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General Electric Company
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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

Prepared by: S. Mintz
S. Mintz
Plant Upgrade Projects

Approved by: N. C. Shirley
N. C. Shirley
Project Manager,
Engineering & Licensing Consulting Services

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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 first 10 minutes of the DBA-LOCA. One CS pump is available for vessel makeup after 10 minutes. The analyses further assume that from 10 minutes into the accident, 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 results of analyses of the long-term containment response to the DBA-LOCA for Dresden Units 2 and 3. The evaluations in References 1 and 2 assumed two long-term containment cooling configurations: a) 1 LPCI/Containment Cooling pump and 1 containment cooling service water(CCSW) pump, and b) 2 LPCI/Containment Cooling pumps and 2 CCSW pumps.

In response to a request by ComEd (Reference 3), the suppression pool temperature and suppression chamber pressure responses to the DBA-LOCA are analyzed assuming the following ECCS and containment cooling configuration.

> 2 LPCI/Containment Cooling Pump and 1 core spray (CS) pump for vessel makeup, and no containment cooling up to 600 seconds following the DBA-LOCA.
>
> 1 CS pump for vessel makeup, and 1 LPCI/Containment Cooling Pump, 2 CCSW pumps for containment cooling after 600 seconds.

This report also provides the containment cooling system heat exchanger heat transfer rates, which were used in the containment cooling analyses.

1.1 SCOPE OF WORK

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

Task 1 - Heat Exchanger Performance Evaluation

In Task 1, the heat exchanger performance is evaluated for two cases, assuming a combined flow of 7000 gpm from two CCSW pumps. One case is based on the assumption that the LPCI/Containment Cooling pump operates at a nominal flow rate of 5000 gpm. The other case is based on an above-nominal LPCI/Containment Cooling pump flow rate of 5800 gpm.

The evaluation of the heat exchanger performance is based on heat exchanger data used in the 1992 evaluation (Reference 4), 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 with 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 here as a time period from the beginning of the DBA-LOCA to 600 seconds. For the short-term evaluation no credit for operator actions is taken. "Long-term" is defined here as a time period after the short-term, namely from 600 seconds into the event, at which time the operator takes actions to initiate containment cooling or to control pump flows.. For both the short-term and long-term analyses, the SHEX computer code is used with current standard assumptions for containment cooling analyses, including the use of the ANS 5.1 decay heat model.

All cases presented in this report were analyzed with the following assumptions. During the first 10 minutes 2 LPCI/Containment Cooling pumps and 1 CS pump are used for vessel makeup. At 10 minutes into the event, 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 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. For all cases the combined CCSW flow rate through for the 2 CCSW pumps is assumed to be 7000 gpm. The heat exchanger performance values obtained from Task 1 were used for Task 2.

In Task 2, various cases as described in Section 7 were analyzed, assuming three different combinations of pump flow rates and two different sets of initial containment conditions for each combination of pump flow rates. Sensitivity cases have also been analyzed to minimize the suppression chamber pressure response. The sensitivity parameters considered include heat sinks and the efficiency of thermal mixing between liquid break flow and drywell atmosphere. See Section 7 for a description of all cases including sensitivity 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 performance values are given in Table 1 for LPCI/Containment Cooling pump flows of 5000 gpm and 5800 gpm respectively (See Section 7 for the definition of K-value.) A combined two CCSW pump flow of 7000 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

The results for all cases, including sensitivity cases, are summarized in Table 2. This table includes 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 through 6 show the suppression pool temperature and suppression chamber pressure responses for Case 1 and Case 1a (with 100% and 20% mixing efficiency). Figures 7 through 12 show the suppression pool temperature and suppression chamber pressure responses for Case 2 and Case 2a (with 100% and 20% mixing efficiency). Figures 13 through 18 show the suppression pool temperature and suppression chamber pressure responses for Case 3 and Case 3a (with 100% and 20% mixing efficiency). Figures 19 through 22 show the suppression pool temperature and suppression chamber pressure responses for Case 2a1 (heat sinks with 100% and 20% mixing efficiency). Figures 23 through 26 show the suppression pool temperature and suppression chamber pressure responses for Case 3a1 (heat sinks with 100% and 20% mixing efficiency).

As shown in Table 2, there are small differences in the suppression pool temperature at 600 seconds and also 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 3.

The slightly lower suppression pool temperature at 600 seconds for Cases 1 and 1a relative to the values for Cases 2, 2a, 3 and 3a is attributed to the lower LPCI/Containment Cooling pump and CS pump flow for Cases 1 and 1a during the first 600 seconds. The lower pump flow results in less energy being transferred from the vessel to the suppression pool.

The lower peak suppression pool temperature for Cases 3 and 3a, relative to Cases 1, 1a, 2 and 2a, is attributed to the higher heat exchanger heat transfer rate (K-value) resulting from the higher LPCI/Containment Cooling pump flow rate for Cases 3 and 3a.

