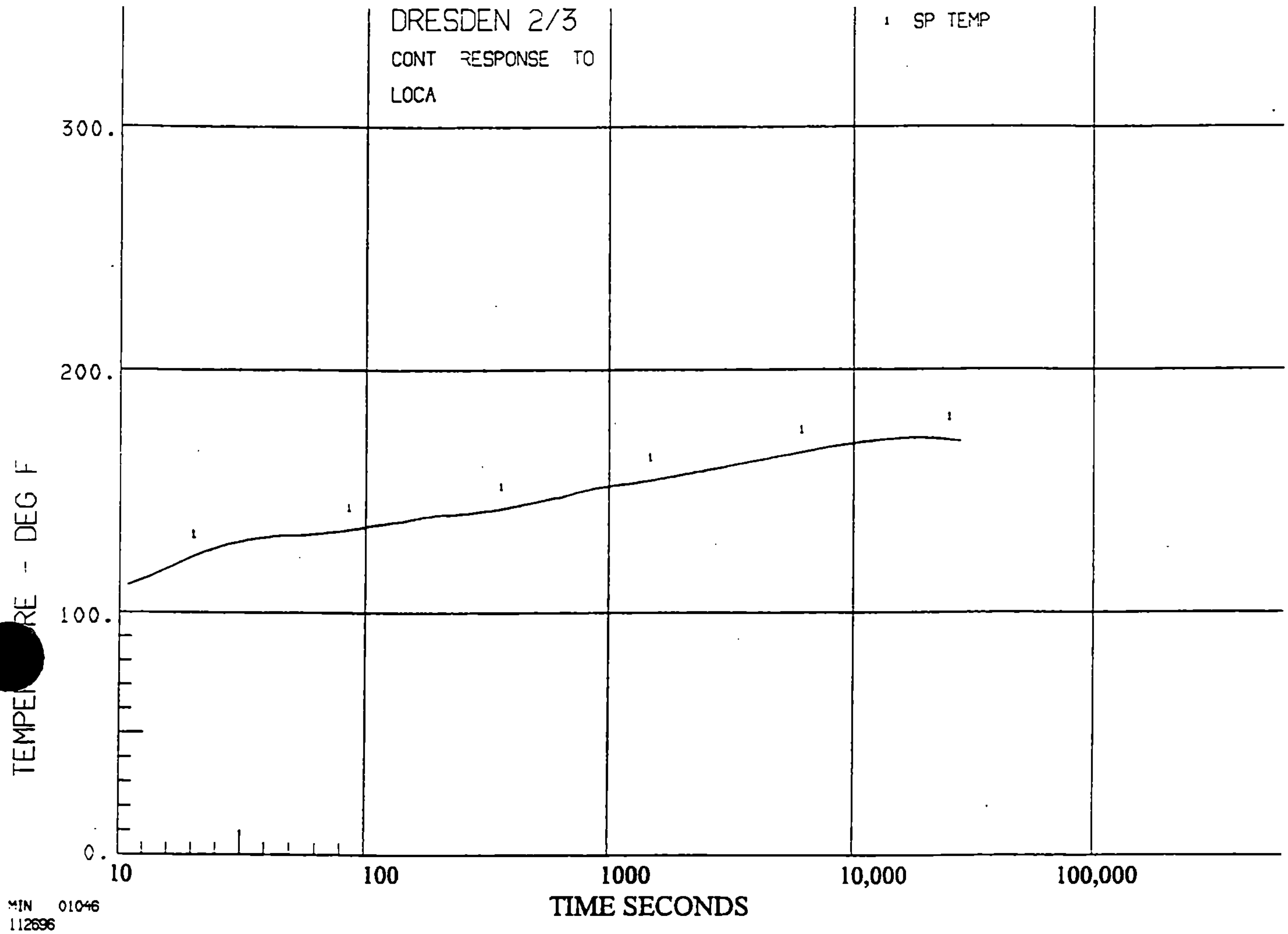

Figure 1 - DBA-LOCA Suppression Pool Temperature Response. Case S-1

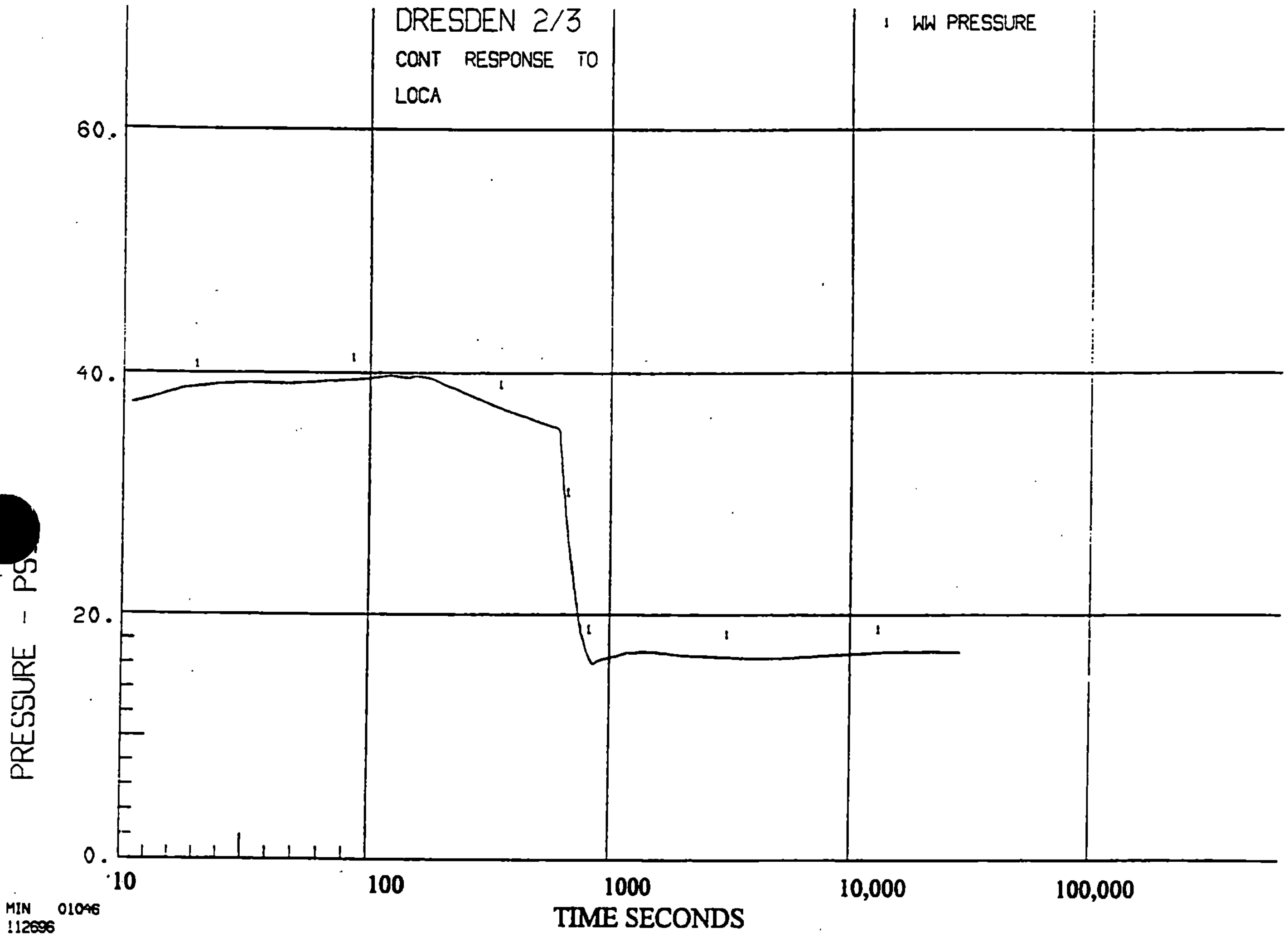

Figure 2 - DBA-LOCA Suppression Chamber Pressure Response. Case S-1

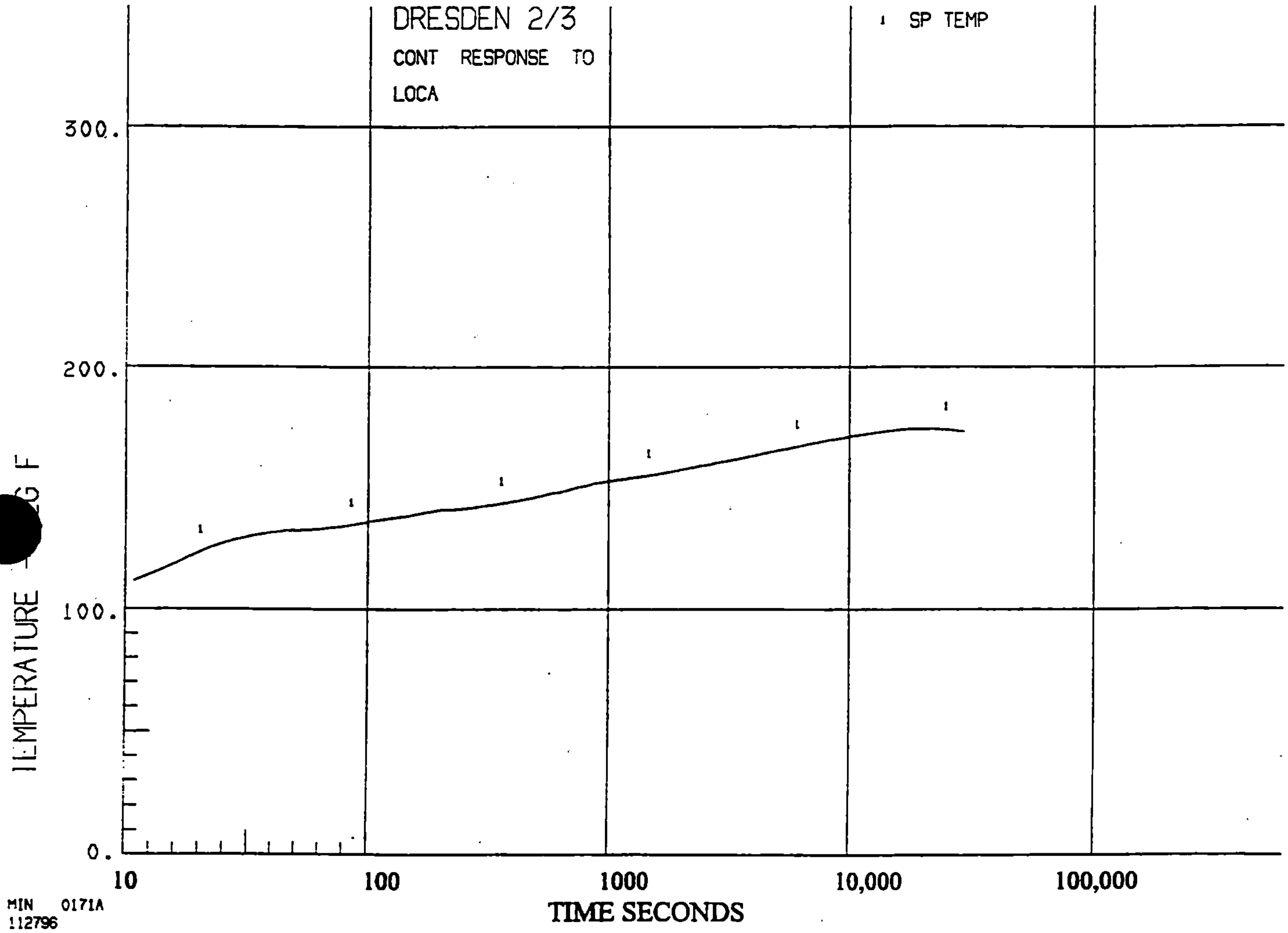

Figure 3 - DBA-LOCA Suppression Pool Temperature Response. Case S-2-

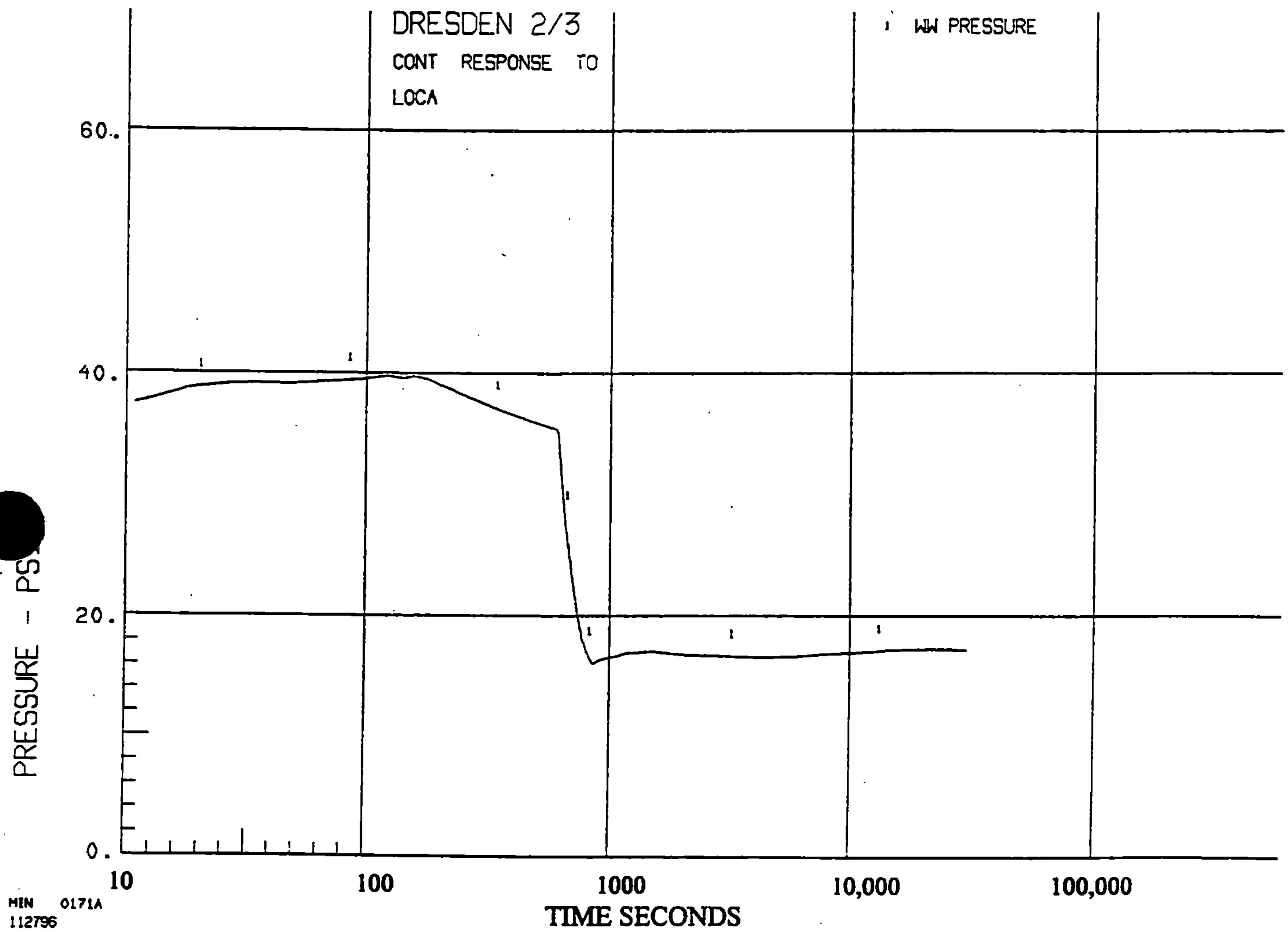

Figure 4 - DBA-LOCA Suppression Chamber Pressure Response. Case S-2

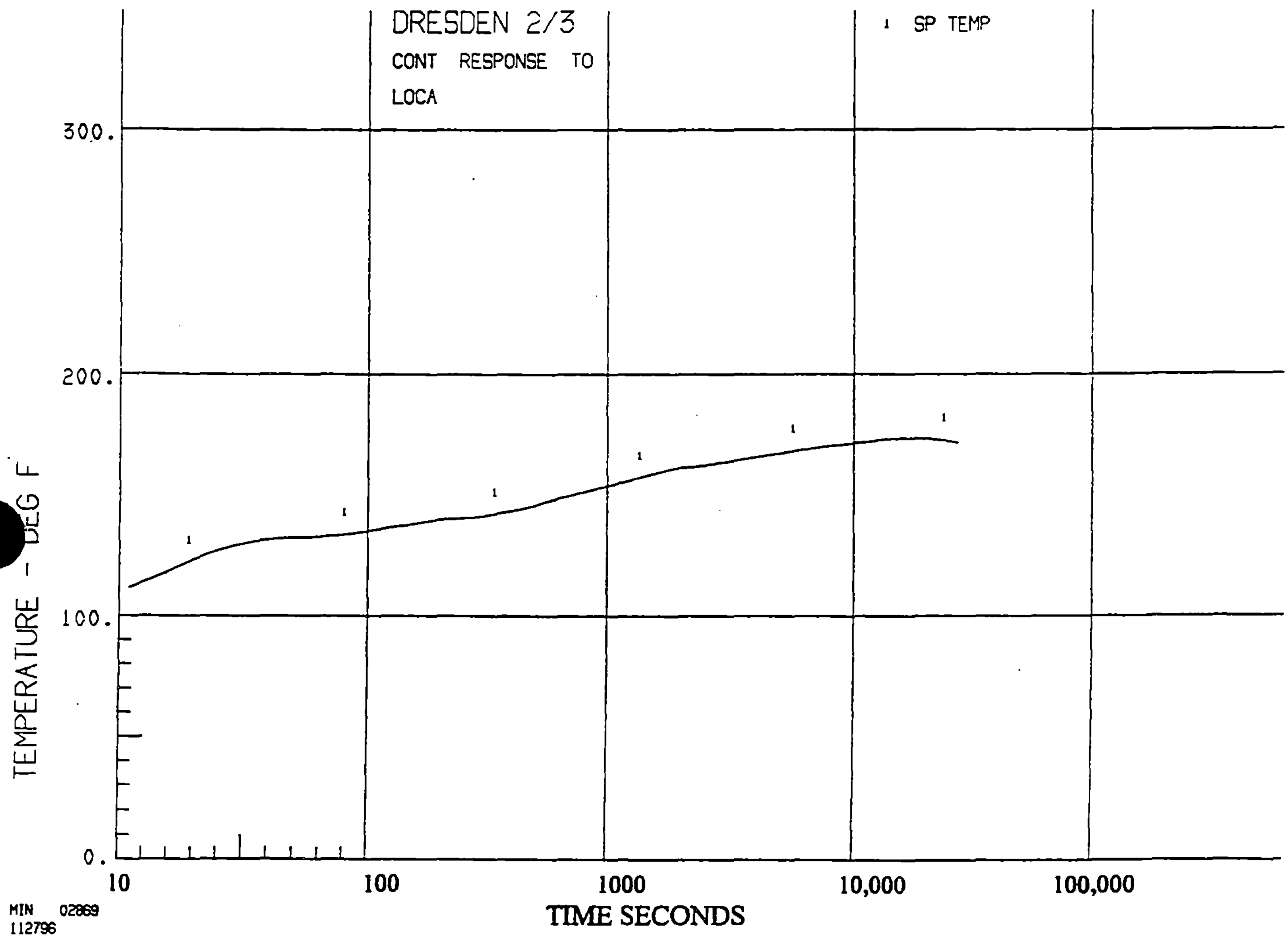

Figure 5 - DBA-LOCA Suppression Pool Temperature Response. Case S-3a

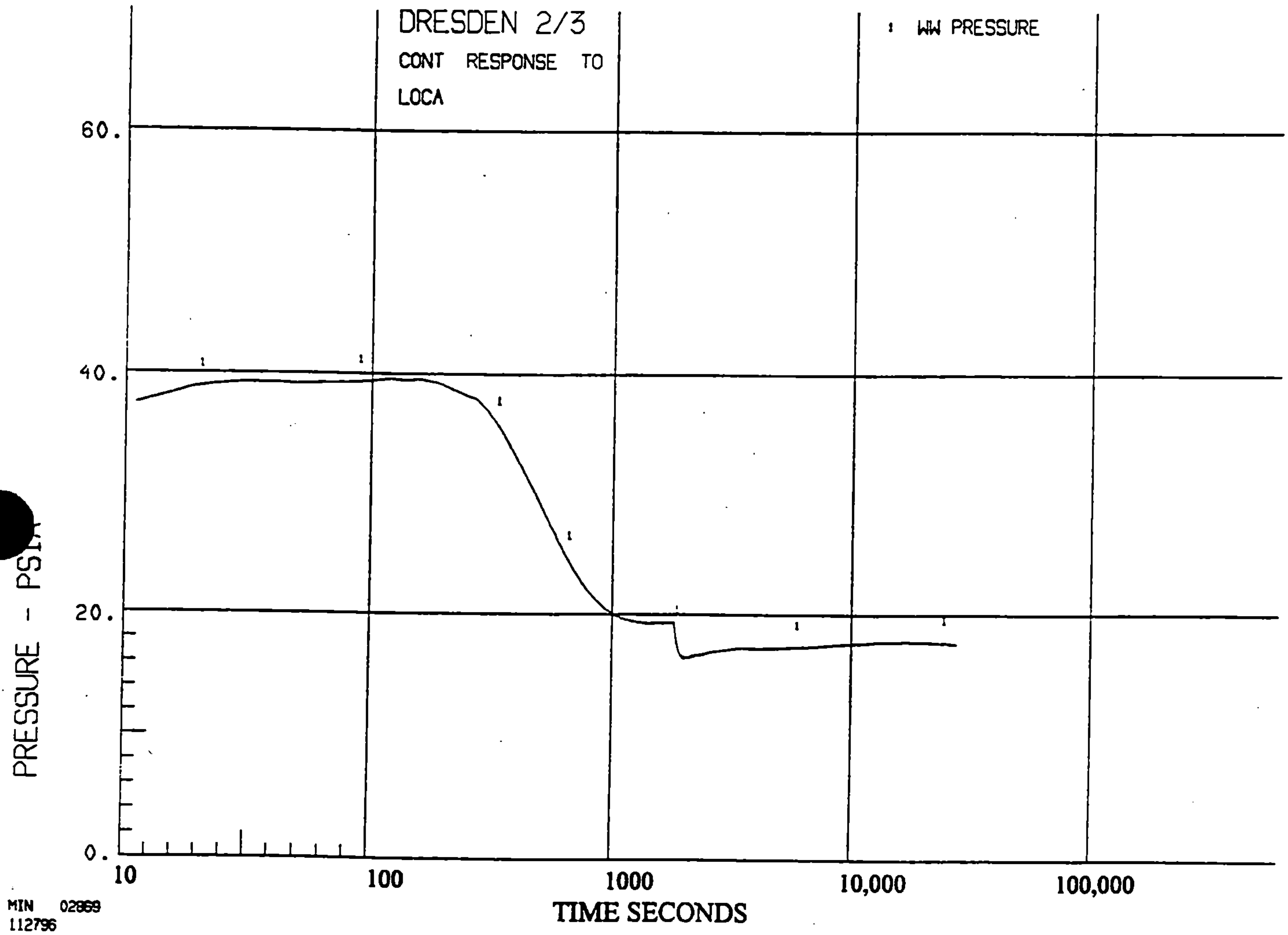

Figure 6 - DBA-LOCA Suppression Chamber Pressure Response. Case S-3a

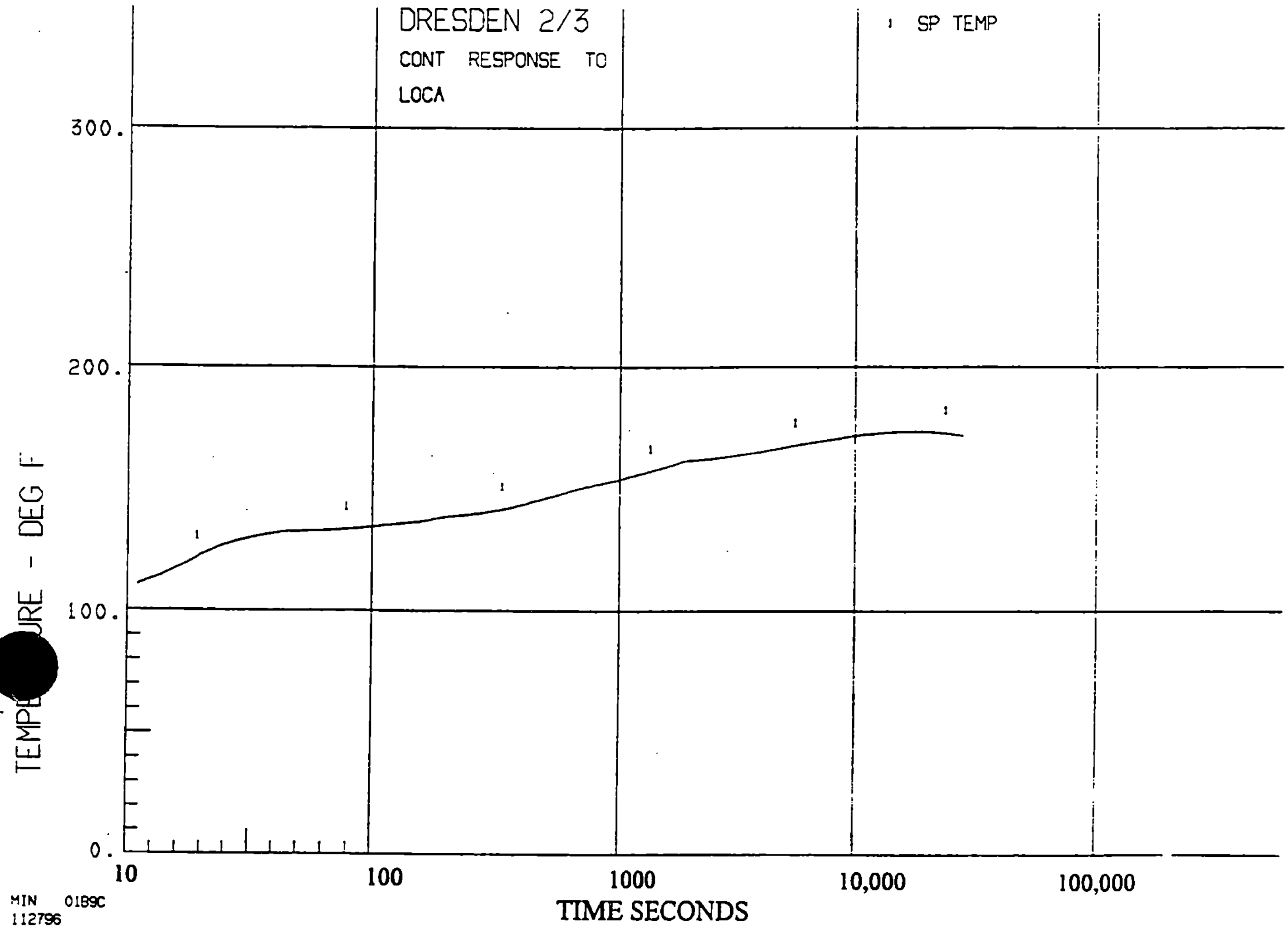

Figure 7 - DBA-LOCA Suppression Pool Temperature Response.. Case S-3b

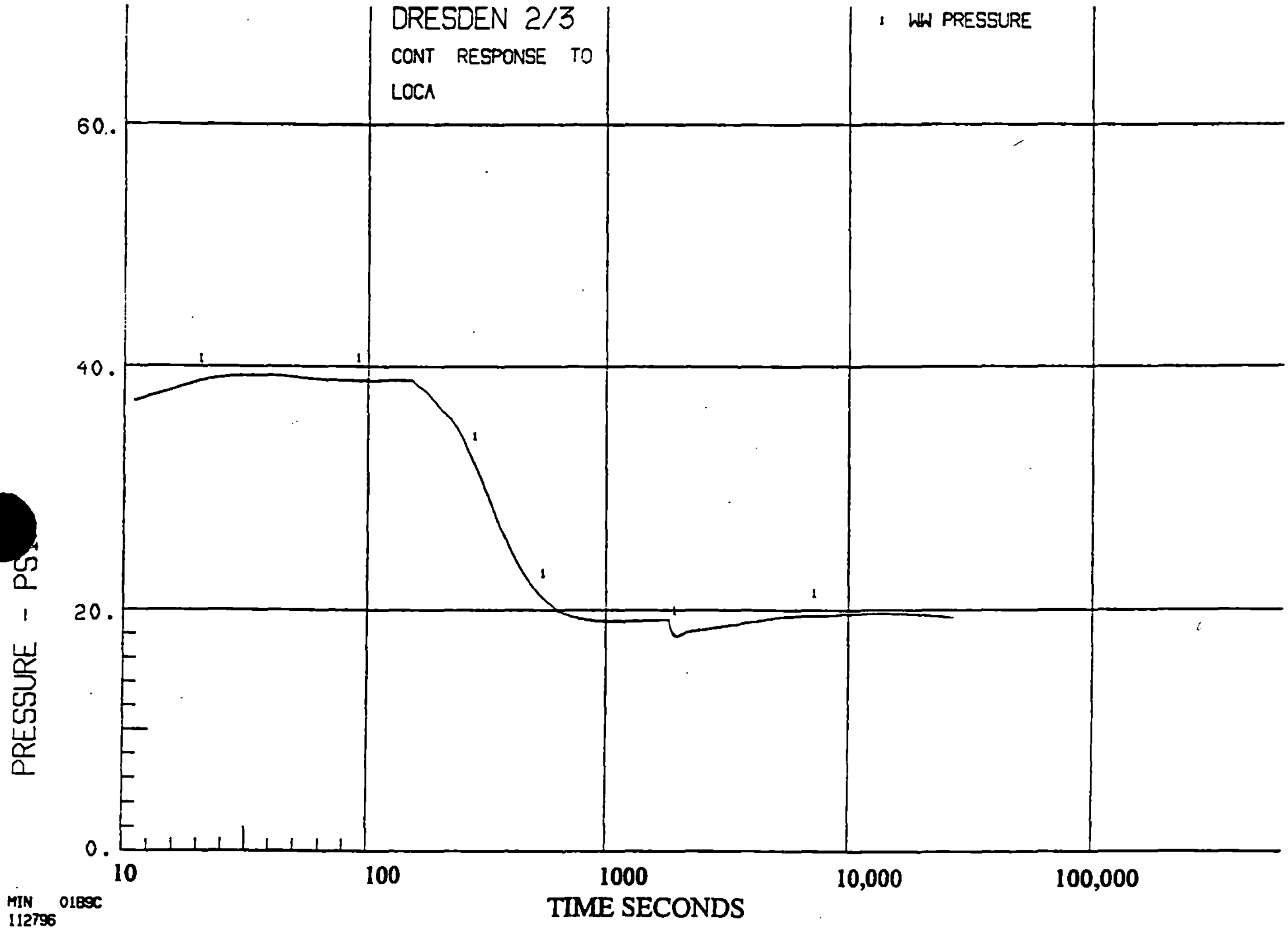

Figure 8 - DBA-LOCA Suppression Chamber Pressure Response. Case S-3b

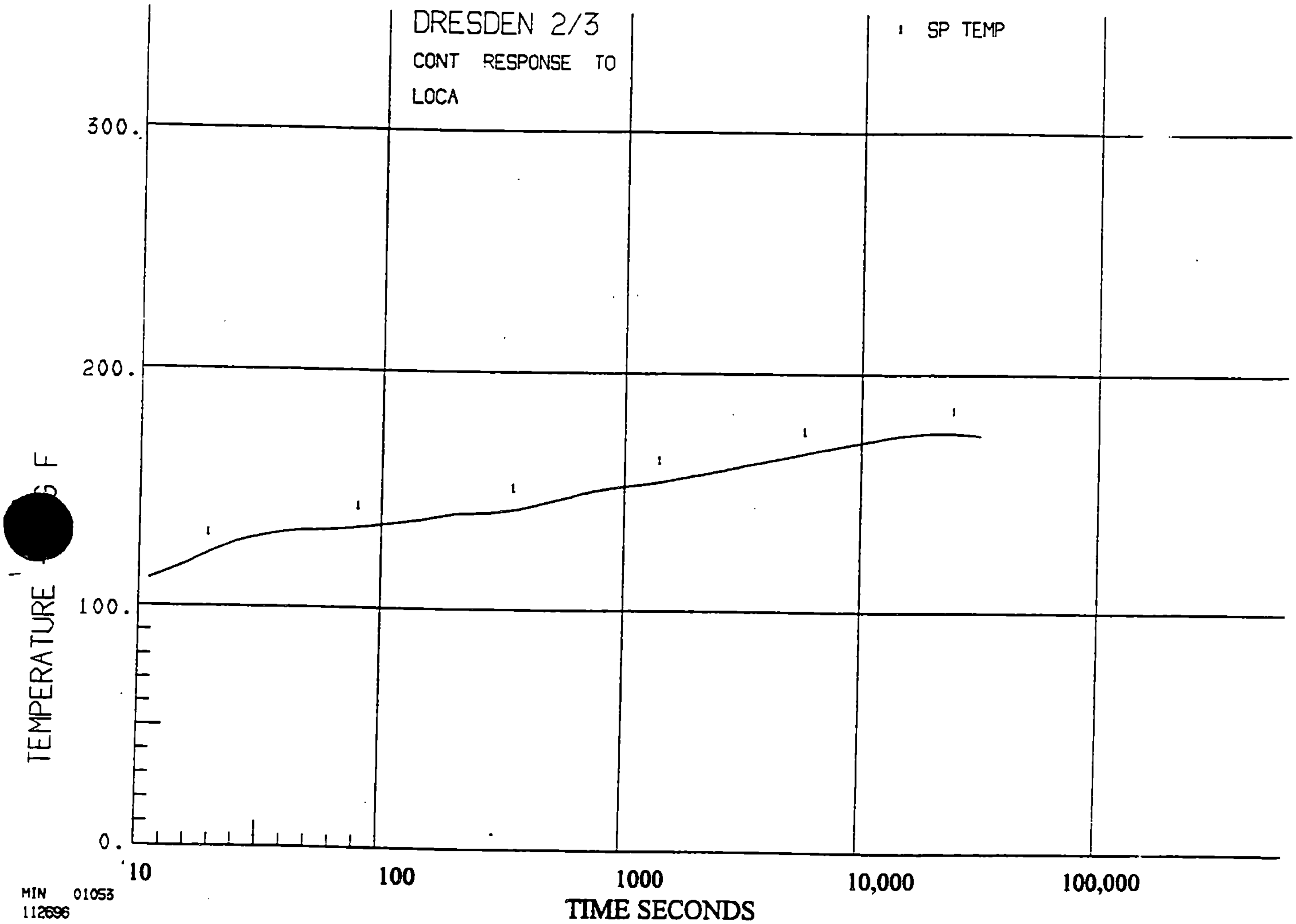

Figure 9 - DBA-LOCA Suppression Pool Temperature Response. Case S-4a

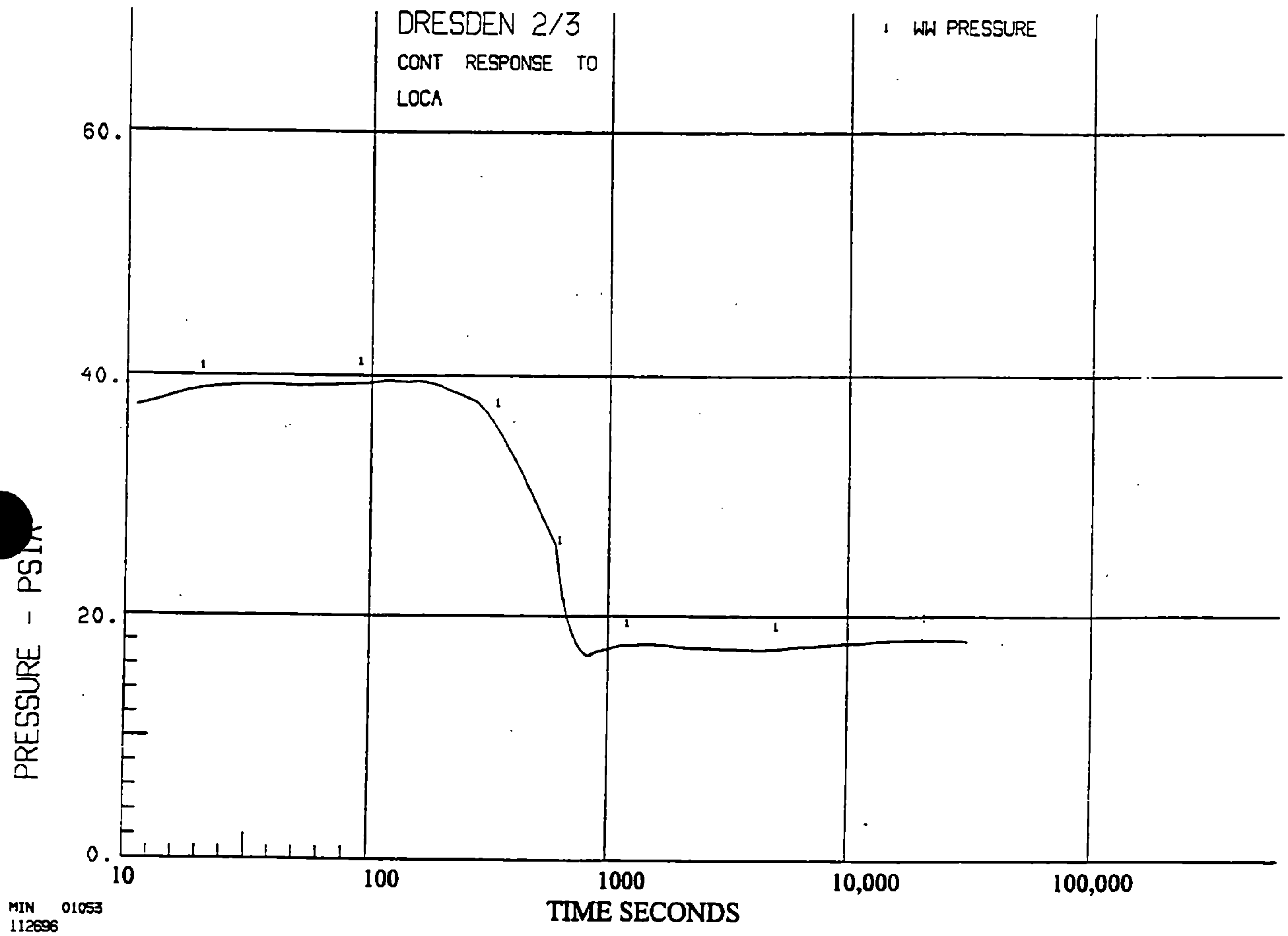

Figure 10 - DBA-LOCA Suppression Chamber Pressure Response. Case S-4a

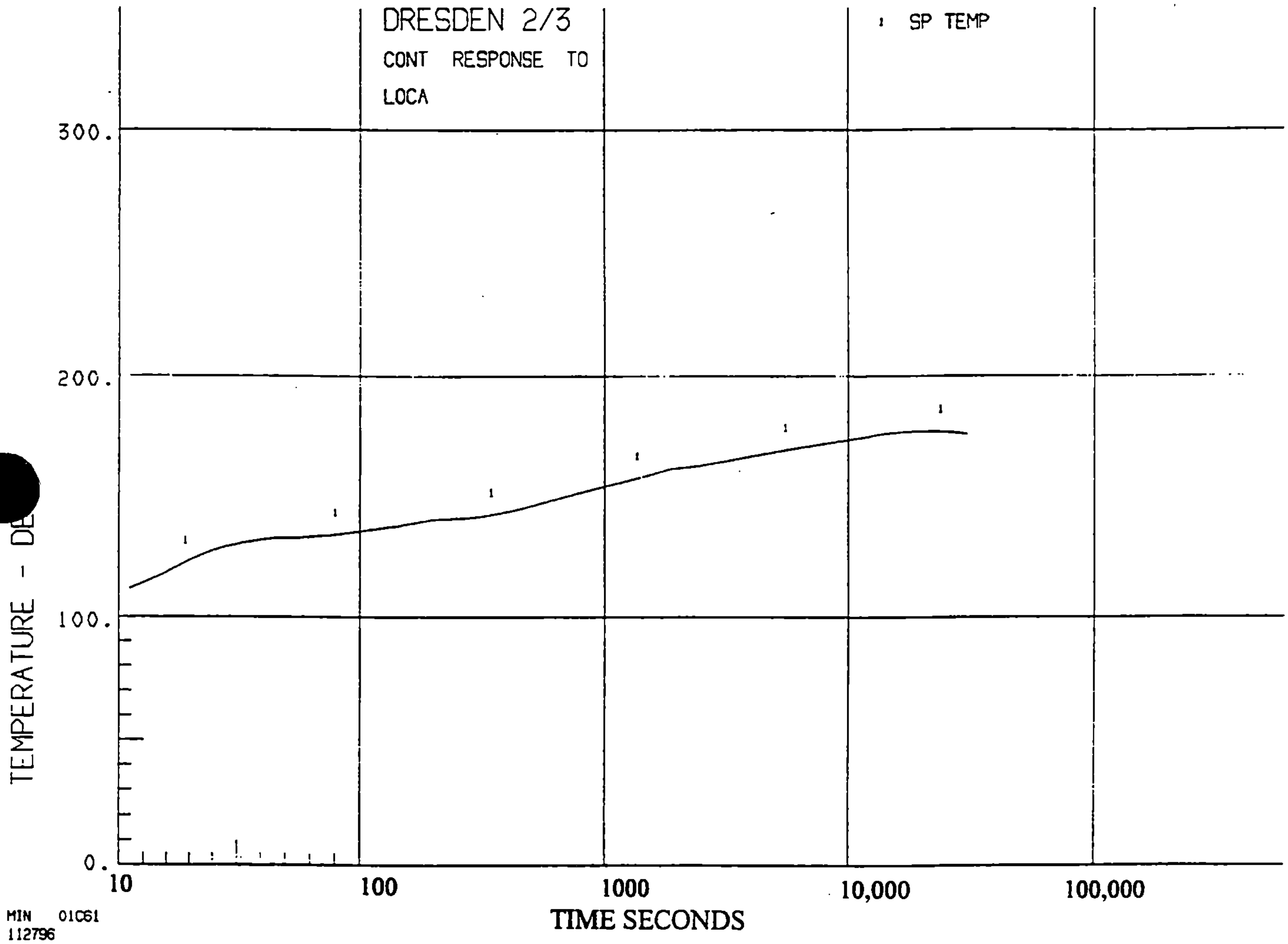

Figure 11 - DBA-LOCA Suppression Pool Temperature Response. Case S-4b

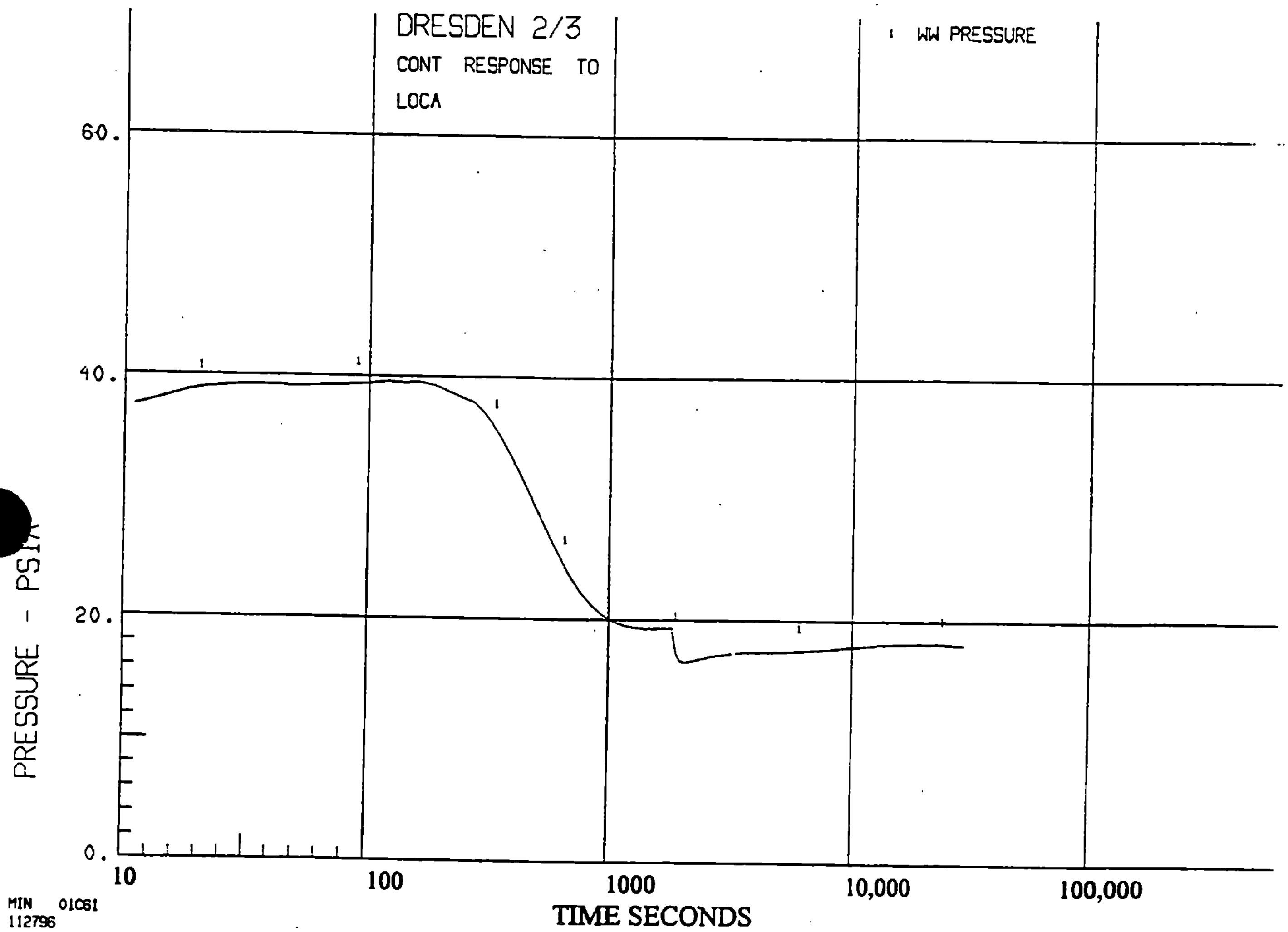

Figure 12 - DBA-LOCA Suppression Chamber Pressure Response. Case S-4b

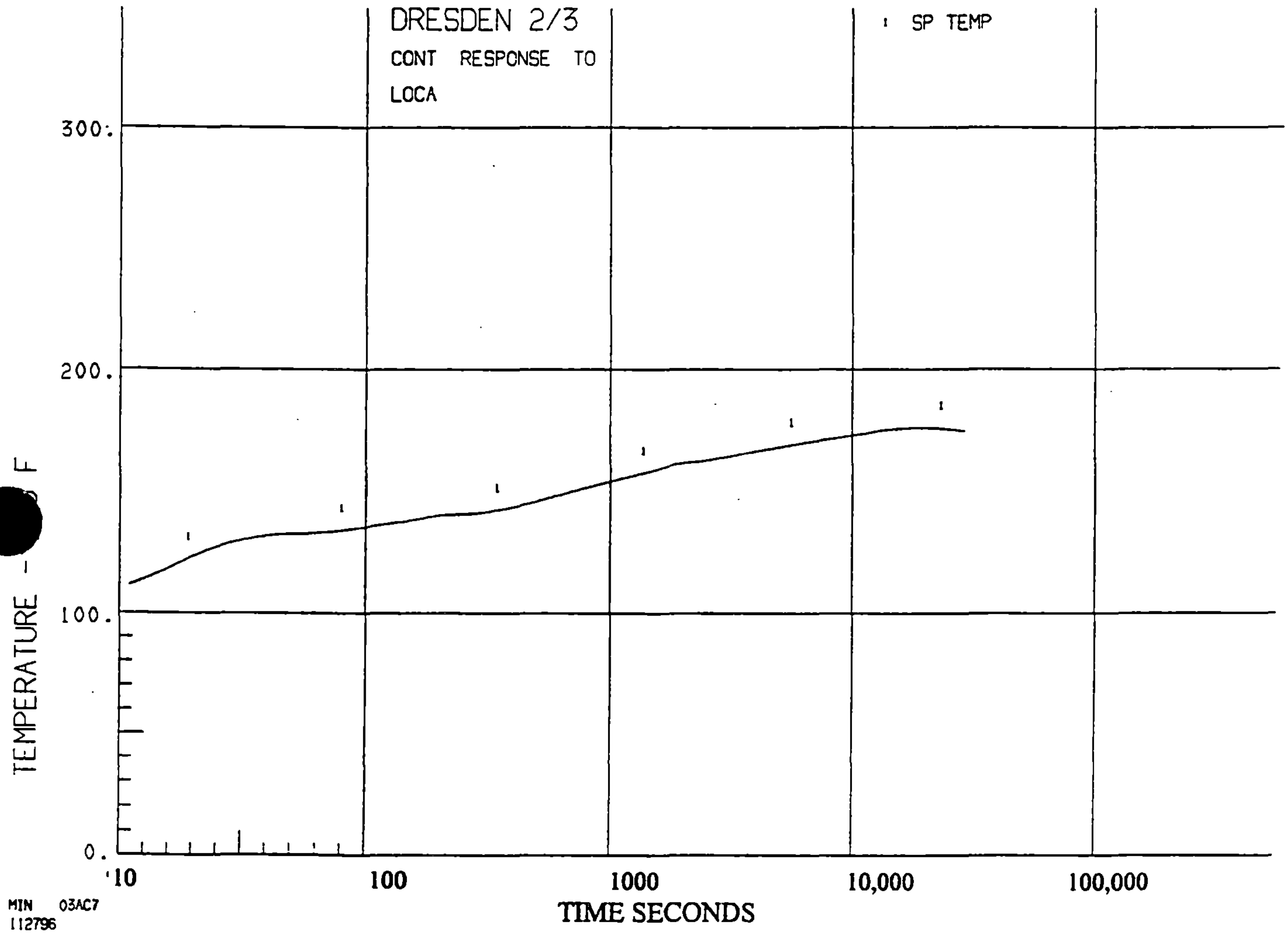

Figure 13 - DBA-LOCA Suppression Pool Temperature Response. Case S-5

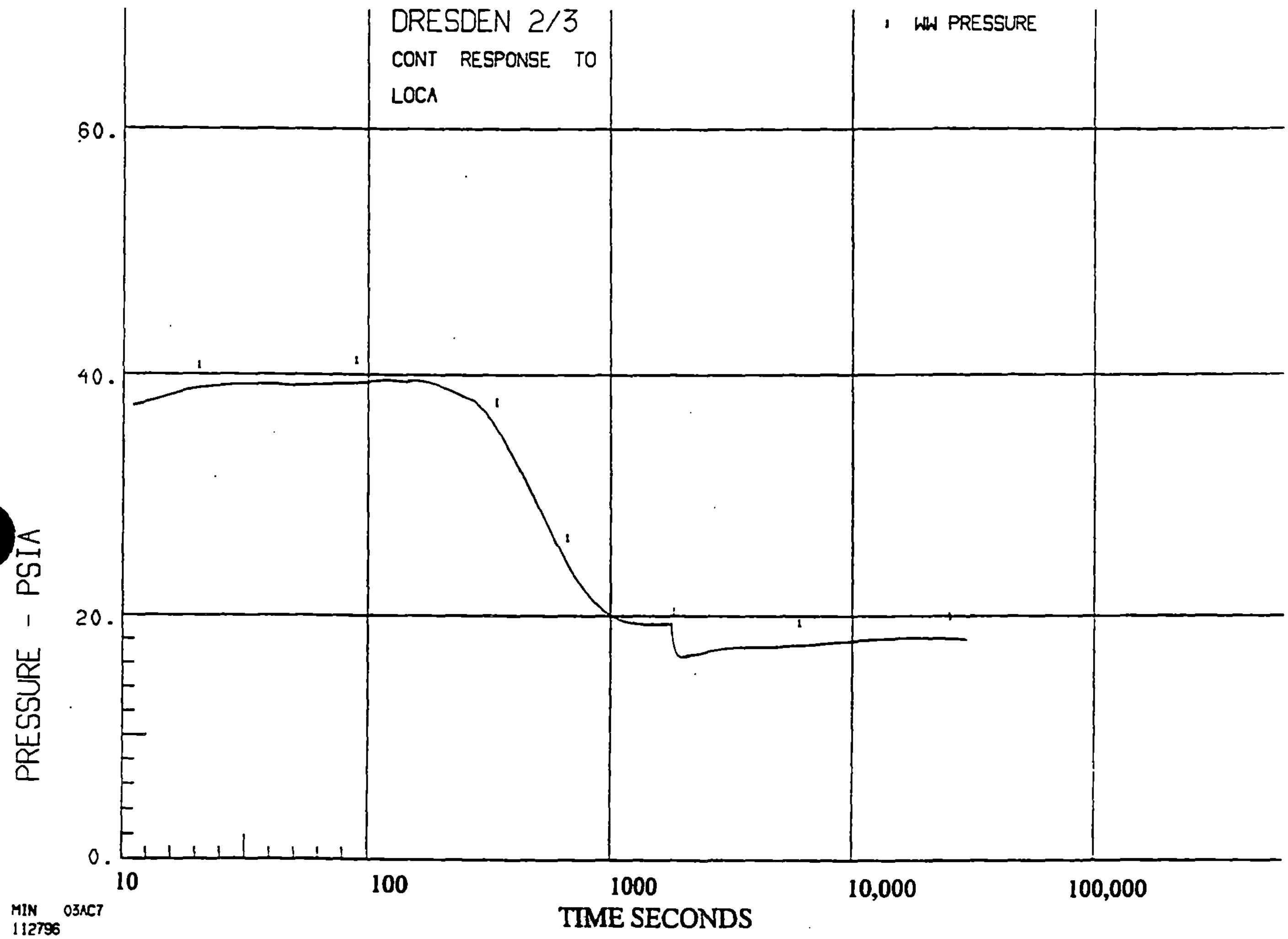

Figure 14 - DBA-LOCA Suppression Chamber Pressure Response. Case S-5

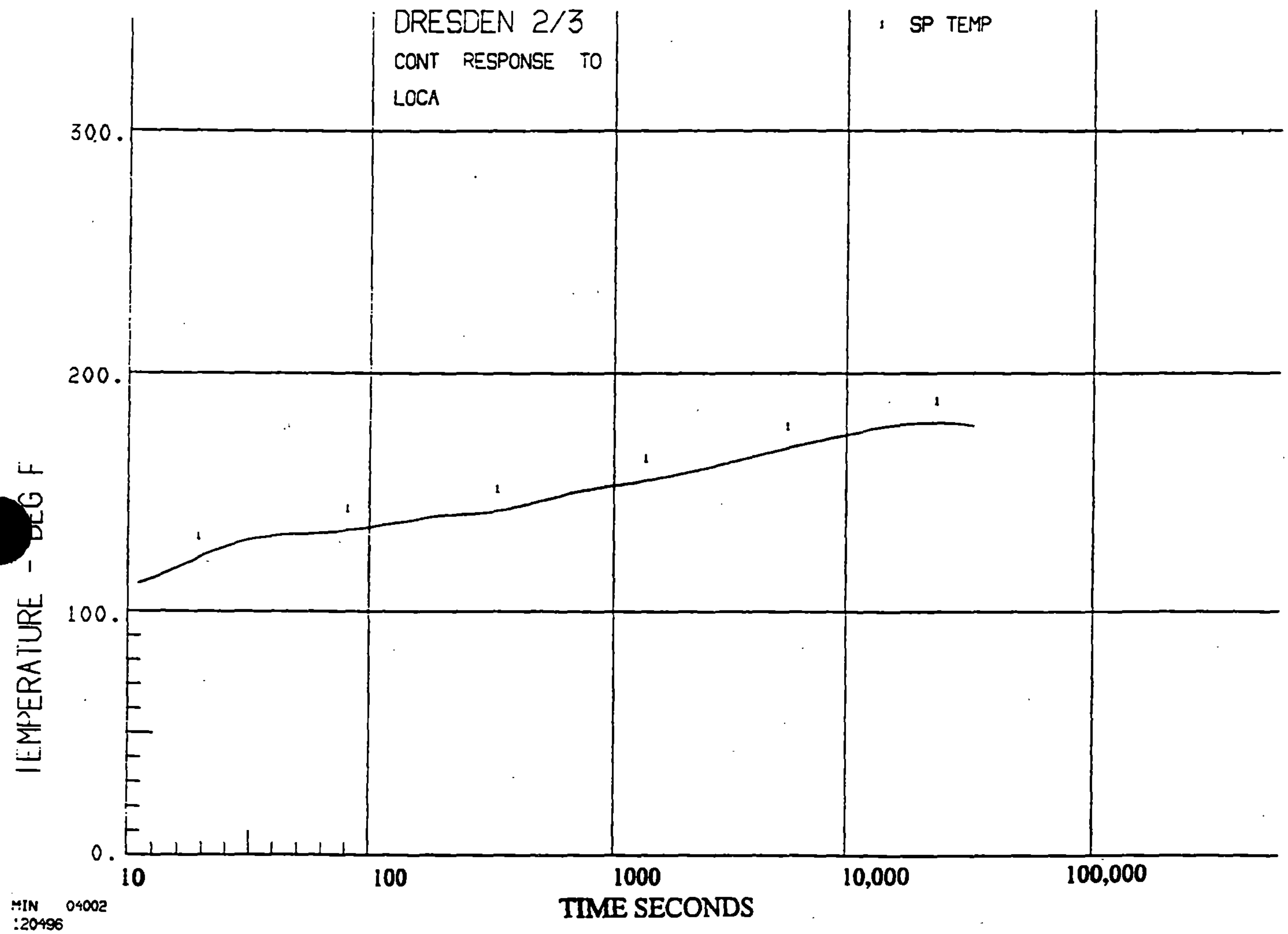

Figure 15 - DBA-LOCA Suppression Pool Temperature Response. Case S-6

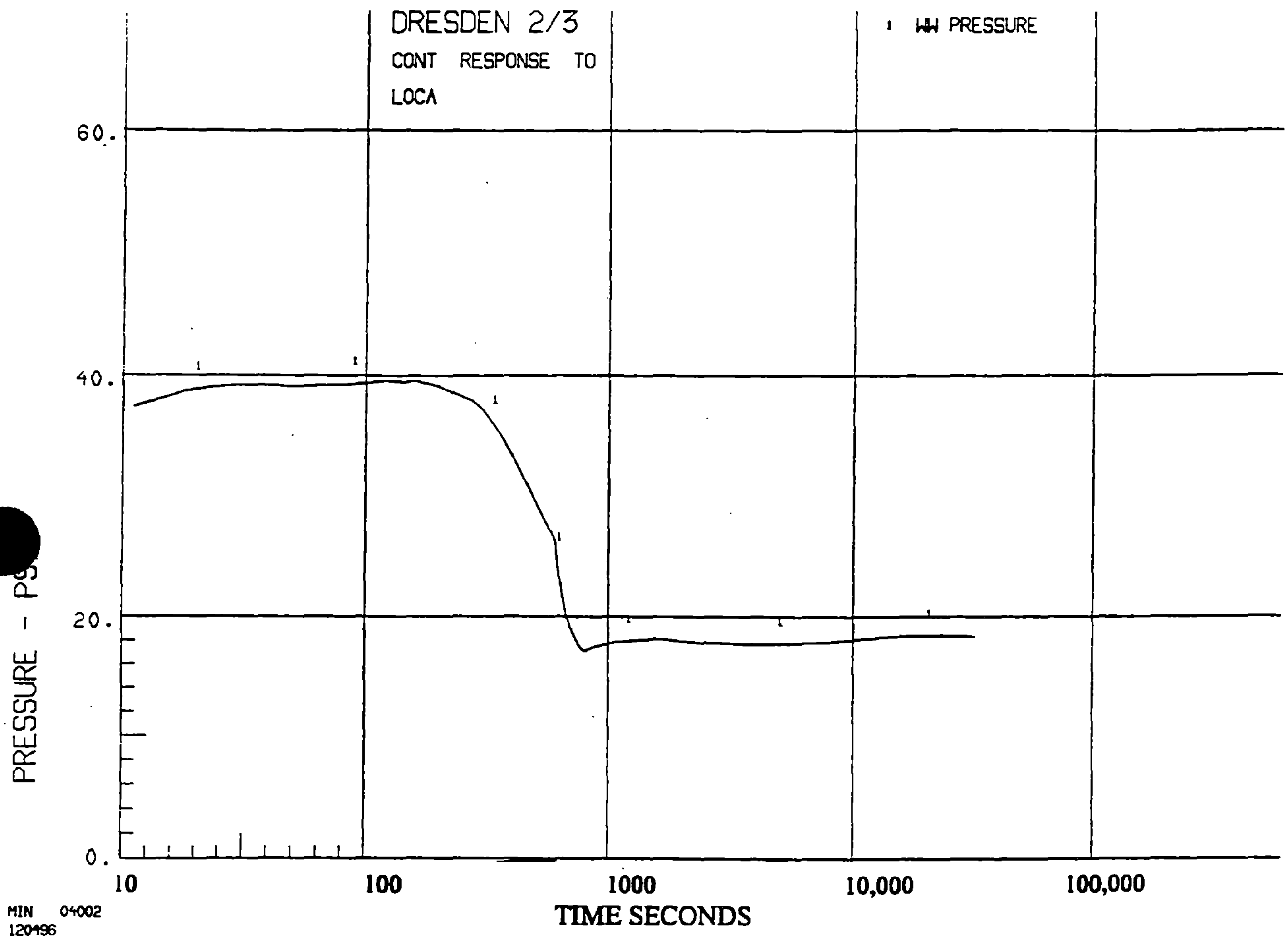

Figure 16 - DBA-LOCA Suppression Chamber Pressure Response. Case S-6

10.0 APPENDICES

A. CORE HEAT DATA

B. METHODOLOGY USED TO CALCULATE HEAT EXCHANGER PERFORMANCE AT OFF-RATED LPCI/CONTAINMENT COOLING AND CCSW PUMP FLOWS

APPENDIX A
CORE DECAY HEAT DATA

Table A-1 provides the core heat (Btu/sec) based on the ANS 5.1 (Reference 1) decay heat model used for the analyses of Section 7.0. The core heat includes decay heat (ANS 5.1-1979), metal-water reaction energy, fission power and fuel relaxation energy. The core heat in Table A.1 is normalized to the initial core thermal power of 2578 MWt.