Comparisons with Reference 2 Analyses

The results for Cases 4.1 and 4.2 of Reference 2 are shown in Table 4. A comparison of the suppression chamber pressure at the time of the peak suppression pool temperature for Case 4.1 of Reference 1 with the results for Case 1a (20% mixing efficiency)shows that the suppression chamber pressure shown for Case 1a is lower than that for Case 4.2 even though the suppression pool temperature is higher for Case 1a. This is attributed to the different containment (drywell and suppression chamber) spray temperatures for these cases. The containment spray temperature is critical in establishing the suppression chamber pressure. This is because the suppression chamber pressure is strongly affected by the suppression chamber temperature, which will approach the containment spray temperature, as explained below..

The containment spray temperature can be determined by the following relation:

$$T_{spray} = T_{pool} - K(T_{pool} - T_{ccsw})/W_s$$

where:

T_{spray} = spray temperature (°F)

T_{pool} = pool temperature (°F)

T_{ccsw} = CCSW temperature (°F)

K = heat exchanger heat transfer rate (BTU/sec-°F)

W_s = shell side flow rate through heat exchanger = total containment spray flow (lbm/sec)

For Case 4.2 of Reference 2 the spray temperature at the time of the peak suppression pool temperature based on the relation shown above is:

$$T_{spray} = 167°F - 365.2(167°F--95°F)/ 1387\ lbm/sec = 148.0°F$$

For Case 1a, the spray temperature at the time of the peak suppression pool temperature is:

T_{spray} = 171°F - 307.4(171°F--95°F)/ 693 lbm/sec = 137.3°F

The lower spray temperature for Case 1a, relative to Case 4.2 of Reference 2, results in a lower suppression chamber temperature and pressure even though the suppression pool temperature for Case 1a is higher.

Effects of Heat Sinks

A comparison of the results between Case 2a and Case 2a1 and between Case 3a and 3a1 (see Table 2) shows that the heat sinks have a negligible effect on the suppression pool temperature. As for the impact of the suppression chamber pressure, the inclusion of the heat sinks resulted in a reduction of approximately 0.8 psi at 600 seconds, and a reduction of 0.2 psi in the minimum suppression chamber pressure following initiation of suppression chamber sprays. However, the heat sink effect on the suppression chamber pressure is negligible at the time of peak suppression chamber temperature. The results demonstrate that once containment sprays are initiated the effects of heat sinks become insignificant.

Based on the results shown in Table 2 Cases 2a1, 3a1 with heat sinks and with high mixing efficiency provide the limiting conditions at 600 seconds (at initiation of containment sprays) with respect to available NPSH. Cases 1a. 2a, 2a1, 3a and 3a1 with low mixing efficiency provide the limiting conditions for evaluating available NPSH after initiation of containment sprays including available NPSH at the time of 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 for the analysis in Task 2 Cases 1a, 2a and 3a are chosen to conservatively minimize the suppression chamber pressure and, therefore, minimize the available NPSH. These input assumptions were compared in Reference 12 to the NRC guidelines provided by the NRC for Pressurized Water Reactors (PWRs) in Reference 11 and in Branch Technical Position CSB 6-1 for evaluation of NPSH. It was concluded in Reference 12 that the modeling approach used for the Dresden analysis is consistent with the guidence provided for PWRs in Reference 11 and in Branch Technical Position CSB 6-1. The key input assumptions which are used in performing the Dresden containment DBA-LOCA pressure and temperature response analysis are described below. Table 5 provides values of key containment parameters common to all cases, while Table 6 and Table 7 provide case-specific inputs.

1. The reactor is assumed to be operating at 102% of the rated thermal power.

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 6).

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 heat transfer to the drywell airspace from the liquid flow from the break which does not flash is assumed to be 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. For Cases 1a, 2a, 2a1, 3a and 3a1 of Task 2 the initial drywell and suppression chamber pressure are at the minimum expected operating values to minimize the containment pressure.

10. For Cases 1a, 2a, 2a1, 3a and 3a1 of Task 2, 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 at 600 seconds, it is assumed that containment sprays are operated continuously with no throttling of the LPCI/Containment Cooling pumps below rated pump flow.

13. Passive heat sinks in the drywell, suppression chamber airspace and suppression pool are conservatively neglected to maximize the suppression pool temperature. For the sensitivity cases with heat sinks(Cases 2a1 and 3a1), 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 10. 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 negligible 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 7.

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 6).

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.

The modeling approach used for the Dresden containment response analysis which are being used in evaluating NPSH is consistent with the guidence provided for PWRs in Reference 11 and n Branch Technical Position CSB 6-1.

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 8 and Reference 9 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. 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 heat exchanger shell side and tube side inlet temperatures.

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 7000 gpm from two CCSW pumps. Two cases were evaluated. One case was based on a rated LPCI/Containment Cooling pump flow rate of 5000 gpm and the other case was based on a LPCI/Containment Cooling pump flow rate of 5800 gpm.

The evaluation of the heat exchanger performance was based on the 1992 evaluation (Reference 4), 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 with a tube side inlet temperature of 95°F and a shell side inlet temperature of 165°F.

The overall heat transfer rates for the two cases with 1 LPCI/Containment Cooling pump flow were determined by adjusting the shell side heat transfer coefficient based on the 2 LPCI/Containment Cooling pump flow of 10,700 gpm to the new LPCI/Containment Cooling pump flows. The effectiveness (NTU) method was then applied with the revised values of the overall heat transfer rates to calculate the K value for the two cases.

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.

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 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 Reference 1 and Reference 2 analyses, as confirmed in Reference 7.

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. 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 LPCI/Containment Cooling System 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 7000 gpm and the analysis uses heat exchanger performance values obtained from Task 1.

The analyses for Cases 1a, 2a and 3a 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 2a and Case 3a are also evaluated with heat sinks. For these cases, which are identified as Case 2a1 and Case 3a1, the drywell shell, vent system and torus shell are modeled as heat sinks. Both of these cases are evaluated with high and low mixing efficiency.

Table 3 identifies input values (relative to nominal values) used to minimize the suppression chamber pressure response. Heat sinks used for Cases 2a1 and 3a1 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 10.

Case-specific containment input parameters for the different cases are summarized in Tables 6 and 7. Except as identified below and in Tables 6 and 7, the input values used in the analyses for this report are the same as previously used in the analysis described in Reference 1 and Reference 2.

A description of the containment analysis cases is provided below.

Case Specific Assumptions

Case 1 - ***Nominal Pump Flow Rate -Nominal Containment Initial Conditions***

In Case 1 it is assumed that the LPCI/Containment Cooling pumps are operating at the nominal pump flow of 5000 gpm per pump and the CS pump is operating at the rated pump flow of 4500 gpm throughout the event.

Case 1a - ***Nominal Pump Flow Rate -Containment Initial Conditions to Minimize Containment Pressure***

Same as Case 1 except that conservative input assumptions are used to minimize suppression chamber pressure. This case was analyzed with both 100% and 20% thermal mixing efficiency.

Case 2 - ***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 2 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 2a - ***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 2 except that conservative input assumptions are used to minimize suppression chamber pressure. This case was analyzed with both 100% and 20% thermal mixing efficiency.

Case 2a1 - ***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 2a except that the drywell shell, vent system, and torus shell are modeled as heat sinks. This case was analyzed with both 100% and 20% thermal mixing efficiency.

Case 3 - ***Above Nominal Pump Flow Rate -Nominal Containment Initial Conditions***

In Case 3 it is assumed that the LPCI/Containment Cooling pumps are operating at the above nominal pump flow of 5800 gpm per pump and the CS pump is operating at the above nominal pump flow of 5800 gpm throughout the event.

Case 3a - ***Above Nominal Pump Flow Rate - Containment Initial Conditions to Minimize Containment Pressure***

Same as Case 3 except that conservative input assumptions are used to minimize suppression chamber pressure. This case was analyzed with both 100% and 20% thermal mixing efficiency.

Case 3a1 - ***Above Nominal Pump Flow Rate - Containment Initial Conditions to Minimize Containment Pressure, Drywell and Torus shell heat sinks modeled***

Same as Case 3a except that the drywell shell, vent system, and torus shell are modeled as heat sinks. This case was analyzed with both 100% and 20% thermal mixing efficiency.

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, 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-EBO)," October 11, 1996.

4) 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.

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

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

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

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

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

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

11) NRC Information Notice 96-55: Inadequate Net Positive Suction Head of Emergency Core Cooling and Containment Heat Removal Pumps Under Design Basis Accident Conditions.

12) Letter, S. Mintz to J. Nash, "Review of NRC Information Notice 96-55, November 4, 1996.

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.
5000	7000	307.4	77.5
5800	7000	325.4	81.8

TABLE 2 - Summary of Dresden Containment Analysis Results

CASE	1	1a	1a	2	2a	2a	2a1	2a1	3	3a	3a	3a1	3a1
Thermal Mixing Efficiency (%)	100	100	20	100	100	20	100	20	100	100	20	100	20
Heat Sinks	no	no	no	no	no	no	yes	yes	no	no	no	yes	yes
Suppression Pool Temperature at 600 sec (°F) (At initiation of operator actions)	148	149	148	150	150	150	149	148	150	150	150	149	148
Suppression Chamber Airspace Pressure at 600 sec (psig) (At initiation of operator actions)	11.3	8.5	16.5	8.7	6.3	12.5	5.5	10.9	8.8	6.2	12.3	5.5	11.0
Minimum Suppression Chamber Pressure Following Initiation of Containment Spray (psig)	6.9	4.5	2.7	6.3	4.0	2.2	3.6	1.9	6.2	3.9	2.0	3.5	1.7
Peak Long-term Suppression Pool Temperature (°F)	173	173	173	173	173	173	172	173	171	171	171	171	171
Suppression Chamber Airspace Pressure at time of Peak Suppression Pool Temperature (psig)	7.2	4.9	3.0	7.3	4.9	3.0	4.8	2.9	7.2	4.7	3.1	4.7	3.1