Table A-2 provides the core heat (Btu/sec) based on the ANS 5.1 (Reference 1) decay heat model with a 1.1 multiplication factor used for Case S-6 of Section 7.0. The core heat includes decay heat (1.1 * ANS 5.1-1979), metal-water reaction energy, fission power and fuel relaxation energy. The core heat in Table A.2 is normalized to the initial core thermal power of 2578 MWt.

Appendix A References:

1. "Decay Heat Power in Light Water Reactors," ANSI/ANS-5.1 - 1979, Approved by American National Standards Institute, August 29, 1979.

TABLE A-1 - CORE HEAT WITH ANS 5.1 DECAY HEAT

Time (sec)	Core Heat*
0.0	1.0078
0.1	.9976
0.2	.9694
0.6	.7404
0.8	.6907
1.0	.5802
2.0	.5480
3.0	.5852
4.0	.5755
6.0	.5401
8.0	.4637
10.	.3771
20.	.08192
30.	.06405
40.	.04697
60.	.04271
80.	.04064
100.	.03925
120.	.03815
121.**	.03033
200.	.02752
600.	.02212
1000.	.01956
2000.	.01599
4000.	.01273
7800.	.01033
10200.	.01012
20400.	.008491
39600.	.007060
61200.	.006306

*Core Heat (normalized to the initial core thermal power of 2578 MWt)
= decay heat + fission power + fuel relaxation energy + metal-water reaction energy

** Metal-water reaction heat is assumed to end at 120 seconds.

TABLE A-2 - CORE HEAT WITH 1.1 * ANS 5.1 DECAY HEAT

Time (sec)	Core Heat*
0	1.014147
0.1	1.003935
0.2	0.975624
0.6	0.746471
0.8	0.696735
1	0.586165
2	0.553686
3	0.590588
4	0.580807
6	0.545058
8	0.468546
10	0.381785
20	0.086115
30	0.067976
40	0.050708
60	0.046185
80	0.043927
100	0.042398
120	0.041188
121	0.033363
200	0.030272
600	0.024332
1000	0.021516
2000	0.017589
4000	0.014003
7800	0.011363
10200	0.011132
20400	0.00934
39600	0.007766
61200	0.006937

*Core Heat (normalized to the initial core thermal power of 2578 MWt)

= decay heat + fission power + fuel relaxation energy + metal-water reaction energy

** Metal-water reaction heat is assumed to end at 120 seconds.

APPENDIX B

1.0 Introduction

The heat exchanger thermal performance parameter, K, is used in the containment analysis performed with the GE SHEX code. The definition of K is given below:

$$K = Q/(T_{hi}-T_{ci}) \quad (1)$$

Where:

Q = heat exchanger heat transfer rate
T_{hi} = inlet temperature on hot fluid side (suppression pool water)
T_{ci} = inlet temperature on cold fluid side (service water)

For instance, the heat exchanger performance work performed in 1992 (Reference 3) determined that for a configuration consisting of 1 LPCI/Cont. cooling pump (10700 gpm) and 2 CCSW pumps (7000 gpm), the heat transfer rate is 98.6 MBTU/hr with a tube side (SW) inlet temperature of 95°F and a shell side (pool) inlet temperature of 165°F. For this case, the K-value is:

$$K = 98.6E6/(165\text{-}90)/3600$$
$$= 391.3 \text{ Btu/sec-°F}$$

A calculation procedure which is based on a parameter called heat exchanger effectiveness is used to calculate the heat exchanger performance parameter, K.

The heat exchanger effectiveness, ε, is defined in the following way:

ε = actual heat transfer/maximum possible heat transfer

Where:

"actual heat transfer" is the actual heat transfer rate in the heat exchanger. Namely, this value is: Q defined above "maximum possible heat transfer" is the heat transfer rate when the fluid of lower flow rate in the heat exchanger reaches the inlet temperature of the other fluid. Namely, this value is: $W_{min}Cp(T_{hi}-T_{ci})$.

In another way, ε is defined to be:

$$\varepsilon = Q/(W_{min}Cp(T_{hi}-T_{ci})) \qquad (2)$$

Where:

Cp = specific heat of water

W_{min} = lower value between shell-side and tube-side flow rates

From Equations (1) and (2) above, K can be calculated by the following equation:

$$K = \varepsilon\, W_{min}Cp \qquad (3)$$

According to Reference 4, the value of ε for shell-tube heat exchangers is calculated by:

$$\varepsilon = 2*\{\ 1+C+(1+C^2)^{1/2} * (1+\exp[-N(1+C^2)^{1/2}])/\ (1-\exp[-N(1+C^2)^{1/2}])\}^{-1} \qquad (4)$$

Where:

$C = W_{min}/W_{max}$

$N = UA/W_{min}$

and

W_{max} = higher value between shell-side and tube-side flow rates.

W_{min} = lower value between shell-side and tube-side flow rates

U = effective overall heat transfer coefficient

A = tube surface area

Thus, the K-value can be calculated for given shell-side and tube-side flow, using Equations (3) and (4), once the value of UA is determined.

For the evaluation of the Dresden heat exchanger K-value, the value of UA was first determined, based on heat exchanger data provided in Senior Engineering Data Specification. Then, the K-value is calculated using Equations (3) and (4), as shown below.