TABLE 3 - Differences in Input Values Used for Nominal and Minimum Suppression Chamber Pressure Response Evaluation

	Case 1,2 & 3 (nominal pressure response)	Case 1a, 2a & 3a (minimum pressure response without heat sinks)	Case 2a1 & 3a1 (minimum pressure response with heat sinks)
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 (%)	100	100/20	100/20
Heat Sinks Included	No	No	Yes

TABLE 4 - Results of Dresden Containment Analysis Results for Case 4.1 and Case 4.2 of Reference 2

Cases from Reference 2	Description	Peak Pool Temperature (°F)	Suppression Chamber Pressure at Time of Peak Pool Temperature (psig)
4.1 of Ref. 2	1 LPCI/CONTAINMENT COOLING PUMP & 1 CCSW PUMP	180	4.3
4.2 of Ref. 2	2 LPCI/CONTAINMENT COOLING PUMPS & 2 CCSW PUMPS	167	3.7

TABLE 5- 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		
Low Water Level (LWL)	ft^3	120097
Initial Suppression Pool Volume		
Min. Water Level	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 5 - 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 5
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	600

Table 5 - 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 6- Pump Flows for DBA-LOCA Containment Analysis

	CASE 1	CASE 1a	CASE 2	CASE 2a	CASE 3	CASE 3a
CORE SPRAY PUMP FLOW** GPM						
0-600 SEC	4500	4500	5800	5800	5800	5800
AFTER 600 SECONDS	4500	4500	4500	4500	5800	5800
LPCI/CONTAINMENT COOLING PUMP FLOW						
0-600 SEC (2 Pumps, LPCI vessel injection mode*)	11,600	11,600	10000	10000	11,600	11,600
AFTER 600 SEC (1 Pump, Containment Cooling Mode with Drywell and Suppression Chamber Spray)	5000	5000	5000	5000	5800	5800
CCSW PUMP FLOW	7000	7000	7000	7000	7000	7000

*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 difference of 90 psid or less. Pump flow rates at higher pressure differentials are modeled based on the LPCI/Containment Cooling pump flow curve.

TABLE 7

Key Parameters for Containment Analysis

	CASE 1	CASE 1a	CASE 2	CASE 2a CASE 2a1	CASE 3	CASE 3a CASE 3a1
DECAY HEAT MODEL	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1	ANS 5.1
INITIAL SUPPRESSION POOL TEMPERATURE (°F)	95	95	95	95	95	95
FEEDWATER ADDED	Yes	Yes	Yes	Yes	Yes	Yes
PUMP HEAT ADDED	Yes	Yes	Yes	Yes	Yes	Yes
HEAT EXCHANGER K-VALUE (BTU/SEC-°F)	307.4	307.4	307.4	307.4	325.4	325.4
INITIAL DRYWELL PRESSURE (PSIA)	15.95	15.70	15.95	15.70	15.95	15.70
INITIAL SUPPRESSION CHAMBER PRESSURE (PSIA)	14.85	14.70	14.85	14.70	14.85	14.70
INITIAL DRYWELL TEMPERATURE	135	150	135	150	135	150
INITIAL DRYWELL RELATIVE HUMIDITY (%)	20	100	20	100	20	100
INITIAL SUPPRESSION CHAMBER RELATIVE HUMIDITY (%)	100	100	100	100	100	100
MIXING EFFICIENCY BETWEEN BREAK LIQUID AND DRYWELL FLUID (%)	100	100/20**	100	100/20**	100	100/20**

*Case 2a1 and Case 3a1 are the same as Case 2a and Case 3a respectively except that the drywell shell, vent system and torus shell are modeled as heat sinks

** Cases 1a, 2a, 2a1, 3a and 3a1 are evaluated with 100% mixing efficiency between the break liquid and drywell fluid and with 20% mixing efficiency between the break liquid and drywell fluid.