Calculation of UA

The overall heat transfer coefficient ,U, is given by:

$$U = 1/(Rw + Rf,s + Rf,t + Rfoul,s + Rfoul,t) \quad (5)$$

where:

Rw = tube (SW)metal wall resistance
Rf,s = shell (RHR) side fluid resistance
Rf,t = tube side fluid resistance
Rfoul,s = shell side fouling resistance
Rfoul,t = tube side fouling resistance

Values of the above thermal resistances for reference shell-side and tube-side flow conditions were taken from SENIOR Engineering data specification sheets. Appropriate adjustments to the reference resistance values are made to account for the impact of differences in flow conditions on the thermal resistances.

The reference flow conditions used in the present analysis are:

10700 gpm RHR flow for shell side (2 LPCI/Cont. Cooling pumps)
165°F RHR inlet temperature for shell side
7000 gpm SW flow for tube side (2 CCSW pumps)
95°F RHR inlet temperature for tube side

The above flow conditions was also used in 1992 (Reference 4) to confirm the GE heat exchanger performance analysis performed at that time. The Reference 4 analysis determined a heat exchanger heat transfer rate of 98.6 MBTU/hr for the above conditions, closely matching the heat transfer rate specified in the Senior Engineering Spec.

Thermal Resistance Values for Reference Flow Conditions

The thermal resistance values for the above reference flow conditions, which were obtained for Senior Engineering Data Spec., are given in sec-ft^2 /BTU, as follows:

Rw (tube metal resistance) = 0.000250
Rf,s (shell side fluid resistance) = 0.000626
Rf,t (tube side fluid resistance) = 0.000775
Rfoul,s (shell side fouling resistance) = 0.0005
Rfoul,t (tube side fouling resistance) = 0.002300

Sum of resistances = 0.004451

Namely, U = 1/0.004451=224.7 BTU/sec-ft^2.

The resistance values shown above were based on the outside tube diameter, and the effective heat transfer area, A, is given in the Senior Engineering Data Spec. to be:

A= 9880 ft^2

Thermal Resistances for Different Flow Conditions

The thermal resistances given above are based on the reference flow conditions corresponding to a tube side flow of 7000 gpm with a tube side inlet temperature of 95°F and a shell side flow of 10,700 gpm with a shell side inlet temperature of 165°F. Thermal resistances for flow conditions other than the reference flow conditions are calculated by making the following assumptions:

- The impact of differences in the flow conditions on Rw, Rfoul,s and Rfoul,t is negligible within the range of flow conditions considered in the present analysis.

  Rw= 0.00025
  Rfoul,s =0.0005
  Rfoul,t =0.0023

- The fluid (convective heat transfer) resistances (Rf,s and Rf,t) are affected by the flow rate only within the range of flow conditions considered in the analysis, neglecting the temperature effects. The procedure of calculating the values of Rf, s and Rf,t for different flow conditions is described below.

Changes in Rf,s due to Changes to the Shell Side Flow

The value of Rf,s is a reciprocal of the convective heat transfer coefficient. Namely,

Rf,s = 1/hfr,s

where:

hfr,s = convective heat transfer coefficient on shell side

The value of hfr,s is calculated from the following relationship;

$$Nu_d = 0.33 Re_d^{0.6} Pr^{0.333} = (hfr,s * d)/kf$$

Where:

Nu_d =Nusselt number

kf = fluid thermal conductivity

d = tube diameter

Pr = Prandtl Number = $(\mu C_p/kf)$

Re = Reynolds number= $(\rho Vmd/\mu)$

ρ= fluid density

μ= fluid viscosity

Cp = specific heat

For this analysis it is again assumed that the effect of fluid temperature is negligible and the major effect is the effect of fluid velocity. Therefore the major impact of a reduction in pump flow rate is the impact due to a reduced fluid velocity. This means that if pump flow is changed then flow velocity is changed and the Reynolds number (Re) is changed.

Based on the relation for hfr,s given above, the effect on hfr,s due to a change on Re for the shell side is given by:

hfr,s (new shell-side flow) = hfr,s (reference flow)

$$* \text{(new shell-side flow /reference flow)}^{0.6}$$

Since Rf,s= 1/hfr,s

$$\text{Rf,s (new shell-side flow)} = \text{Rf,s (reference flow)} * \text{(new shell-side flow /reference flow)}^{-0.6} \quad (6)$$

Changes in Rt,s due to Changes to the Tube Side Flow

The value of Rf,t is a reciprocal of the convective heat transfer coefficient. Namely,

$$\text{Rf,t} = 1/\text{hfr,t}$$

where:

hfr,s = convective heat transfer coefficient on tube side

The value of hfr,t is calculated from the following relationship;

$$Nu_d = 0.023 Re_d^{0.8} Pr^{0.333} = (\text{hfr,t} * d)/kf$$

For this analysis it is again assumed that the effect of fluid temperature is negligible and the major effect is the effect of fluid velocity. Therefore the major impact of a reduction in pump flow rate is the impact due to a reduced fluid velocity. This means that if pump flow is changed then flow velocity is changed and the Reynolds number (Re) is changed.

In a manner similar to that for the shell side,

$$\text{Rf,t (new tube-side flow)} = \text{Rf,t (reference flow)} * \text{(new tube-side flow /reference flow)}^{-0.8} \quad (7)$$

CALCULATION FOR K

Thus, the value of UA is calculated, using the data from SENIOR Engineering and Equations (5) through (7), for given flow rates. Then, the value of K is calculated using Equations (3) and (4).

These equations are applied to benchmark cases for comparison with the results of the previous analysis. After that, the K-values are calculated for configurations considered for the present analysis.

Benchmark Cases

The K value calculated with the method described above for a 2 LPCI/Containment Cooling pump flow of 10,700 gpm and a 2 CCSW pump flow of 7000 gpm produced a K value of 390.7 BTU/sec-F with a corresponding heat transfer rate of 98.5 MBTU/sec (based on a shell side inlet temp of 165°F and a tube side inlet temp of 95°F). This closely matches the GE calculated heat exchanger heat transfer rate of 98.6 MBTU/hr for this configuration (Reference 4).

The K value calculated with the method described above for a 1 LPCI/Containment Cooling pump flow of 5000 gpm and a 1 CCSW pump flow of 3500 gpm produced a K value of 249.5 BTU/sec-F with a corresponding heat transfer rate of 62.87 MBTU/sec (based on a shell side inlet temp of 165°F and a tube side inlet temp of 95°F). This closely matches the heat exchanger heat transfer rate of 62.89 MBTU/hr previously calculated by GE in 1992 for this configuration (Reference 5).

Table 1 summarizes the results of the benchmark cases described above. Table 2 summarizes the results of the calculations to determine the K values for a long-term containment cooling configuration of 1 LPCI Containment cooling pump and 2 CCSW pumps.

REFERENCES:

1. Heat Transfer, J. P. Holman, Fourth Edition, 1976

2 Reprint from Petroleum Refiner, "Heat Exchanger Design," by D. A. Donohue (Chemical construction Corporation), August 1955.

3. GE Document 384HA497, Heat Exchanger (RHR), Heat Transfer Calculation Computer Program," Oct. 1979.

4. Letter, S. Mintz to S. L. Eldridge/B. M. Viehl, "Dresden LPCI/Containment Cooling System - Comparison of Heat Exchanger Heat Transfer Rates," Dec. 28, 1992.

5. Letter, G. G. Chen to S. Mintz, "K Values for Dresden Units 2 & 3 Containment Heat Exchangers, (undated)

TABLE 1 - HEAT EXCHANGER K VALUE BENCHMARK CASES

SHELL SIDE FLOW RATE (2 LPCI/CONTAINMENT COOLING PUMP) GPM	**TUBE SIDE FLOW RATE (2 CCSW PUMPs)** GPM	**K VALUE** BTU/SEC-°F	**Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature)** Million BTU/hr.
10700	7000	390.7 *391.3 (Ref.4)*	98.5 *98.6 (Ref. 4)*
SHELL SIDE FLOW RATE (1 LPCI/CONTAINMENT COOLING PUMP) GPM	**TUBE SIDE FLOW RATE (1 CCSW PUMPs)** GPM	**K VALUE** BTU/SEC-°F	**Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature)** Million BTU/hr.
5000	7000	249.5 *249.6 (Ref. 5)*	62.87 *62.89 (Ref. 5)*

TABLE 2 - HEAT EXCHANGER K VALUE 1 LPCI/CONTAINMENT COOLING PUMP 2 CCSW PUMPS

SHELL SIDE FLOW RATE (1 LPCI/CONTAINMENT COOLING PUMP) GPM	**TUBE SIDE FLOW RATE (2 CCSW PUMPs)** GPM	**K VALUE** BTU/SEC-°F	**Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature)** Million BTU/hr.
5000	5400	288.0	72.6
5800	7000	325.4	82.0
5000	7000	307.4	77.5
4611	5400	279.1	70.3

GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

November 18, 1996

cc: N. Shirley
DRF T23-00740

To: J. Nash

From: S. Mintz

Subject: Dresden Containment Analyses for Limiting DBA-LOCA.

References:

1. Proposal for Analysis of Hx Performance and Suppression Pool Temperate and Chamber Pressure and Request for Change Order to Purchase Order 118064." Letter K. Dias to S. Konrad (ComEd). Nov. 13, 1996.

2. Letter, K. P. Dias to S. Konrad (ComEd), "Dresden Nuclear Power Station Analysis of HX Performance and Suppression Pool Temperature and Chamber Pressure (GENE Proposal #523-1GY5D-EB0)," October 11, 1996.

Attachment A to this letter provides the results for Task 1 and Task 2 as defined in Reference 1. These tasks are performed to evaluate suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA assuming a two pump CCSW pump flow of 5400 gpm for long-term containment cooling. These analyses supplement the analyses performed for Reference 2 which assumed a 2 CCSW pump flow of 7000 gpm.

The results in Attachment A are verified and can be used by ComEd to perform NPSH evaluations for LPCI/Containment Cooling pumps and CS pumps.

If you have any questions, please, contact me.

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ATTACHMENT A
CONTAINMENT PRESSURE AND TEMPERATURE ANALYSIS
FOR DRESDEN NPSH EVALUATIONS.

2 CCSW PUMP FLOW OF 5400 GPM

ATTACHMENT A

1 Introduction

References 1 and 2 provided the long-term containment response to the DBA-LOCA for Dresden Units 2 and 3. Analyses described in these two references assumed two long-term containment cooling configurations: a) one LPCI/Containment Cooling pump and one containment cooling service water (CCSW) pump, b) two LPCI/Containment cooling pumps and two CCSW pumps.

References 3 and 4 provided the suppression pool temperature and suppression chamber pressure responses to the DBA-LOCA assuming the following ECCS and containment cooling configuration.

2 LPCI/Containment Cooling Pump and 1 core spray (CS) pump up to 600 seconds following the DBA-LOCA.

1 LPCI/Containment Cooling Pump, 2 CCSW pumps and 1 CS pump after 600 seconds.

2 CCSW pump flow rate of 7000 gpm

In response to a request by ComEd (Reference 5), the suppression pool temperature and suppression chamber pressure responses to the DBA-LOCA have been analyzed assuming the ECCS and containment cooling configuration used for the Reference 3 and Reference 4 analysis except that a 2 CCSW pump flow of 5400 gpm has been assumed (Reference 5).

This attachment provides the heat exchanger heat transfer rate for the long-term containment cooling configuration described above (Task 1 of Reference 5). The results for Task 2 of Reference 5 are also provided.

2. Analysis Results

Task 1. Calculation of Heat Exchanger Performance (K value calculation)

The heat exchanger heat transfer rate as defined by K is used in the analyses performed with the GE SHEX code. The definition of K is given below:

$$K = Q/[(T_{si}-T_{ti})*3600]$$

Where

K - heat exchanger heat transfer rate (BTU/sec-°F)
Q = heat exchanger heat transfer rate (BTU/hr)
T_{si}-T_{ti} = Temperature difference between the shell side and tube side inlet temperatures(°F).

The heat exchanger performance (K) for a long-term containment cooling configuration consisting of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and one LPCI/Containment Cooling heat exchanger was evaluated assuming a combined flow of 5400 gpm from two CCSW pumps

The evaluation of the heat exchanger performance was based on the heat exchanger performance work performed in 1992, which determined a heat exchanger heat transfer rate of 98.6 MBTU/hr based on a tube side flow of 7000 gpm with a tube side inlet temperature of 95°F and a shell side flow of 10,700 gpm with a shell side inlet temperature of 165°F.

The overall heat transfer rate (U) with the new LPCI/Containment Cooling pump flow and new CCSW pump flow was revised by adjusting the tube side and shell side heat transfer coefficients based on the new pump flows. New values of K were then calculated with the NTU-effectiveness method for a shell and tube heat exchanger geometry.

This method was validated by a calculation of the K value with tube side flow of 3500 gpm with a tube side inlet temperature of 95°F and a shell side flow of 5000 gpm with a shell side inlet temperature of 165°F. The resultant value of 249.5 BTU/sec-°F closely matches the K value of 249.6 BTU/sec-°F previously calculated by GE for this configuration.

The calculated K values are given in Table 1.

Task 2. Calculation of Suppression Pool Temperature and Suppression Chamber Pressure

The objective of this task is to determine the short-term (0-600 seconds) and long-term (>600 seconds) suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA. The GE computer model SHEX-04 (References 6 and 7) with decay heat based on the ANS 5.1 1979 decay heat model (without adders) was used in the analyses. Analyses performed to benchmark analyses with the SHEX-04 code to the Dresden FSAR analyses were documented in Reference 2. The benchmarking analyses in Reference 2 included sensitivity studies to quantify the effect on peak suppression pool temperature due to differences between the updated analysis and the FSAR original analysis.

Key input assumptions for the present analyses are consistent with the general containment parameters used in the analyses of References 1, 2, 3 and 4, as confirmed in Reference 8.

This attachment provides the results for all cases of Task 2. For all cases it is assumed that during the first 10 minutes 2 LPCI/Containment Cooling pumps and 1 CS pump are used for vessel makeup purposes. It is assumed that at 10 minutes the operator shuts down 1 LPCI/Containment Cooling pump and aligns 1 LPCI/Containment Cooling pumps from vessel injection mode to containment cooling mode. At the same time two CCSW pumps and one RHR heat exchanger are lined up for long-term containment cooling with drywell and suppression chamber sprays. The resulting long-term containment cooling pump configuration consists of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and 1 LPCI/Containment Cooling heat exchanger. The combined CCSW flow rate through the heat exchanger for the 2 CCSW pumps is assumed to be 5400 gpm and the analysis uses heat exchanger performance values obtained from Task 1.

Case Specific Assumptions

The case numbering sequence used in this attachment continues from the numbering sequence used in References 3 and 4.

Case 4 - ***Above nominal flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Nominal Containment Initial Conditions***

In Case 4 it is assumed that the LPCI/Containment Cooling pumps are operating with an above nominal pump flow of 5800 gpm per pump and the CS pump is operating at an above rated pump flow of 5800 gpm for the first 10 minutes . It is assumed that at 10 minutes the operator reduces the LPCI/Containment Cooling pump flows to the nominal flow of 5000 gpm per pump and the CS pump flow to the nominal pump flow of 4500 gpm.

Case 4a - ***Above nominal pump flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Containment Initial Conditions to Minimize Containment Pressure***

Same as Case 4 except that conservative input assumptions are used to minimize suppression chamber pressure.

Case 4a1 - *Above nominal pump flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Containment Initial Conditions to Minimize Containment Pressure, Drywell and Torus shell heat sinks modeled*

Same as Case 4a except that the drywell shell, vent system, and torus shell are modeled as heat sinks.

The analyses for Cases 4a and 4a1 consider two different values of thermal mixing efficiency between the break flow and drywell atmosphere: 100% and 20%. The assumption of a lower mixing efficiency resulted in a lower long-term suppression chamber pressure, whereas a lower short-term suppression chamber pressure was obtained with a higher mixing efficiency. The explanation for this is that following the initial vessel reflood , the break liquid flow from the vessel is colder than the drywell temperature. Therefore, a higher mixing efficiency in the short-term reduces the drywell temperature, drywell pressure and suppression chamber pressure. For the long-term this trend is reversed. After the drywell sprays reduce the drywell temperature to below the vessel liquid temperature, the break liquid heats up drywell temperature. Therefore a lower mixing efficiency results in reduced heating of the drywell by the break liquid, which minimizes suppression chamber pressure.

In addition, Case 4a with high and low thermal mixing efficiency are also evaluated with heat sinks. For these cases (Case 4a1), the drywell shell, vent system and torus shell are modeled as heat sinks.

The results for Cases 4a and 4a1 with the two values of mixing efficiency can be used to evaluate the limiting conditions with respect to available NPSH for the DBA-LOCA.

Table 2 identifies input differences between Cases 4 (nominal assumptions on suppression chamber pressure) and Cases 4a and 4a1 (assumptions used which minimize suppression chamber pressure). Heat sinks used for Cases 4a1 were developed based on the Dresden drywell and torus geometry parameters which were compiled during the Mark I Containment Long Term Program and which are documented in Reference 9.

SHEX Analysis Results

Table 3-1 summarize the results for of the containment analyses performed for Dresden.

The results in Tables 3-1 include the suppression pool temperature and suppression chamber pressure at 600 seconds (at initiation of operator actions) , the minimum suppression chamber pressure following initiation of containment (drywell and suppression chamber) sprays, and the suppression pool temperature and suppression chamber pressure at the time of the peak suppression pool temperature.

Figures 1-10 show the suppression pool temperature and suppression chamber pressure responses.

As shown in Table 3-1, there are small differences in the suppression pool temperature at 600 seconds and at the time of peak suppression pool temperature between all cases. There are however significant changes in the suppression chamber pressure due to the differences in input assumptions shown in Table 2. This is consistent with the trend shown in the analyses of References 3 and 4.

As expected suppression pool temperatures and suppression chamber pressures at 600 seconds for Cases 4, 4a and are the same as for Cases 2, 2a of Reference 3 and Case 2a1 of Reference 4.

The minimum suppression chamber pressures for Cases 4, 4a and 4a1 following initiation of sprays are higher than the respective minimum pressures for Cases 2, 2a and 2a1. This is due to the lower heat exchanger heat transfer rate (K) which results in a warmer containment spray temperature.

The higher peak suppression pool temperature obtained for Case 4, 4a and 4a1 vs. the peak suppression pool temperatures obtained for Cases 2, 1a, 2 and 2a1 is attributed to the lower heat exchanger heat transfer rate (K) resulting from the lower CCSW pump flow for Case 4, 4a and 4a1.

3. References

1. GENE-770-26-1092, "Dresden Nuclear Power Station, Units 2 and 3, LPCI/Containment Cooling System Evaluation," November 1992.

2. GENE-637-042-1193, "Dresden Nuclear Power Station, Units 2 and 3, Containment Analyses of the DBA-LOCA to Update the Design Basis for the LPCI/Containment Cooling System. February 1994.

3. Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for Limiting DBA-LOCA," October 23, 1996

4. Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for Limiting DBA-LOCA," October 31, 1996

5. Proposal for Analysis of Hx Performance and Suppression Pool Temperate and Chamber Pressure and Request for Change Order to Purchase Order 118064." Letter K. Dias to S. Konrad (ComEd). Nov. 13, 1996.

6. NEDO-10320, "The GE Pressure Suppression Containment System Analytical Model," May 1971.

7. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," June 1974.

8. Letter, J. W. Dingler (ComEd) to J. Nash (GE), "Inputs Parameters for Suppression Pool Pressure and Temperature Analysis," October 1996.

9. GE Document 22A5743 and GE Document 22A5744, Containment Data, September 1982. (Customer Interface Data Documents for Dresden 2 and Dresden 3 respectively).

TABLE 1 - HEAT EXCHANGER K VALUE

SHELL SIDE FLOW RATE (1 LPCI/CONTAINMENT COOLING PUMP) GPM	TUBE SIDE FLOW RATE (2 CCSW PUMPs) GPM	K BTU/SEC-°F	Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature) Million BTU/hr.
5000	5400	288.0	72.6

TABLE 2 - INPUT DIFFERENCES BETWEEN CASES 4 AND CASES 4a, 4a1

Input Parameter	Case 4	Case 4a,4a1 (high mixing efficiency)	Case 4a, 4a1 (low mixing efficiency)
Initial Drywell Temperature (°F)	135	150	150
Initial Drywell Relative Humidity (%)	20	100	100
Initial Drywell Pressure (psig)	1.25	1.0	1.0
Initial Wetwell Pressure (psig)	0.15	0.0	0.0
Mixing Efficiency = Percentage of liquid break flow mixing with drywell atmosphere (%)	100	100	20

TABLE 3-1 - SUMMARY OF DRESDEN CONTAINMENT ANALYSIS RESULTS

CASE	4	4a	4a	4al	4al
Thermal Mixing Efficiency (%)	100	100	20	100	20
Heat Sinks	No	No	No	Yes	Yes
Suspression Pool Temperature at 600 sec (°F) (At initiation of operator actions)	150	150	150	149	148
Suppression Chamber Airspace Pressure at 600 sec (psig) (At initiation of operator actions)	8.7	6.3	12.5	5.5	10.9
Minimum Suppression Chamber Pressure Following Initiation of Containment Spra (psig)	6.3	4.0	2.4	3.7	2.0
Peak Long-term Suppression Pool Temperature (°F)	175	175	175	175	175
Suppression Chamber Airspace Pressure time of Peak Suppression Pool Temperat (psig)	7.6	5.3	3.4	5.2	3.3

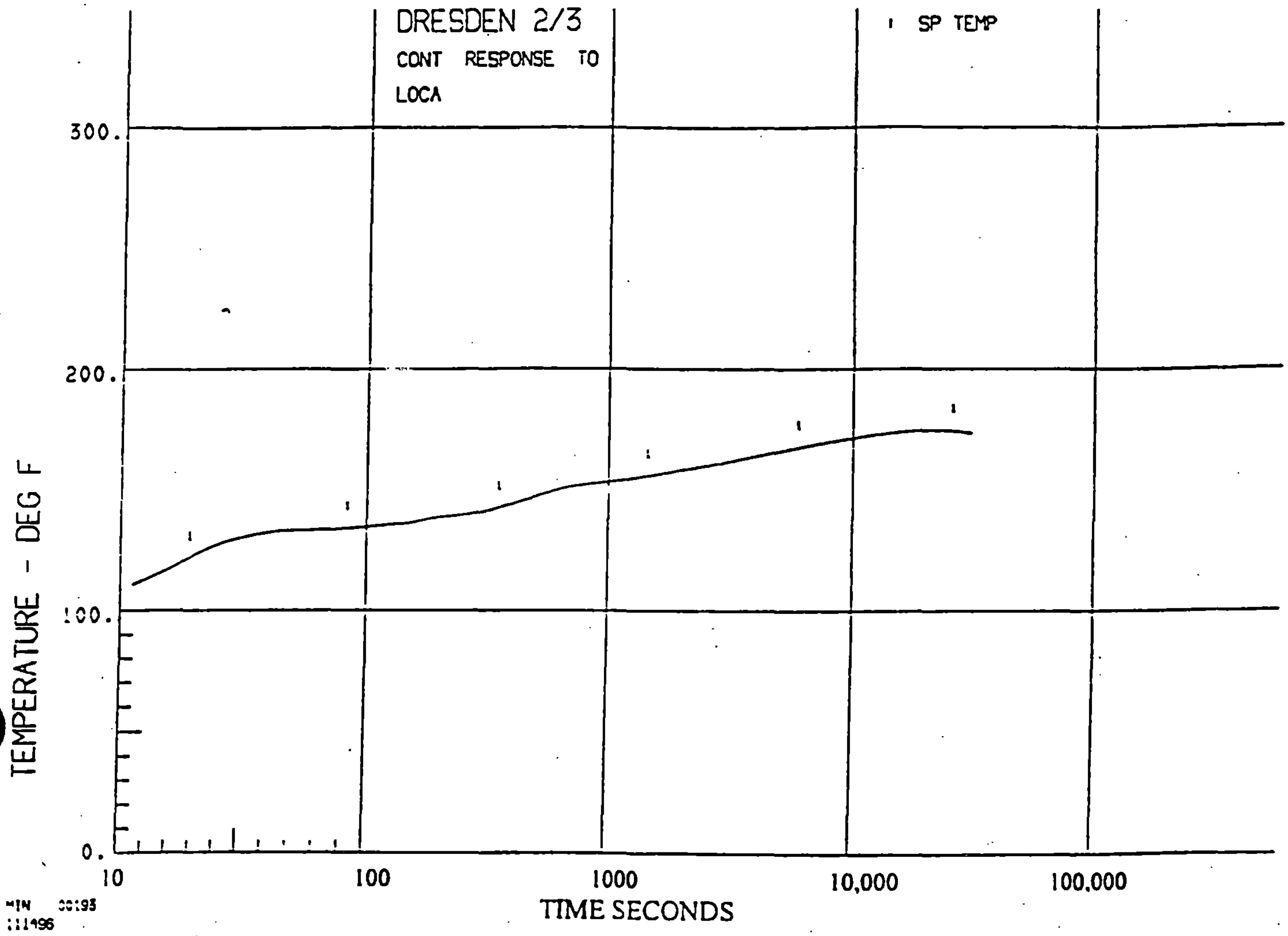

Figure 1 - DBA-LOCA Suppression Pool Temperature Response. Case 4

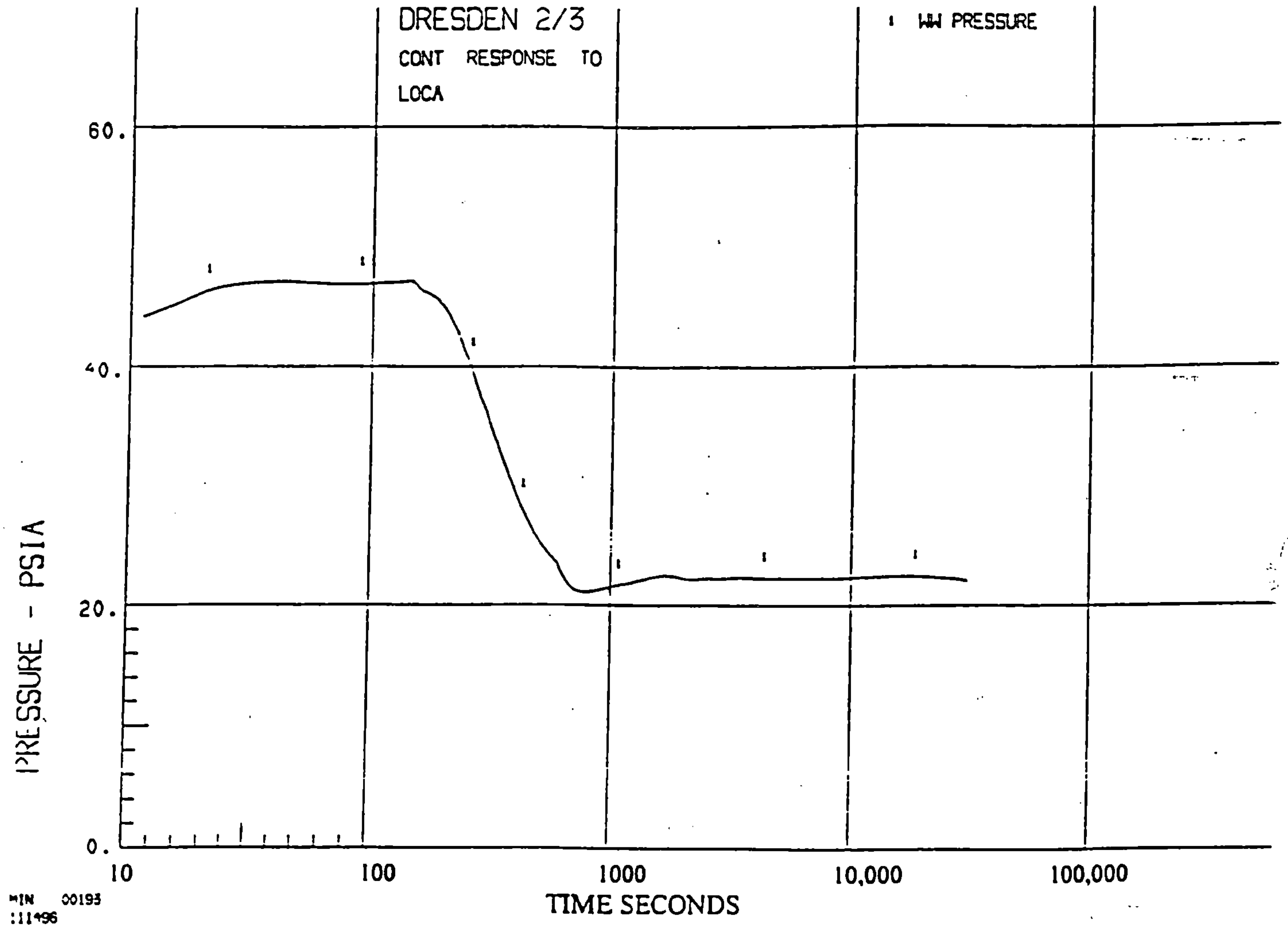

Figure 2 - DBA-LOCA Suppression Chamber Pressure Response. Case 4

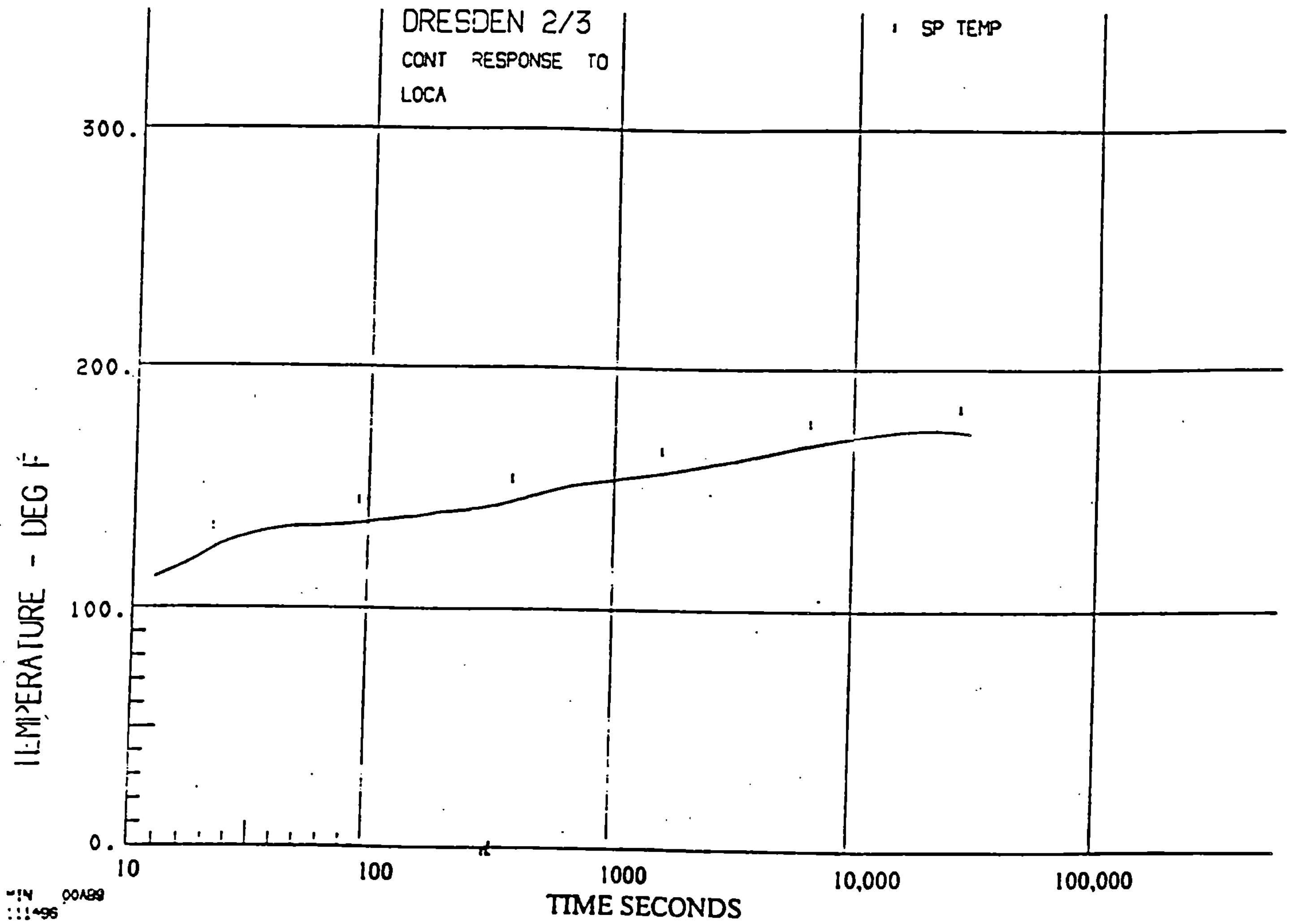

Figure 3 - DBA-LOCA Suppression Pool Temperature Response. Case 4a - High (100%) Mixing Efficiency

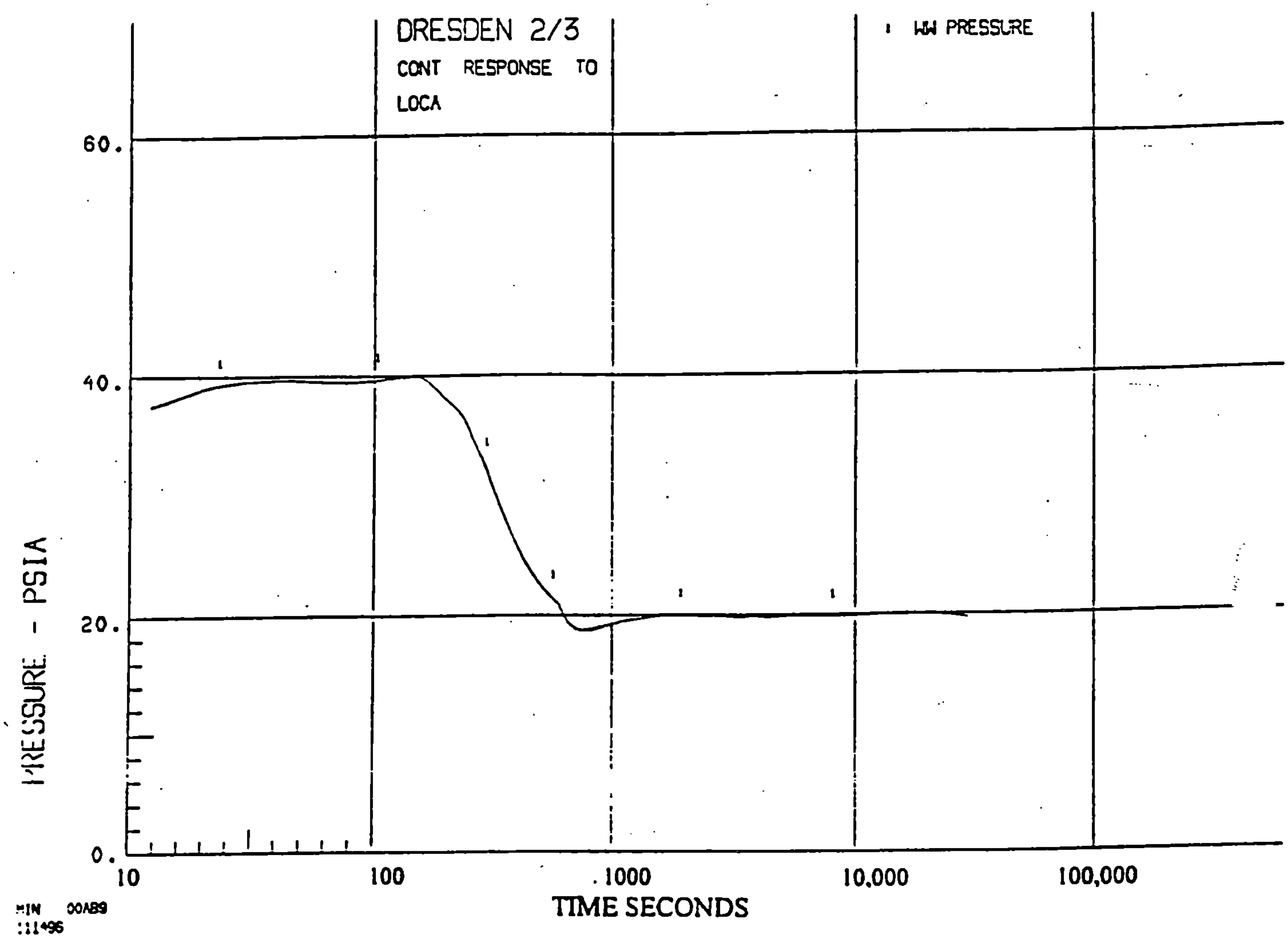

Figure 4 - DBA-LOCA Suppression Chamber Pressure Response. Case 4a - High (100%) Mixing Efficiency

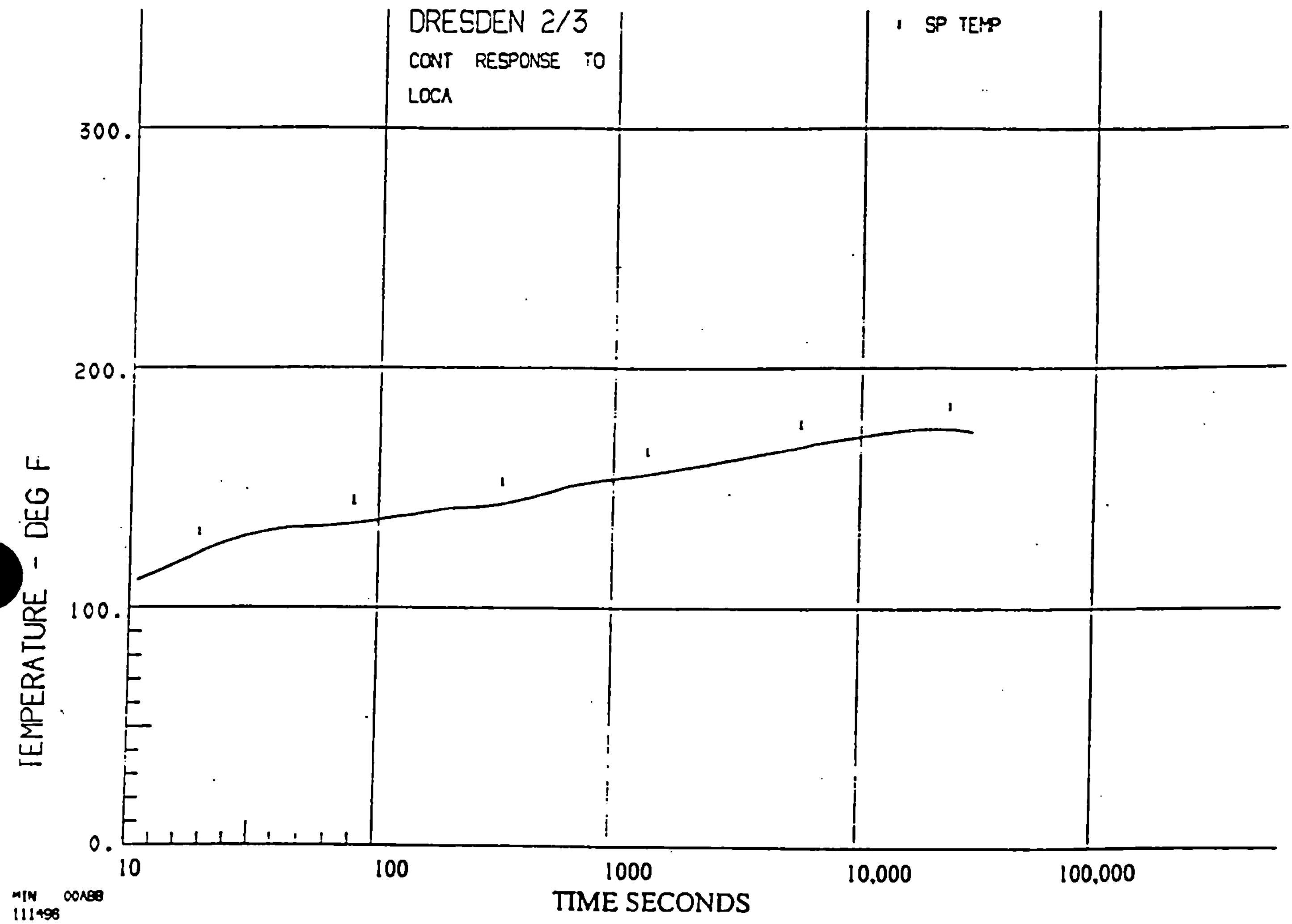

Figure 5 - DBA-LOCA Suppression Pool Temperature Response. Case 4a -Low (20%) Mixing Efficiency

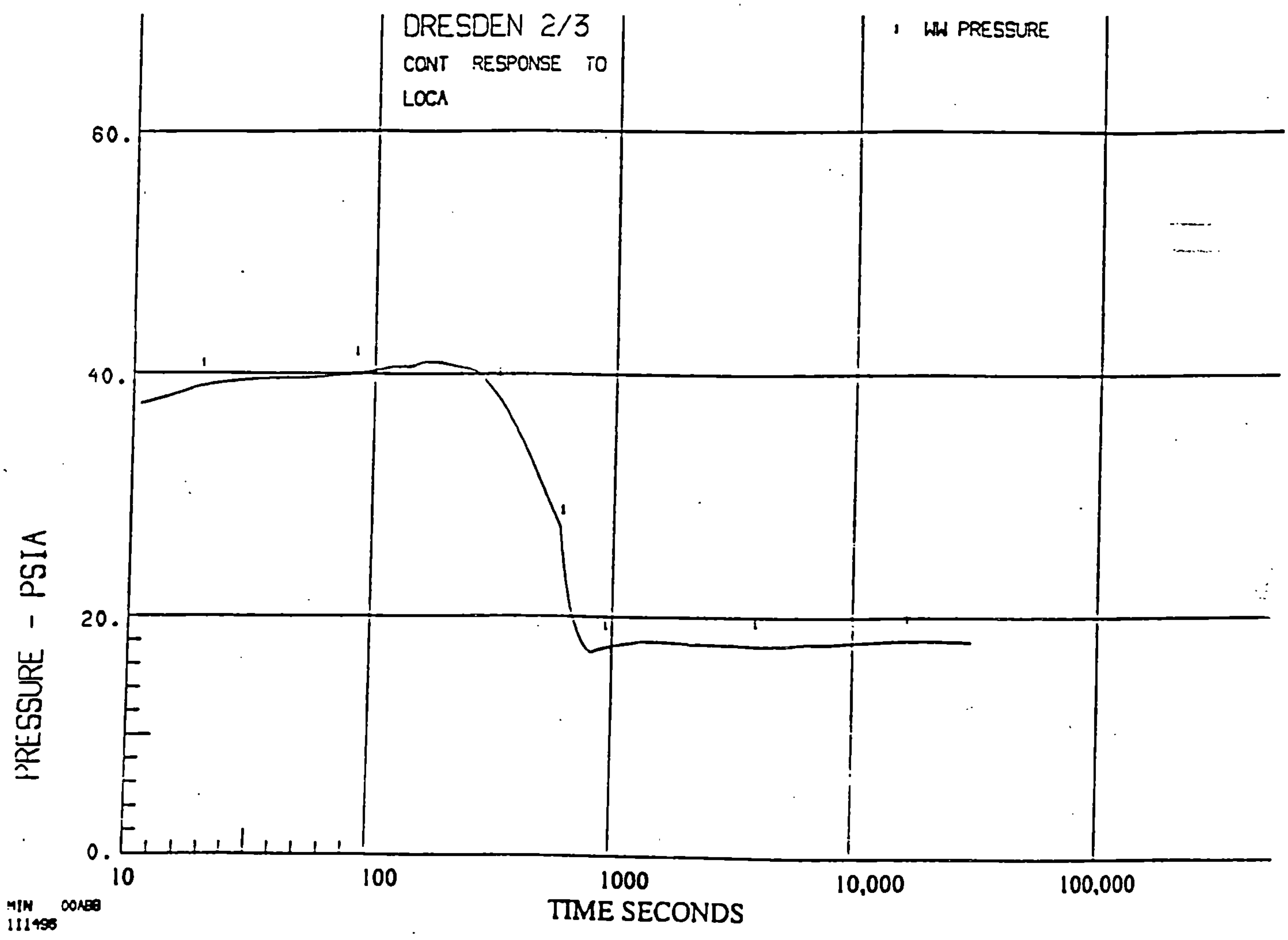

Figure 6 - DBA-LOCA Suppression Chamber Pressure Response. Case 4a - Low (20%) Mixing Efficiency