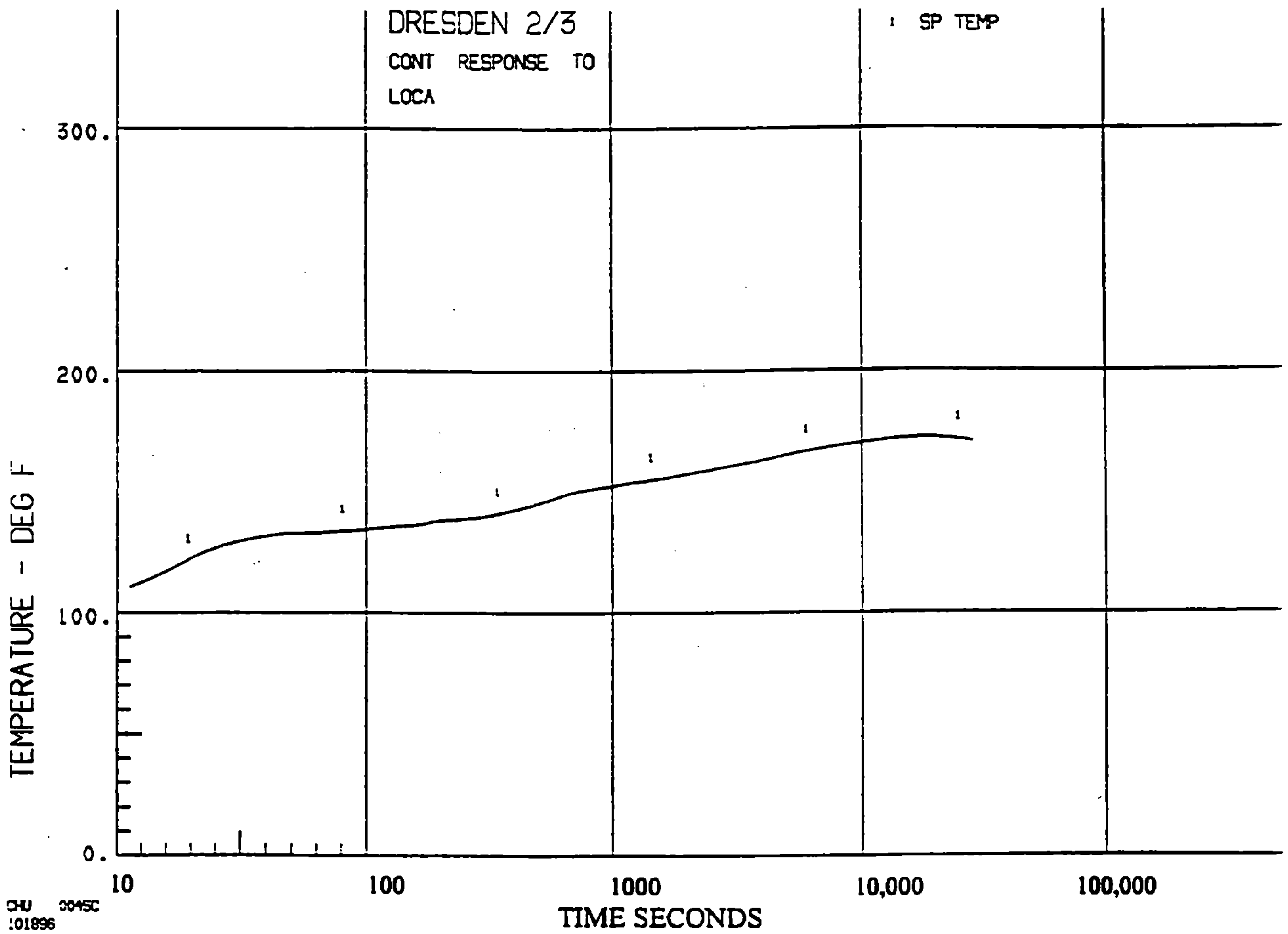

Figure 1 - DBA-LOCA Suppression Pool Temperature Response. Case 1

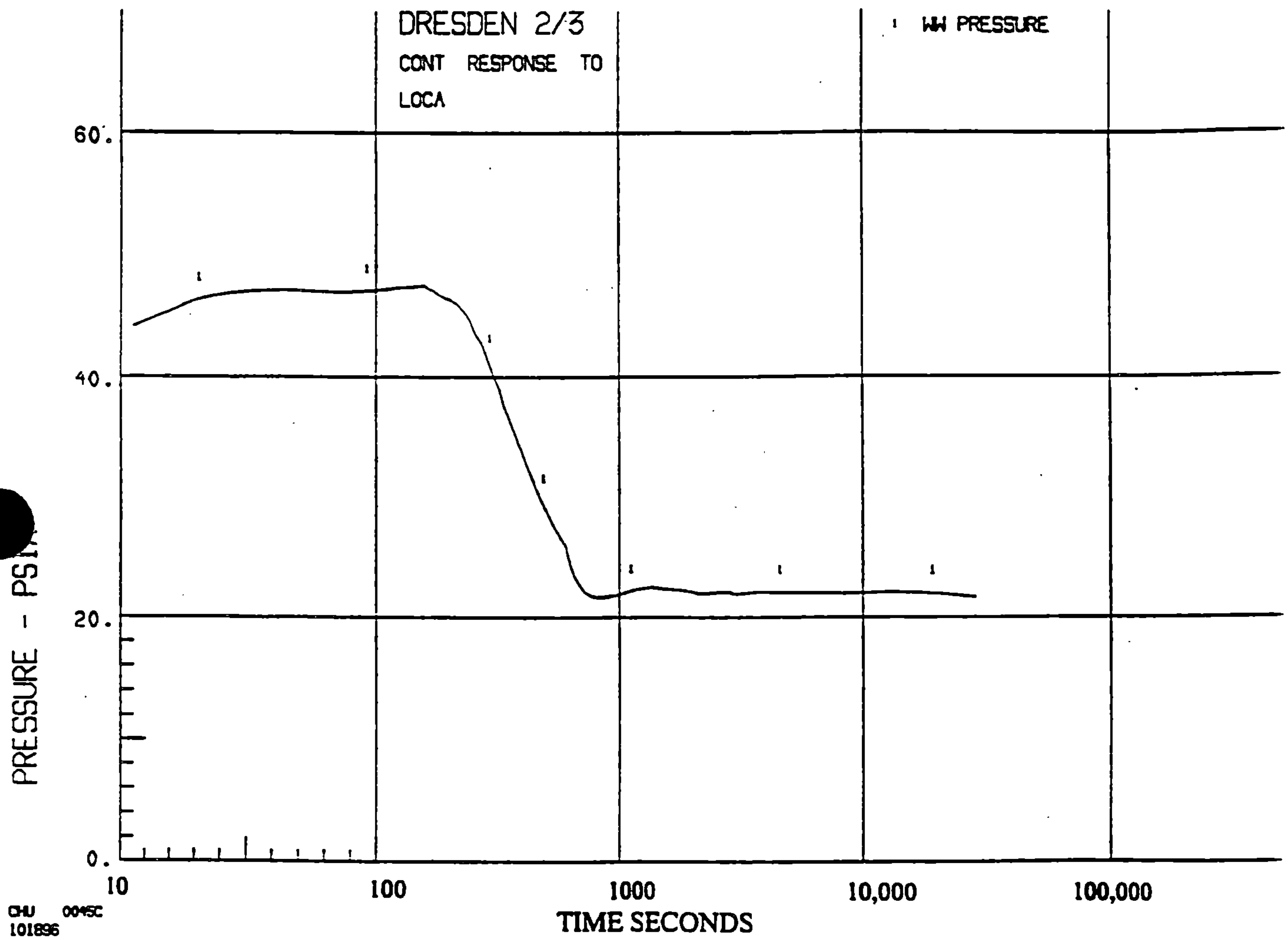

Figure 2 - DBA-LOCA Suppression