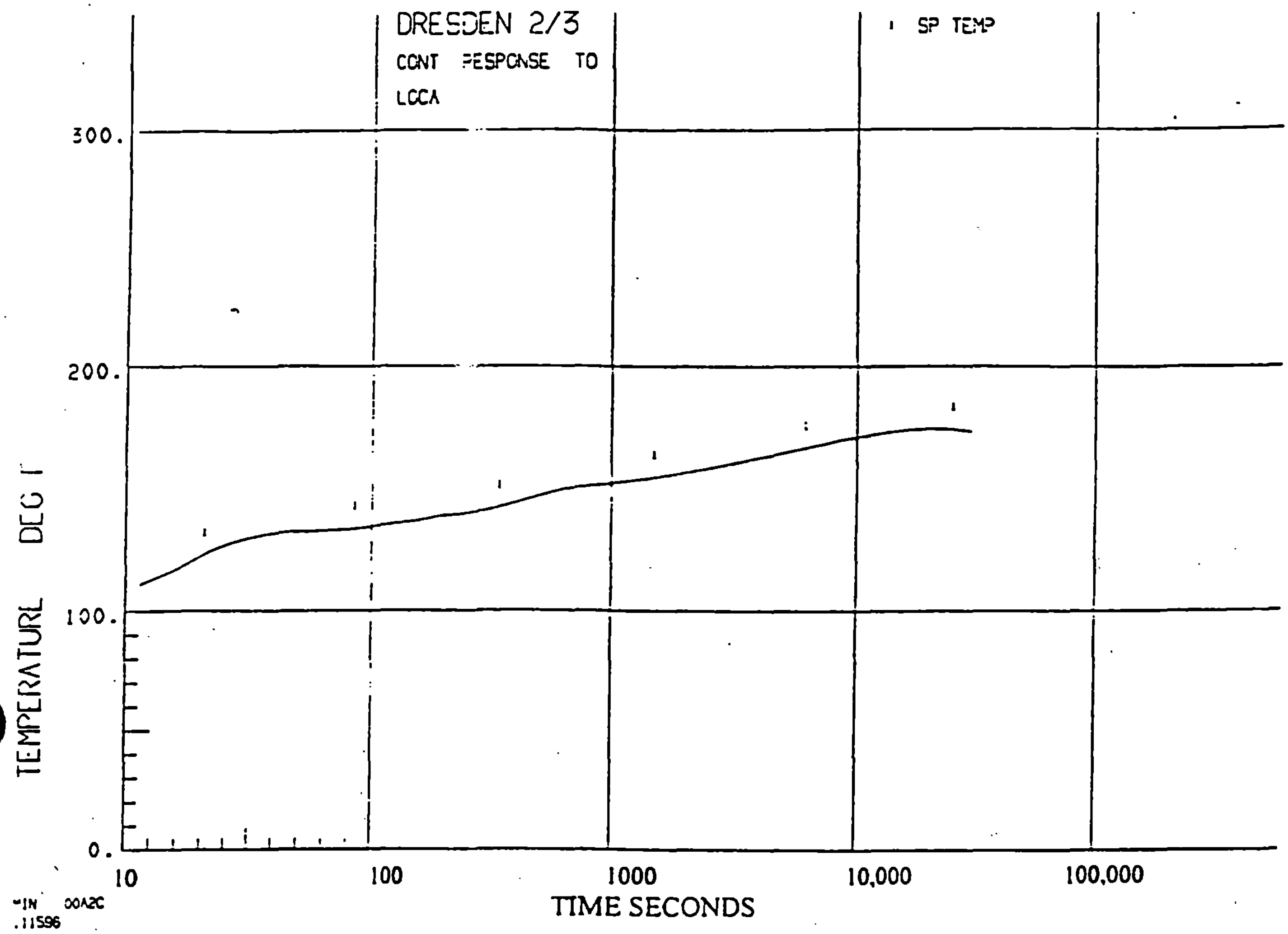

Figure 7 - DBA-LOCA Suppression Pool Temperature Response. . Case 4a1 -High (100%) Mixing Efficiency with Heat Sinks

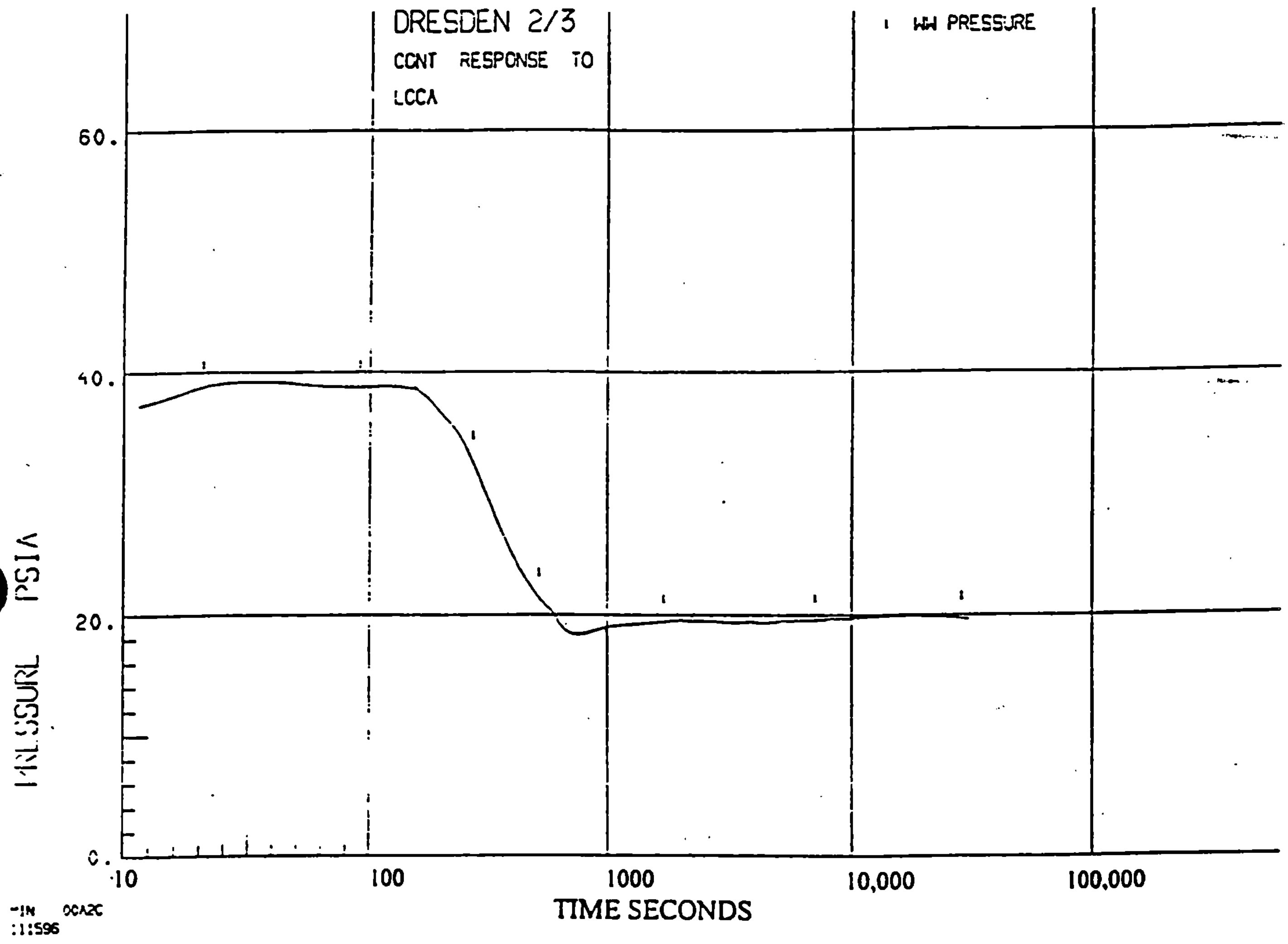

Figure 8 - DBA-LOCA Suppression Chamber Pressure Response. Case 4a1 -High (100%) Mixing Efficiency with Heat Sinks

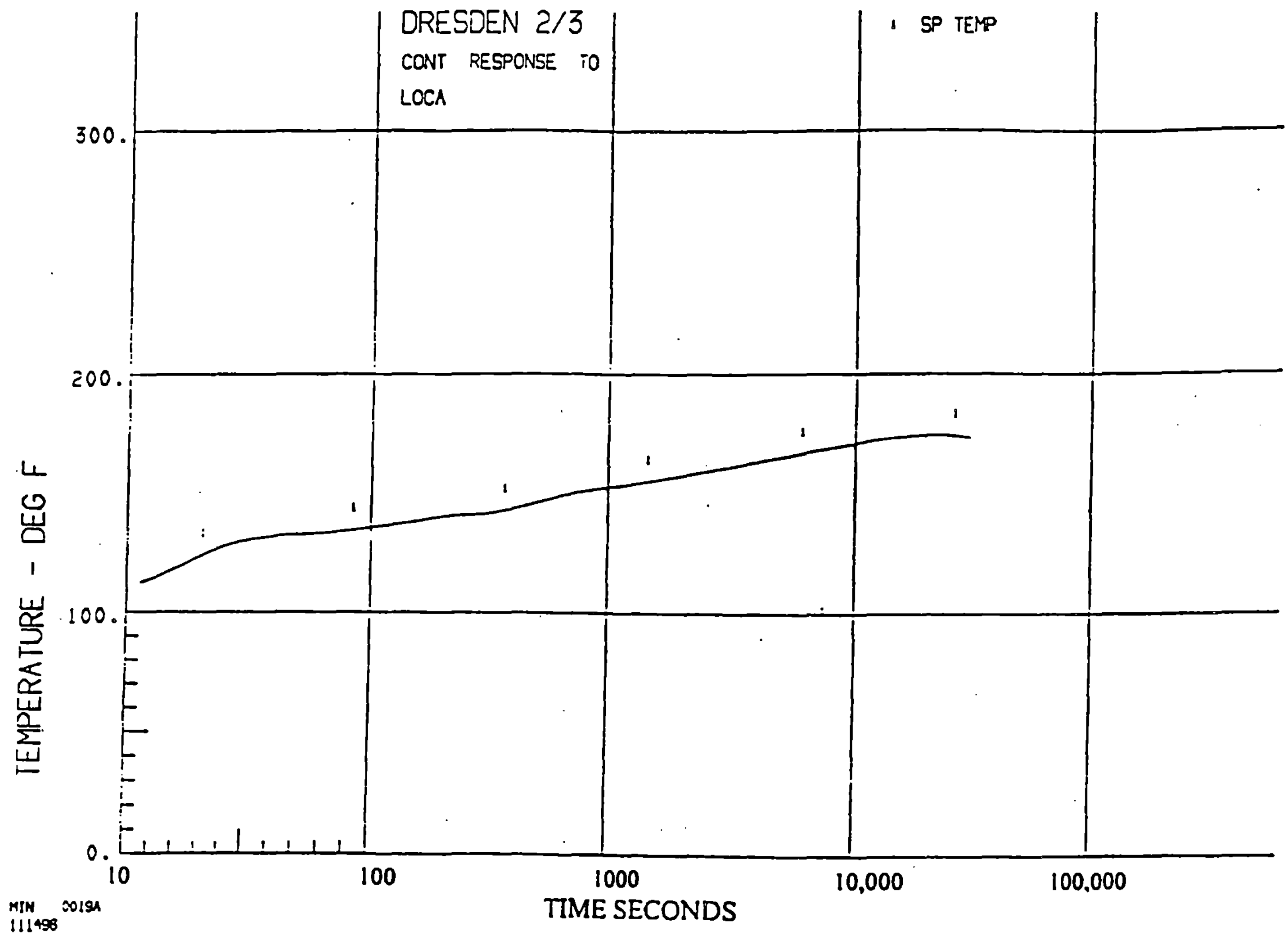

Figure 9 - DBA-LOCA Suppression Pool Temperature Response. Case 4a1 -Low (20%) Mixing Efficiency with Heat Sinks

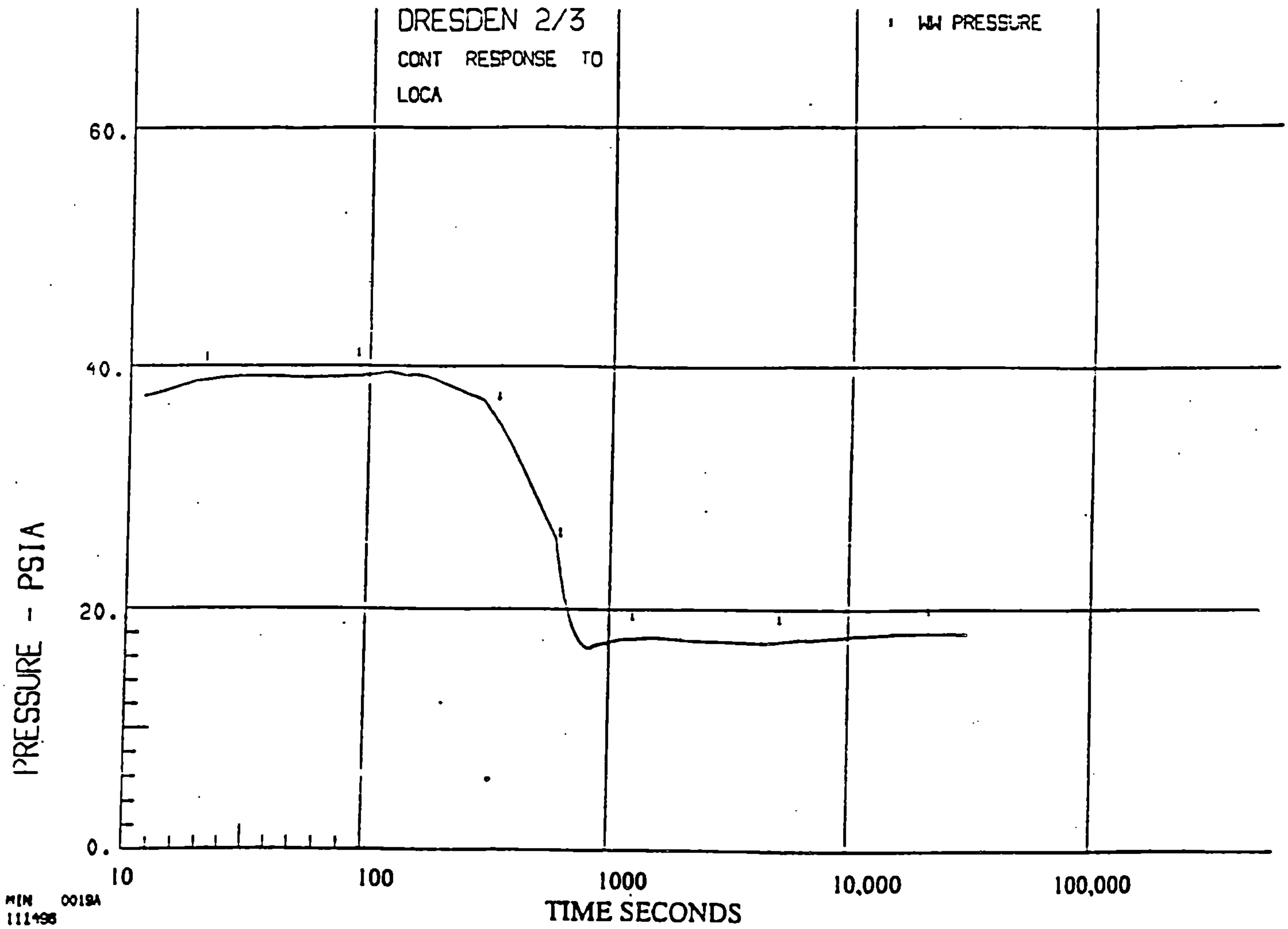

Figure 10 - DBA-LOCA Suppression Chamber Pressure Response. Case 4a1 -Low (20%) Mixing Efficiency with Heat Sinks

GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

December 26, 1996

cc: N. Shirley
DRF T23-00740

To: J. Nash

From: S. Mintz

Subject: Dresden Containment Analyses for Limiting DBA-LOCA.

References:

1. Proposal for Analysis of Hx Performance and Suppression Pool Temperate and Chamber Pressure and Request for Third Change Order to Purchase Order 118064, (GE Proposal No. 523-1GY44-EB0)," Letter K. Dias to S. Konrad (ComEd). December 24, 1996.

Attachment A to this letter provides the results for Task 1 and Task 2 as defined in Reference 1. These tasks are performed to evaluate suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA assuming a one-LPCI/Containment Cooling pump flow of 5000 gpm and a two-CCSW pump flow of 5000 gpm for long-term containment cooling.

The results in Attachment A are verified and can be used by ComEd to perform NPSH evaluations for LPCI/Containment Cooling pumps and CS pumps.

If you have any questions, please, contact me.

Performer	Verifier
S. Mintz	S. K. Rhow
S. Mintz	S. K. Rhow
Plant Upgrade Projects	Plant Upgrade Projects
M/C 172 Ext. 1791	M/C 172 Ext 1356

ATTACHMENT A
CONTAINMENT PRESSURE AND TEMPERATURE ANALYSIS FOR DRESDEN NPSH EVALUATIONS.

1-LPCI/CONTAINMENT COOLING PUMP FLOW OF 5000 GPM
2-CCSW PUMP FLOW OF 5000 GPM

ATTACHMENT A

1 Introduction

References 1 and 2 provided the long-term containment response to the DBA-LOCA for Dresden Units 2 and 3. Analyses described in these two references assumed two long-term containment cooling configurations: a) one LPCI/Containment Cooling pump and one containment cooling service water (CCSW) pump, b) two LPCI/Containment cooling pumps and two CCSW pumps.

Reference 3 provided the suppression pool temperature and suppression chamber pressure responses to the DBA-LOCA assuming the following ECCS and containment cooling configuration.

> 2 LPCI/Containment Cooling Pump and 1 core spray (CS) pump up to 600 seconds following the DBA-LOCA.
>
> 1 LPCI/Containment Cooling Pump, 2 CCSW pumps and 1 CS pump after 600 seconds.
>
> 2 CCSW pump flow rate of 7000 gpm

Reference 4 provided additional analyses using the ECCS and containment cooling configuration described above but with a 2 CCSW pump flow rate of 5400 gpm. In response to a request by ComEd (Reference 5), the suppression pool temperature and suppression chamber pressure responses to the DBA-LOCA have been analyzed assuming the ECCS and containment cooling configuration used for the Reference 4 analysis except that a 2 CCSW pump flow of 5000 gpm has been assumed (Reference 5).

This attachment provides the heat exchanger heat transfer rate for the long-term containment cooling configuration described above (Task 1 of Reference 5). The results for Task 2 of Reference 5 are also provided.

2. Analysis Results

Task 1. Calculation of Heat Exchanger Performance (K value calculation)

The heat exchanger heat transfer rate as defined by K is used in the analyses performed with the GE SHEX code. The definition of K is given below:

$K = Q/[(T_{si}-T_{ti})*3600]$

Where

K - heat exchanger heat transfer rate (BTU/sec-°F)
Q = heat exchanger heat transfer rate (BTU/hr)
T_{si}-T_{ti} = Temperature difference between the shell side and tube side inlet temperatures(°F).

The heat exchanger performance (K) for a long-term containment cooling configuration consisting of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and one LPCI/Containment Cooling heat exchanger was evaluated assuming a combined flow of 5000 gpm from two CCSW pumps

The evaluation of the heat exchanger performance was based on the heat exchanger performance work performed in 1992, which determined a heat exchanger heat transfer rate of 98.6 MBTU/hr based on a tube side flow of 7000 gpm with a tube side inlet temperature of 95°F and a shell side flow of 10,700 gpm with a shell side inlet temperature of 165°F.

The overall heat transfer rate (U) with the new LPCI/Containment Cooling pump flow and new CCSW pump flow was revised by adjusting the tube side and shell side heat transfer coefficients based on the new pump flows. New values of K were then calculated with the NTU-effectiveness method for a shell and tube heat exchanger geometry.

This method was validated by a calculation of the K value with tube side flow of 3500 gpm with a tube side inlet temperature of 95°F and a shell side flow of 5000 gpm with a shell side inlet temperature of 165°F. The resultant value of 249.5 BTU/sec-°F closely matches the K value of 249.6 BTU/sec-°F previously calculated by GE for this configuration.

The calculated K values are given in Table 1.

Task 2. Calculation of Suppression Pool Temperature and Suppression Chamber Pressure

The objective of this task is to determine the short-term (0-600 seconds) and long-term (>600 seconds) suppression pool temperature and suppression chamber pressure for the limiting DBA-LOCA. The GE computer model SHEX-04 (References 6 and 7) with decay heat based on the ANS 5.1 1979 decay heat model (without adders) was used in the analyses. Analyses performed to benchmark analyses with the SHEX-04 code to the Dresden FSAR analyses were documented in Reference 2. The benchmarking analyses in Reference 2 included sensitivity studies to quantify the effect on peak suppression pool temperature due to differences between the updated analysis and the FSAR original analysis.

Key input assumptions for the present analyses are consistent with the general containment parameters used in the analyses of References 1, 2, 3 and 4, as confirmed in Reference 8.

This attachment provides the results for all cases of Task 2. For all cases it is assumed that during the first 10 minutes 2 LPCI/Containment Cooling pumps and 1 CS pump are used for vessel makeup purposes. It is assumed that at 10 minutes the operator shuts down 1 LPCI/Containment Cooling pump and aligns 1 LPCI/Containment Cooling pumps from vessel injection mode to containment cooling mode. At the same time two CCSW pumps and one RHR heat exchanger are lined up for long-term containment cooling with drywell and suppression chamber sprays. The resulting long-term containment cooling pump configuration consists of 1 LPCI/Containment Cooling pump, 2 CCSW pumps and 1 LPCI/Containment Cooling heat exchanger. The combined CCSW flow rate through the heat exchanger for the 2 CCSW pumps is assumed to be 5000 gpm and the analysis uses heat exchanger performance values obtained from Task 1.

Case Specific Assumptions

The case numbering sequence used in this attachment continues from the numbering sequence used in Reference 4.

Case 5 - *Above nominal flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Nominal Containment Initial Conditions*

In Case 5 it is assumed that the LPCI/Containment Cooling pumps are operating with an above nominal pump flow of 5800 gpm per pump and the CS pump is operating at an above rated pump flow of 5800 gpm for the first 10 minutes . It is assumed that at 10 minutes the operator reduces the LPCI/Containment Cooling pump flows to the nominal flow of 5000 gpm per pump and the CS pump flow to the nominal pump flow of 4500 gpm.

Case 5a - *Above nominal pump flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Containment Initial Conditions to Minimize Containment Pressure*

Same as Case 5 except that conservative input assumptions are used to minimize suppression chamber pressure.

Case 5a1 - *Above nominal pump flow rate for LPCI/Containment Cooling Pump and CS for first 10 minutes and Nominal Pump Flow Rate after 10 minutes - Containment Initial Conditions to Minimize Containment Pressure, Drywell and Torus shell heat sinks modeled*

Same as Case 5a except that the drywell shell, vent system, and torus shell are modeled as heat sinks.