Chamber Pressure Response. Case 1

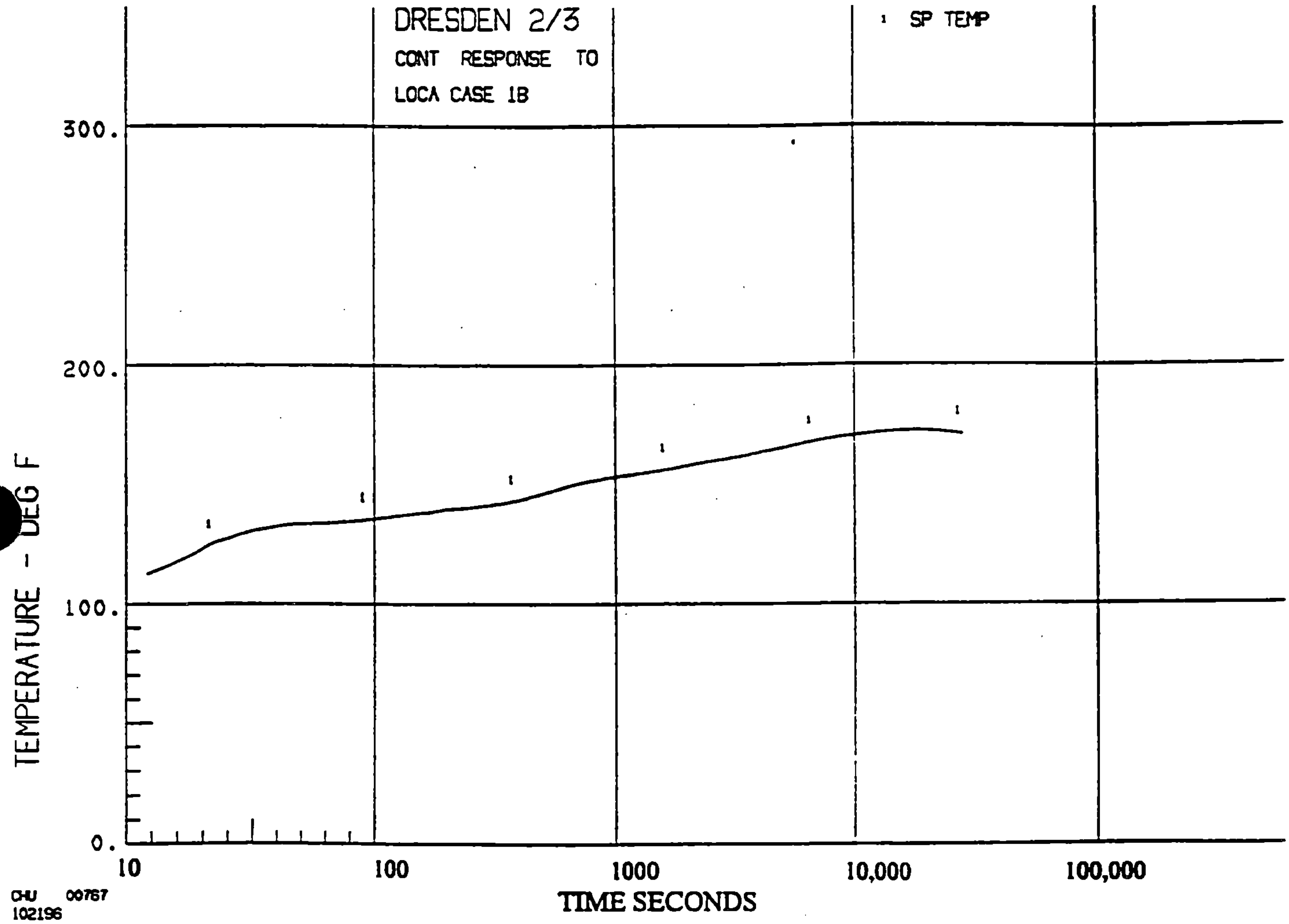

Figure 3 - DBA-LOCA Suppression Pool Temperature Response. Case 1a - High (100%) Mixing Efficiency

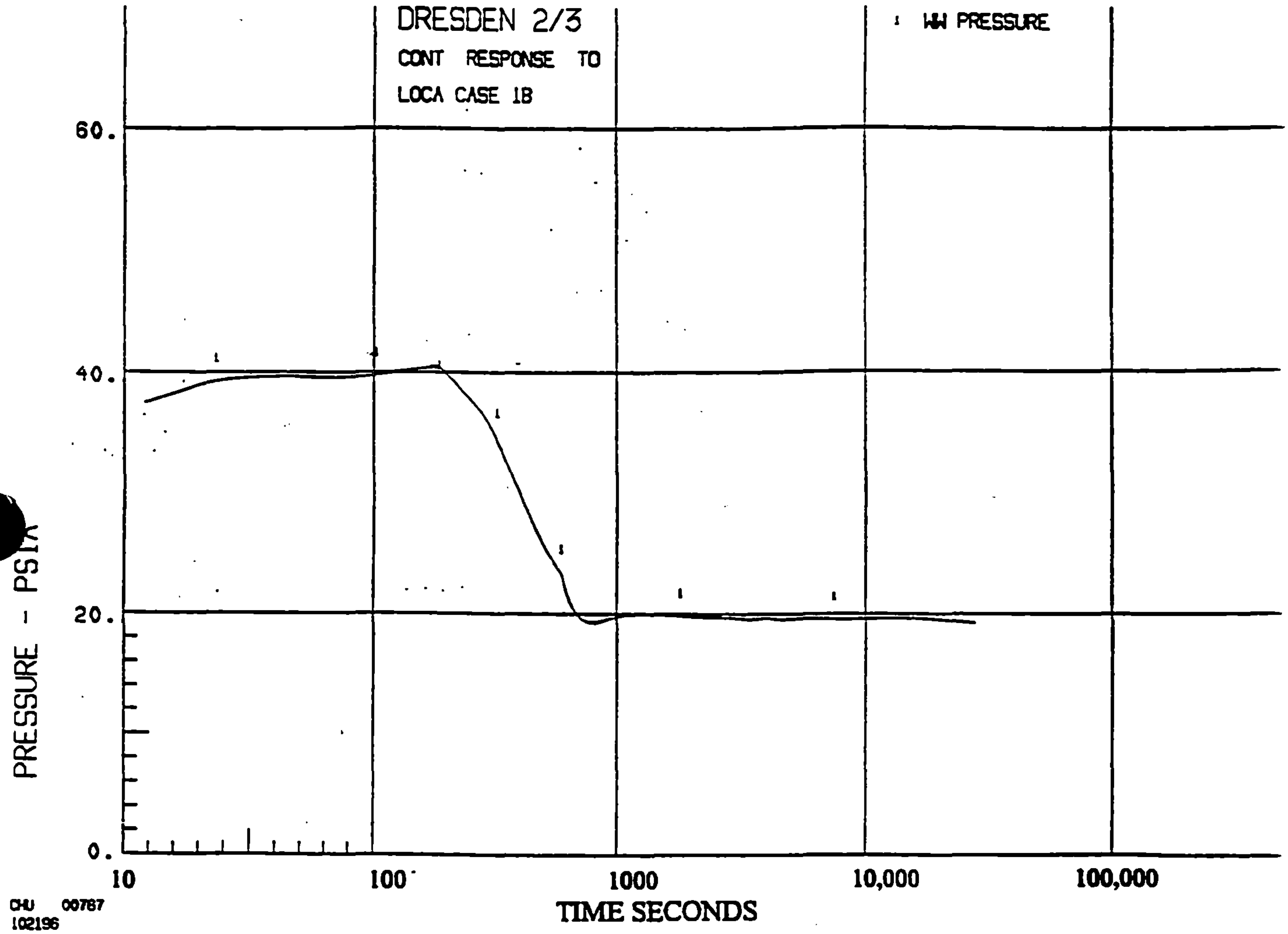

Figure 4 - DBA-LOCA Suppression Chamber Pressure Response. Case 1a - High (100%) Mixing Efficiency