The analyses for Cases 5a and 5a1 consider two different values of thermal mixing efficiency between the break flow and drywell atmosphere: 100% and 20%. The assumption of a lower mixing efficiency resulted in a lower long-term suppression chamber pressure, whereas a lower short-term suppression chamber pressure was obtained with a higher mixing efficiency. The explanation for this is that following the initial vessel reflood, the break liquid flow from the vessel is colder than the drywell temperature. Therefore, a higher mixing efficiency in the short-term reduces the drywell temperature, drywell pressure and suppression chamber pressure. For the long-term this trend is reversed. After the drywell sprays reduce the drywell temperature to below the vessel liquid temperature, the break liquid heats up drywell temperature. Therefore a lower mixing efficiency results in reduced heating of the drywell by the break liquid, which minimizes suppression chamber pressure.

In addition, Case 5a with high and low thermal mixing efficiency are also evaluated with heat sinks. For these cases (Case 5a1), the drywell shell, vent system and torus shell are modeled as heat sinks.

The results for Cases 5a and 5a1 with the two values of mixing efficiency can be used to evaluate the limiting conditions with respect to available NPSH for the DBA-LOCA.

Table 2 identifies input differences between Cases 5 (nominal assumptions on suppression chamber pressure) and Cases 5a and 5a1 (assumptions used which minimize suppression chamber pressure). Heat sinks used for Cases 5a1 were developed based on the Dresden drywell and torus geometry parameters which were compiled during the Mark I Containment Long Term Program and which are documented in Reference 9.

SHEX Analysis Results

Table 3 summarize the results for of the containment analyses performed for Dresden.

The results in Tables 3 include the suppression pool temperature and suppression chamber pressure at 600 seconds (at initiation of operator actions) , the minimum suppression chamber pressure following initiation of containment (drywell and suppression chamber) sprays, and the suppression pool temperature and suppression chamber pressure at the time of the peak suppression pool temperature.

Figures 1-10 show the suppression pool temperature and suppression chamber pressure responses.

As shown in Table 3, there are small differences in the suppression pool temperature at 600 seconds and at the time of peak suppression pool temperature between all cases. There are however significant changes in the suppression chamber pressure due to the differences in input assumptions shown in Table 2. This is consistent with the trend shown in the analyses of References 4.

As expected suppression pool temperatures and suppression chamber pressures at 600 seconds for Cases 5, 5a and are the same as for Cases 4, 4a and Case 4a1 of Reference 4.

The minimum suppression chamber pressures for Cases 5, 5a and 5a1 following initiation of sprays are slightly higher than the respective minimum pressures for Cases 4, 4a and 4a1. This is due to the lower heat exchanger heat transfer rate (K) which results in a slightly higher containment spray temperature.

The slightly higher peak suppression pool temperature obtained for Case 5, 5a and 5a1 vs. the peak suppression pool temperatures obtained for Cases 4, 4a and 4a1 is attributed to the lower heat exchanger heat transfer rate (K) resulting from the lower CCSW pump flow for Case 5, 5a and 5a1.

(Note: The results of the current analysis are very similar to the results obtained in Reference 4. Therefore, in some instances suppression pool temperatures and suppression chamber pressures, after initiation of containment sprays, are shown to be unchanged from the values given in Reference 4. This is attributed to round-off in reporting the results.)

3. References

1. GENE-770-26-1092, "Dresden Nuclear Power Station, Units 2 and 3, LPCI/Containment Cooling System Evaluation," November 1992.

2. GENE-637-042-1193, "Dresden Nuclear Power Station, Units 2 and 3, Containment Analyses of the DBA-LOCA to Update the Design Basis for the LPCI/Containment Cooling System. February 1994.

3. GE-NE-T2300740-1, "Dresden Nuclear Power Station, Units 2 and 3, Containment Analyses of the DBA-LOCA Base on Long-Term LPCI/Containment Cooling System Configuration of One LPCI/Containment Cooling System Pump and 2 CCSW Pumps, "Class II, December 1996.

4. Letter, S. Mintz to J. Nash, "Dresden Containment Analyses for Limiting DBA-LOCA," November 18, 1996

5. Proposal for Analysis of Hx Performance and Suppression Pool Temperate and Chamber Pressure and Request for Third Change Order to Purchase Order 118064, (GE Proposal No. 523-1GY44-EB0)," Letter K. Dias to S. Konrad (ComEd). December 24, 1996.

6. NEDO-10320, "The GE Pressure Suppression Containment System Analytical Model," May 1971.

7. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," June 1974.

8. Letter, J. W. Dingler (ComEd) to J. Nash (GE), "Inputs Parameters for Suppression Pool Pressure and Temperature Analysis," October 1996.

9. GE Document 22A5743 and GE Document 22A5744, Containment Data, September 1982. (Customer Interface Data Documents for Dresden 2 and Dresden 3 respectively).

TABLE 1 - HEAT EXCHANGER K VALUE

SHELL SIDE FLOW RATE (1 LPCI/CONTAINMENT COOLING PUMP) GPM	TUBE SIDE FLOW RATE (2 CCSW PUMPs) GPM	K BTU/SEC-°F	Heat Transfer Rate (165°F Shell Side Temperature, 95°F Tube Side Temperature) Million BTU/hr.
5000	5000	281.7	71.0

TABLE 2 - INPUT DIFFERENCES BETWEEN
CASES 5 AND CASES 5a, 5a1

Input Parameter	Case 5	Case 5a,5a1 (high mixing efficiency)	Case 5a, 5a1 (low mixing efficiency)
Initial Drywell Temperature (°F)	135	150	150
Initial Drywell Relative Humidity (%)	20	100	100
Initial Drywell Pressure (psig)	1.25	1.0	1.0
Initial Wetwell Pressure (psig)	0.15	0.0	0.0
Mixing Efficiency = Percentage of liquid break flow mixing with drywell atmosphere (%)	100	100	20

TABLE 3 - SUMMARY OF DRESDEN CONTAINMENT ANALYSIS RESULTS

CASE	5	5a	5a	5a1	5a1
Thermal Mixing Efficiency (%)	100	100	20	100	20
Heat Sinks	No	No	No	Yes	Yes
Suppression Pool Temperature at 600 sec (°F) (At initiation of operator actions)	150	150	150	149	148
Suppression Chamber Airspace Pressure at 600 sec (psig) (At initiation of operator actions)	8.7	6.3	12.5	5.5	10.9
Minimum Suppression Chamber Pressure Following Initiation of Containmen Spray (psig)	6.4	4.0	2.4	3.7	2.0
Peak Long-Term Suppression Pool Temperature (°F)	176	176	176	175	176
Suppression Chamber Airspace Pressure at time of Peak Suppression Pool Temperature (psig)	7.8	5.4	3.5	5.3	3.5

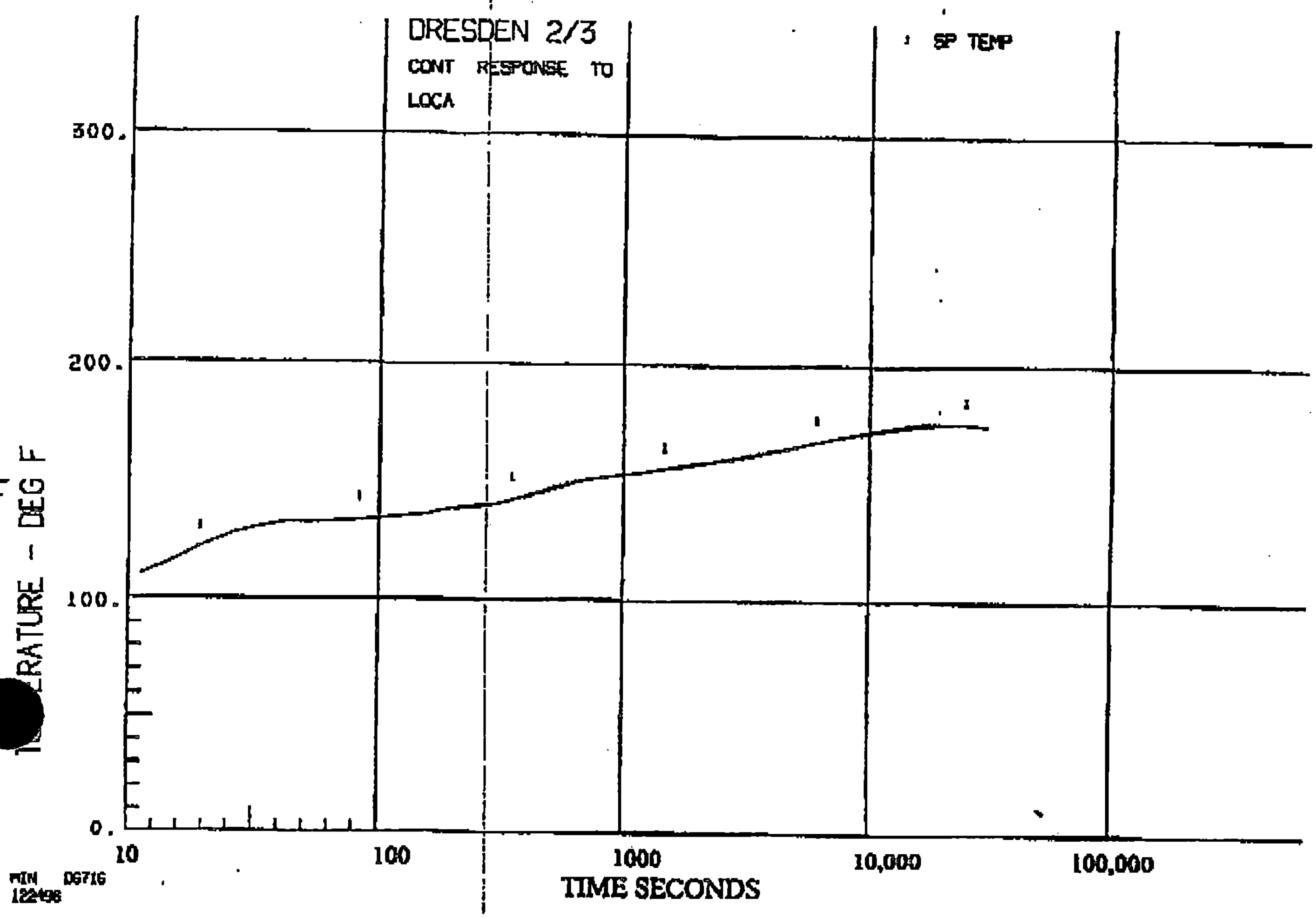

Figure 1 - DBA-LOCA Suppression Pool Temperature Response. Case 5

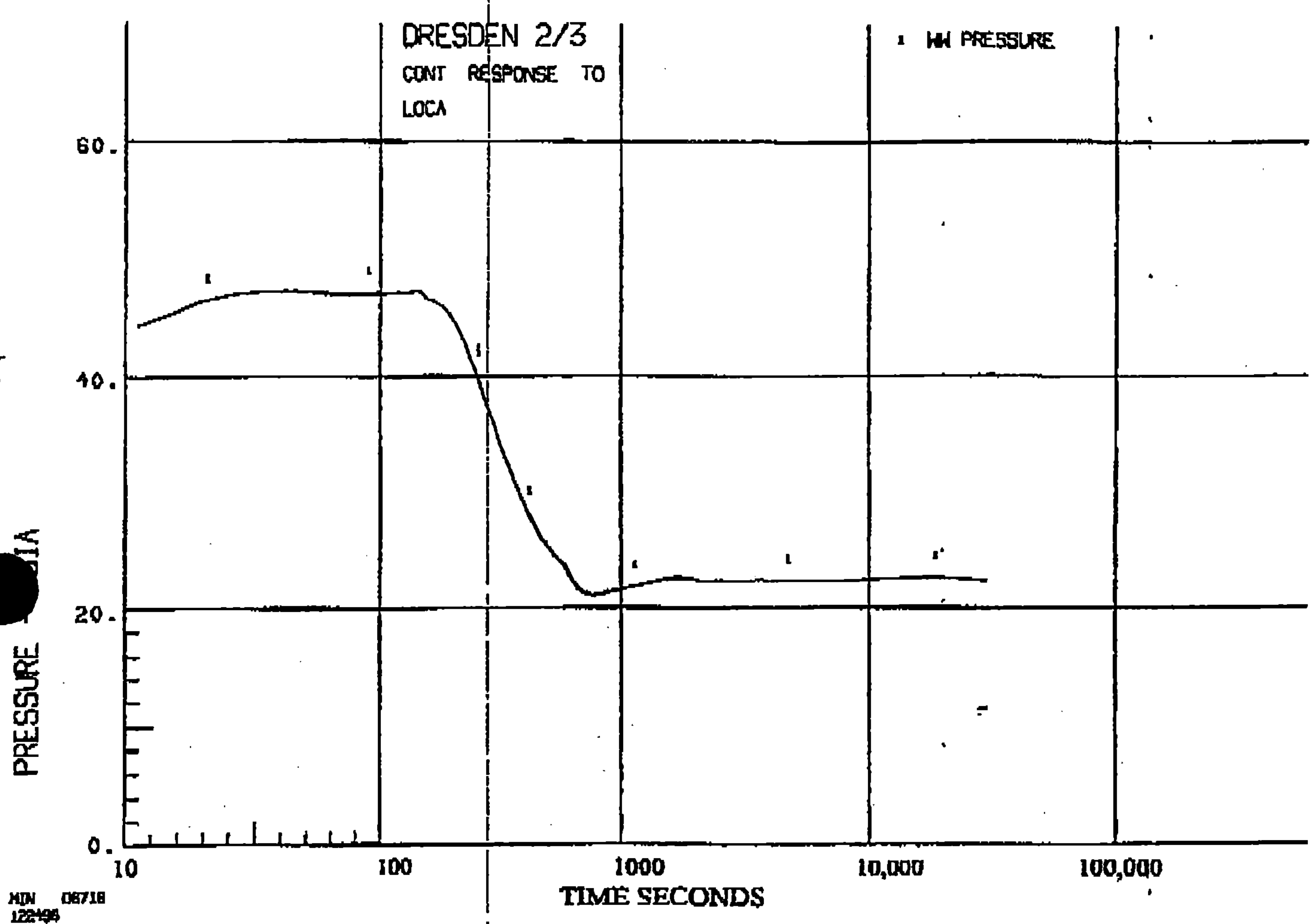

Figure 2 - DBA-LOCA Suppression Chamber Pressure Response. Case 5

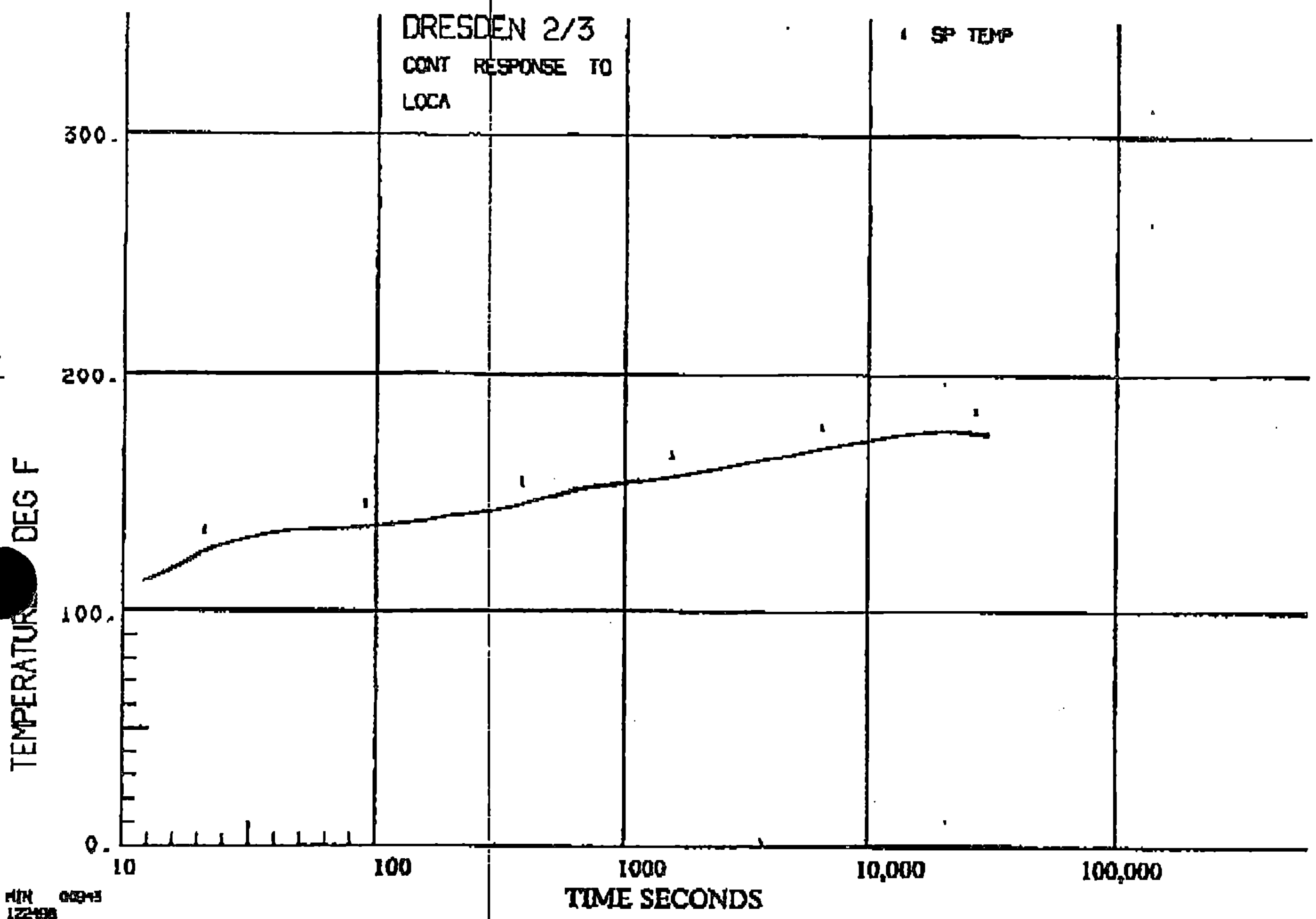

Figure 3 - DBA-LOCA Suppression Pool Temperature Response. Case 5a - High (100%) Mixing Efficiency

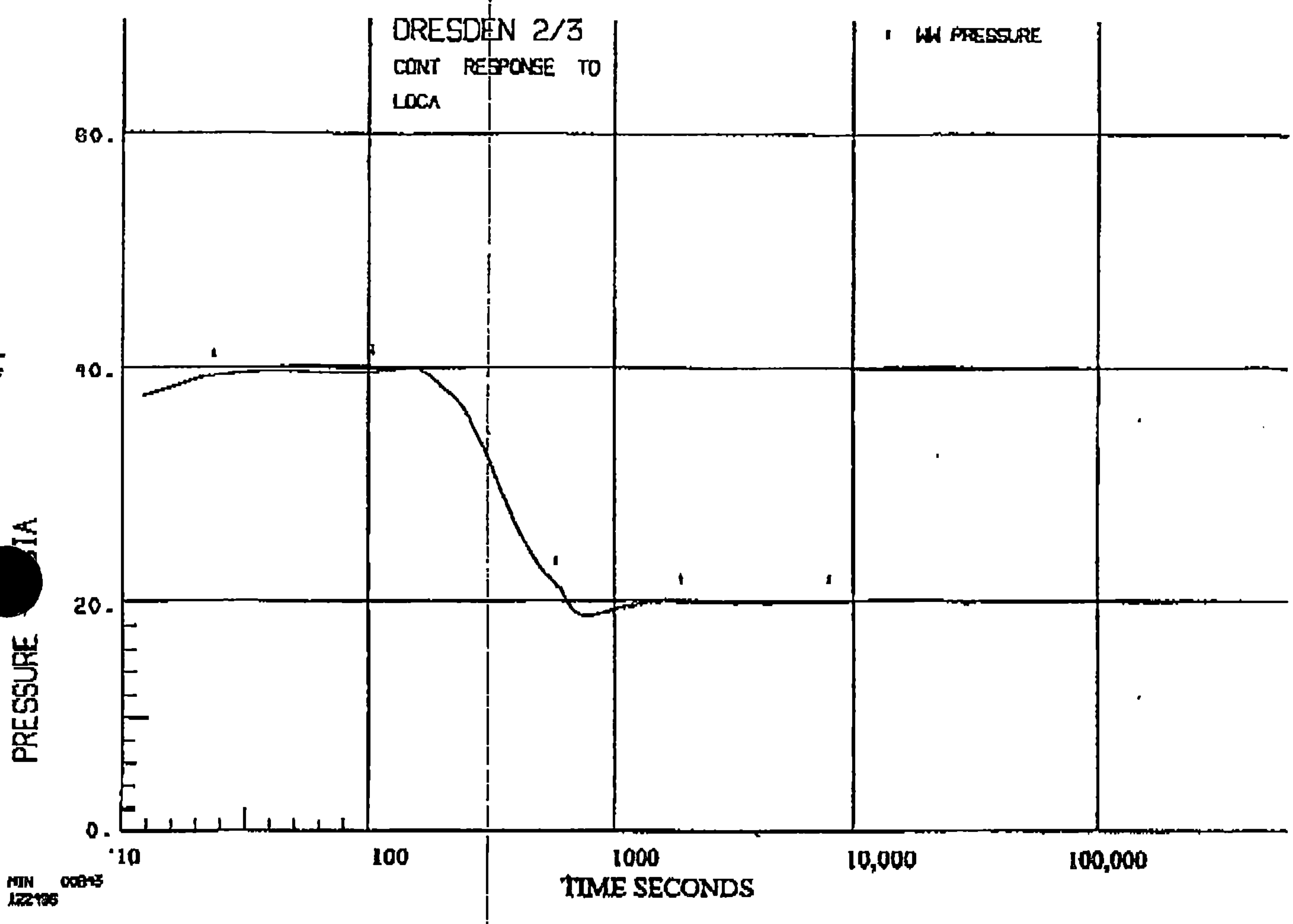

Figure 4 - DBA-LOCA Suppression Chamber Pressure Response. Case 5a - High (100%) Mixing Efficiency

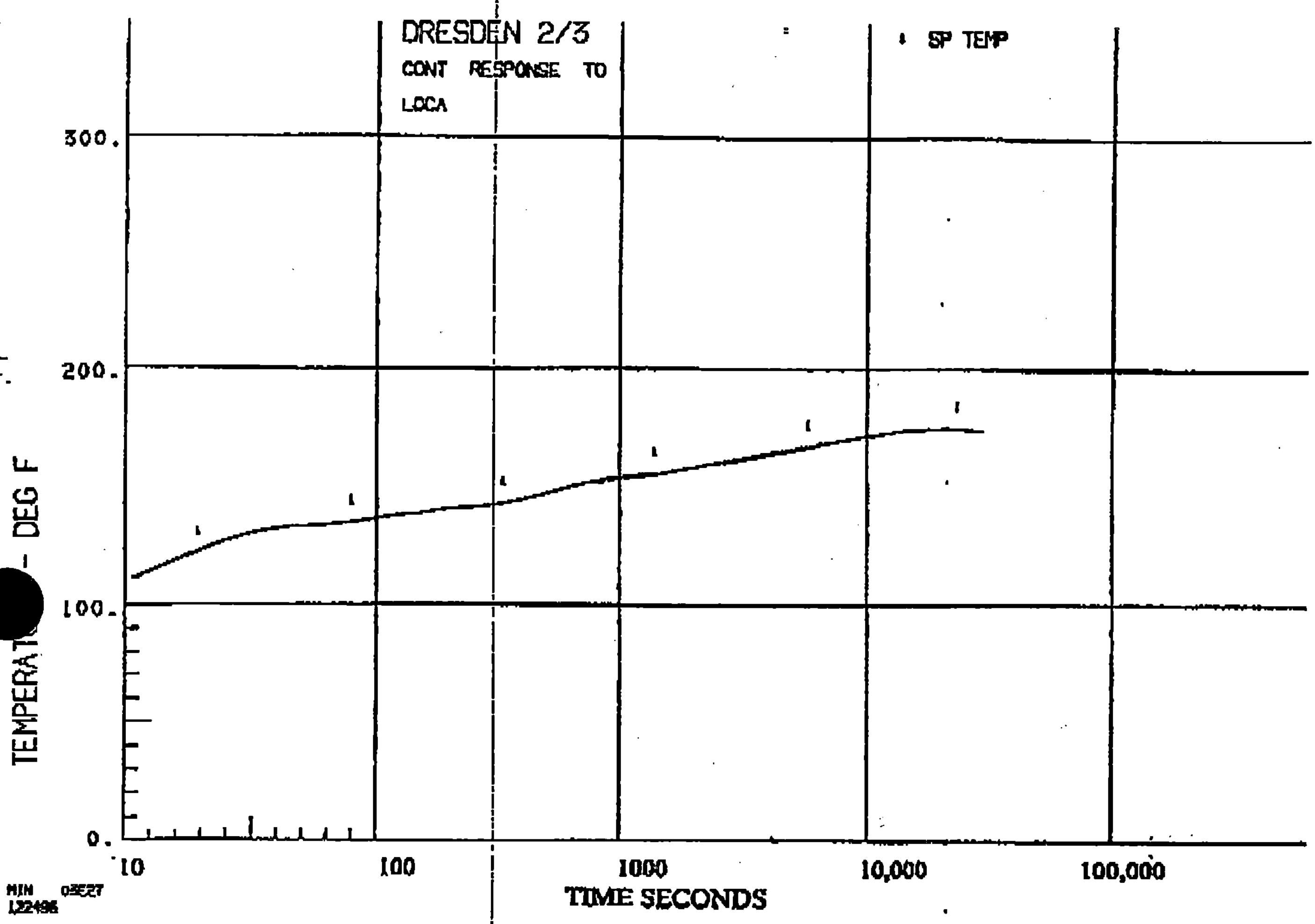

Figure 5 - DBA-LOCA Suppression Pool Temperature Response. Case 5a -Low (20%) Mixing Efficiency

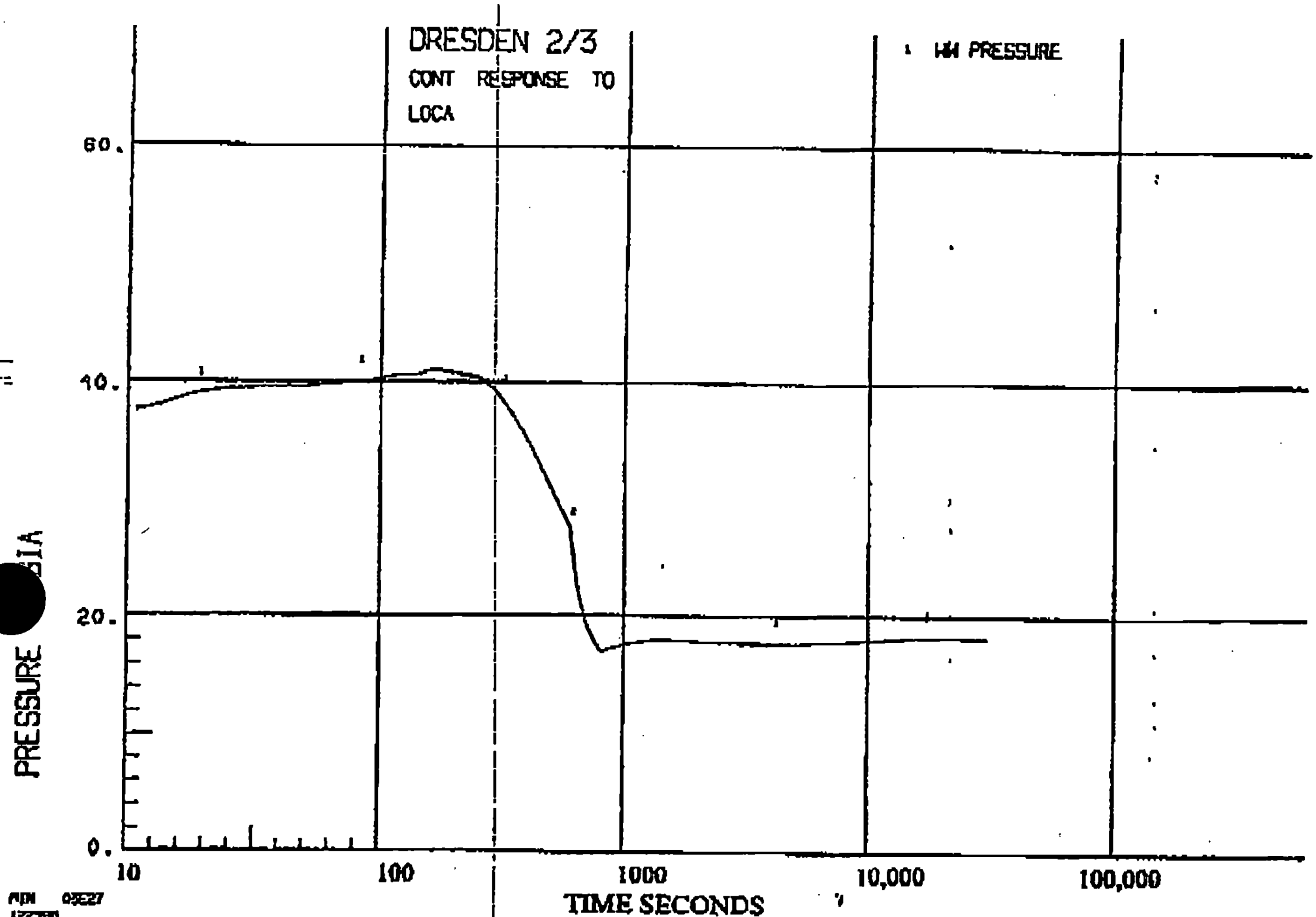

Figure 6 - DBA-LOCA Suppression Chamber Pressure Response. Case 5a - Low (20%) Mixing Efficiency

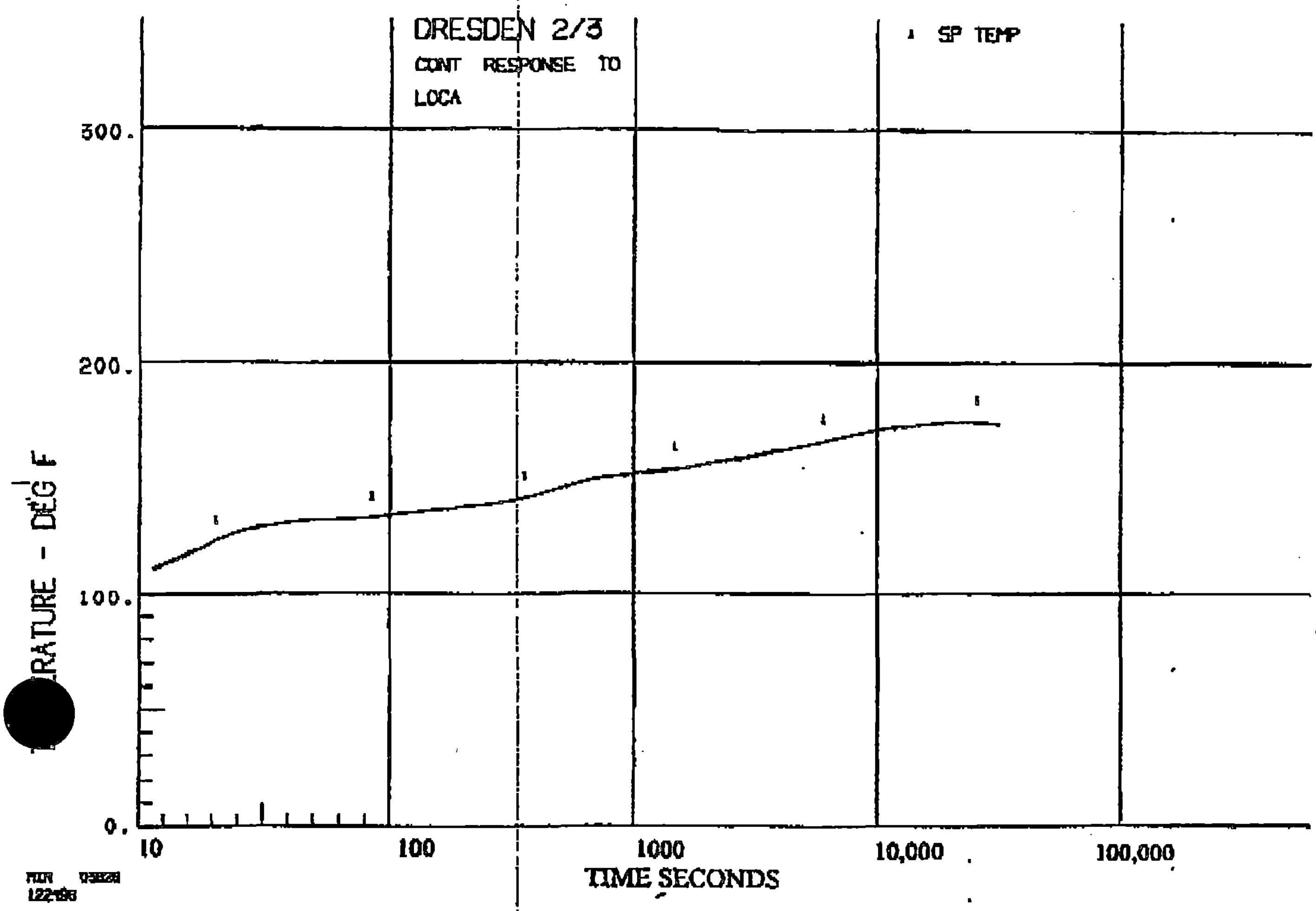

Figure 7 - DBA-LOCA Suppression Pool Temperature Response.. Case 5a1 -High (100%) Mixing Efficiency with Heat Sinks

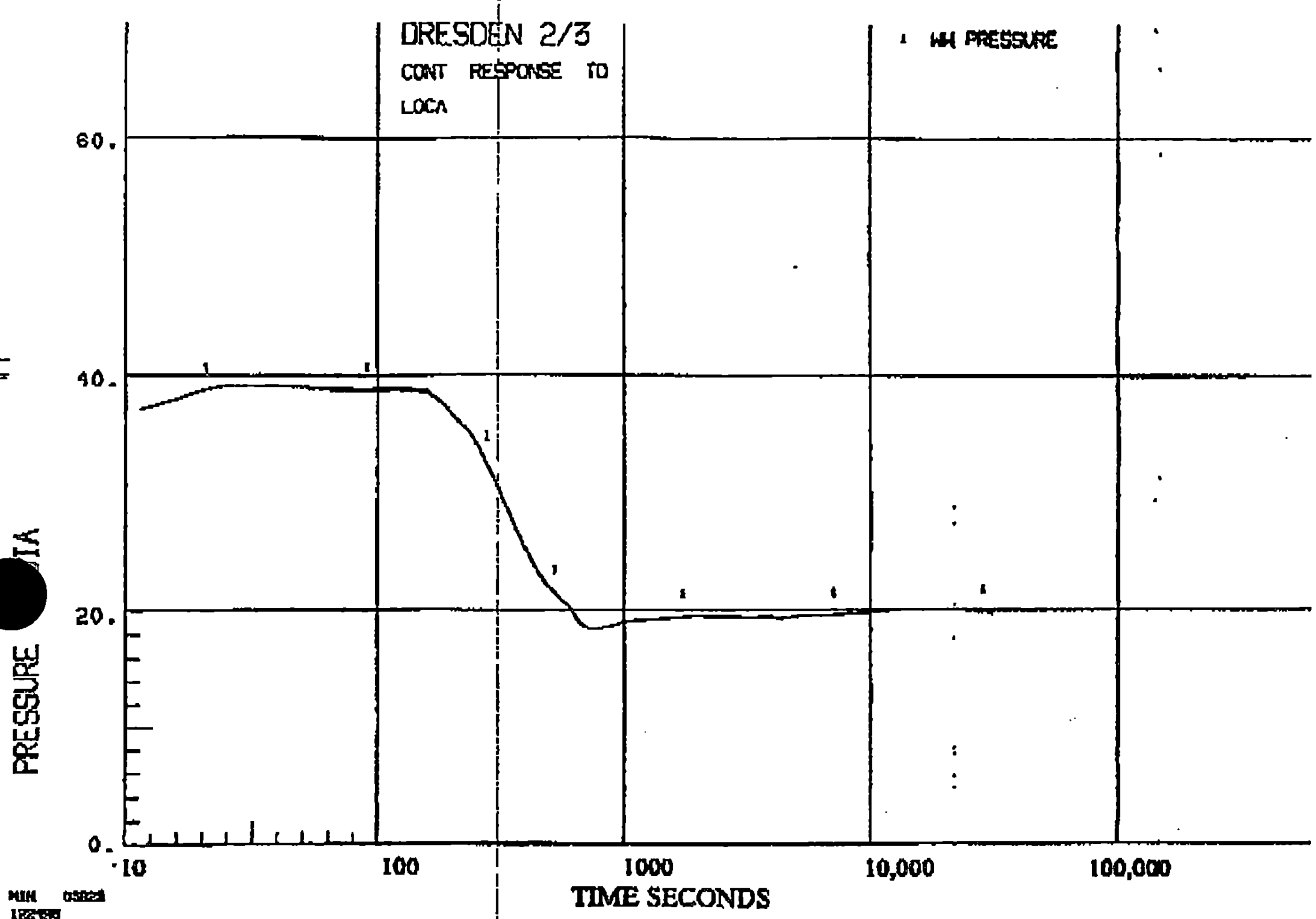

Figure 8 - DBA-LOCA Suppression Chamber Pressure Response. Case 5a1 -High (100%) Mixing Efficiency with Heat Sinks

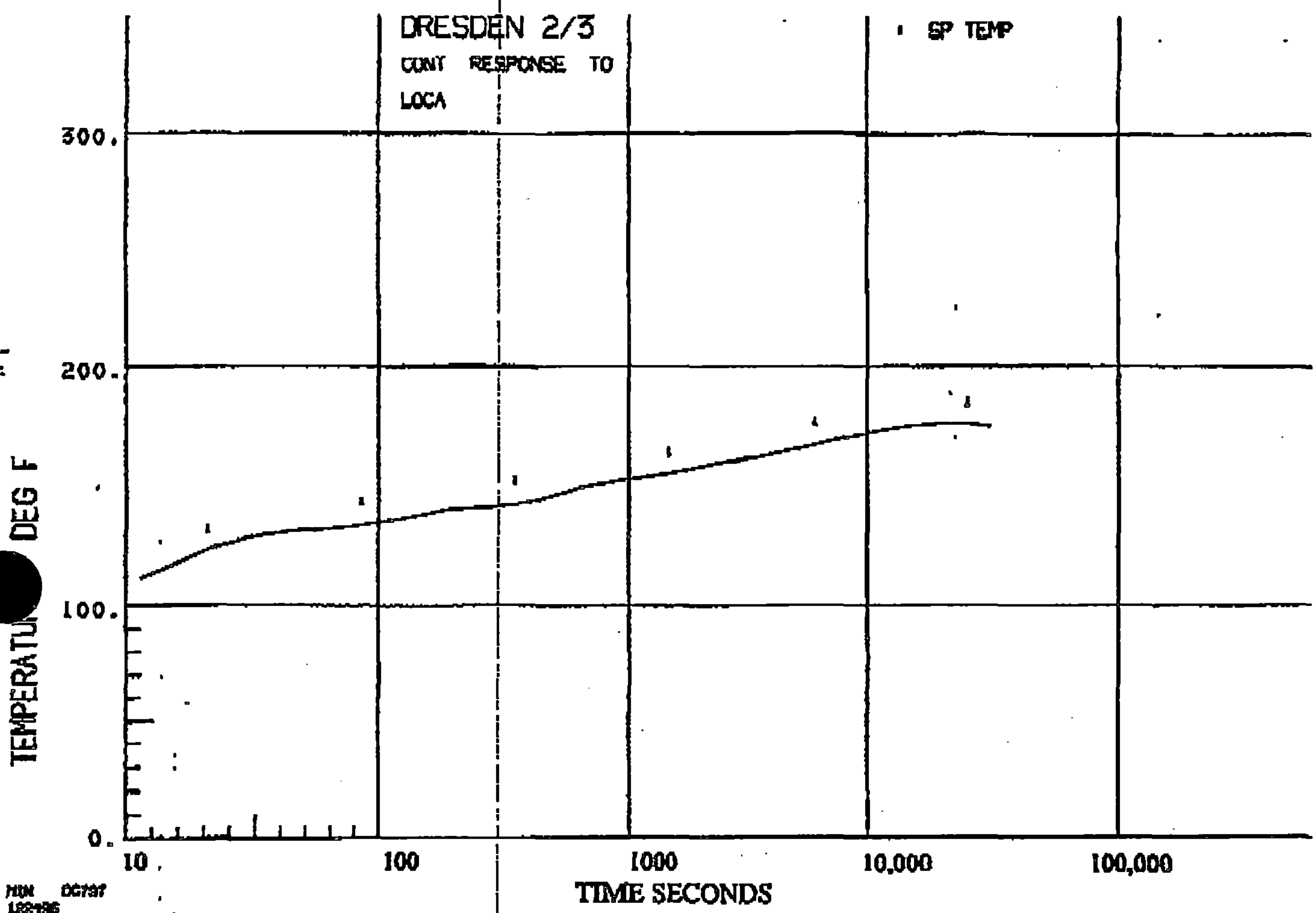

Figure 9 - DBA-LOCA Suppression Pool Temperature Response. Case 5a1 -Low (20%) Mixing Efficiency with Heat Sinks

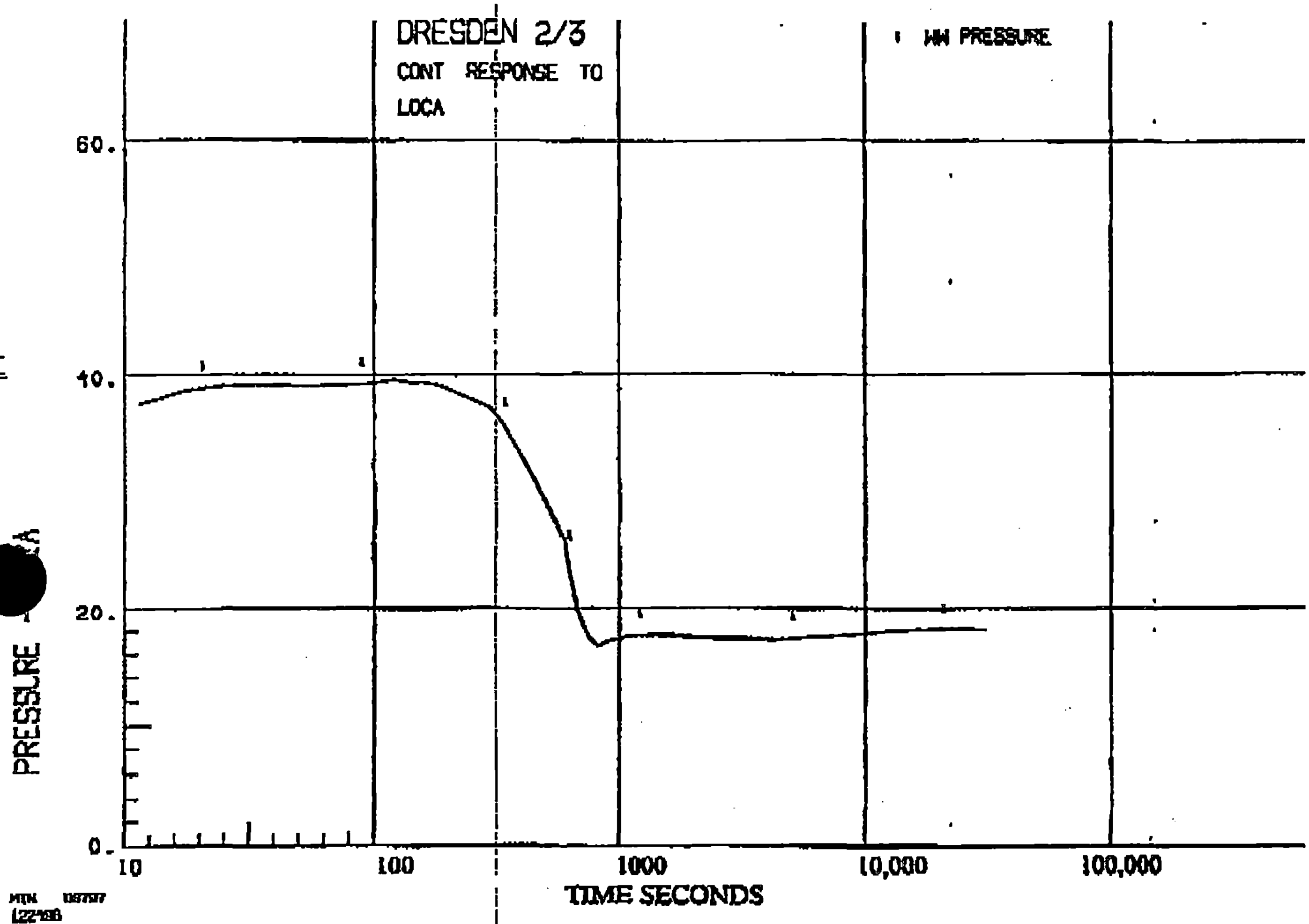

Figure 10 - DBA-LOCA Suppression Chamber Pressure Response. Case 5a1 -Low (20%) Mixing Efficiency with Heat Sinks