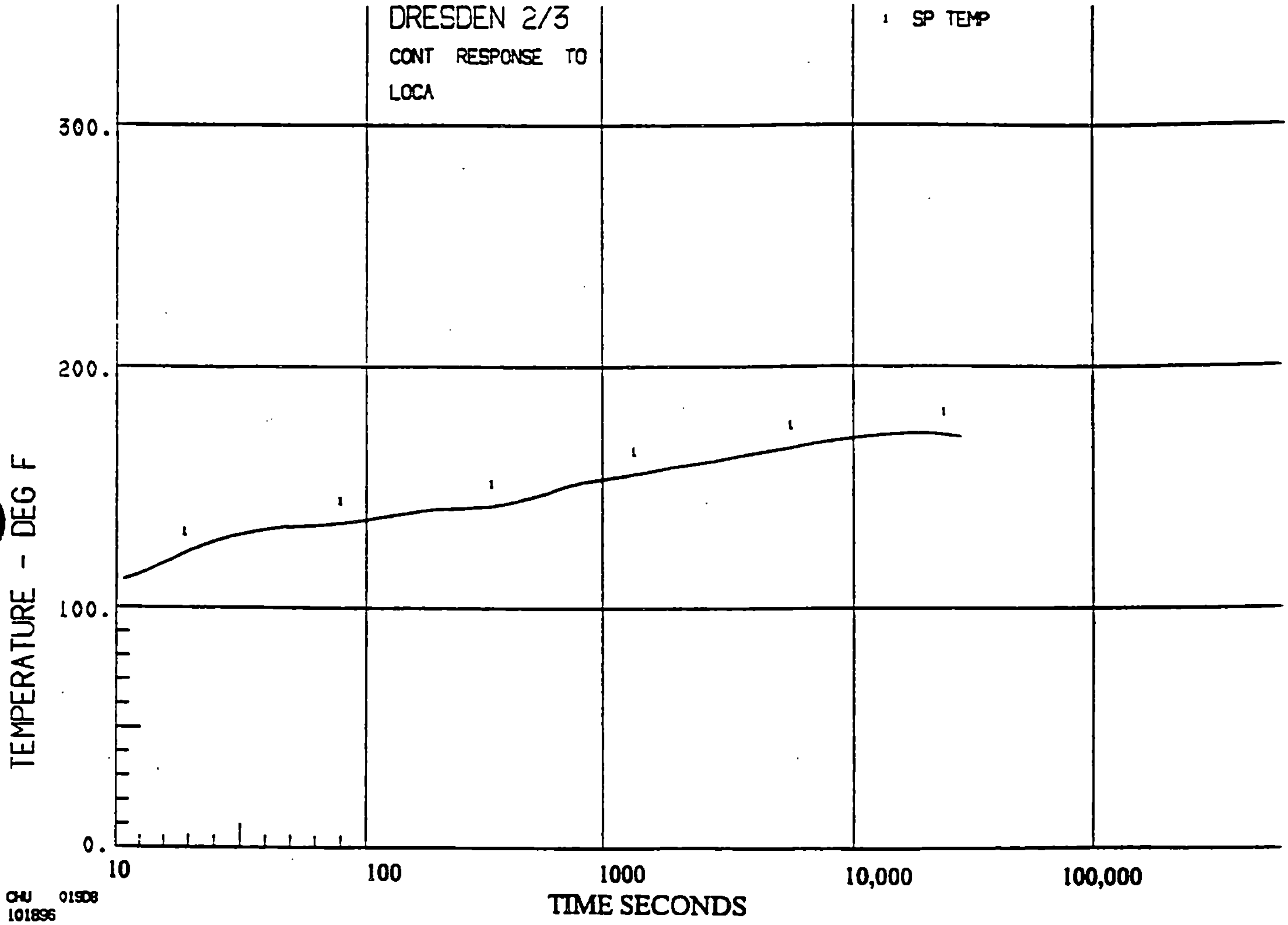

Figure 5 - DBA-LOCA Suppression Pool Temperature Response. Case 1a -Low (20%) Mixing Efficiency

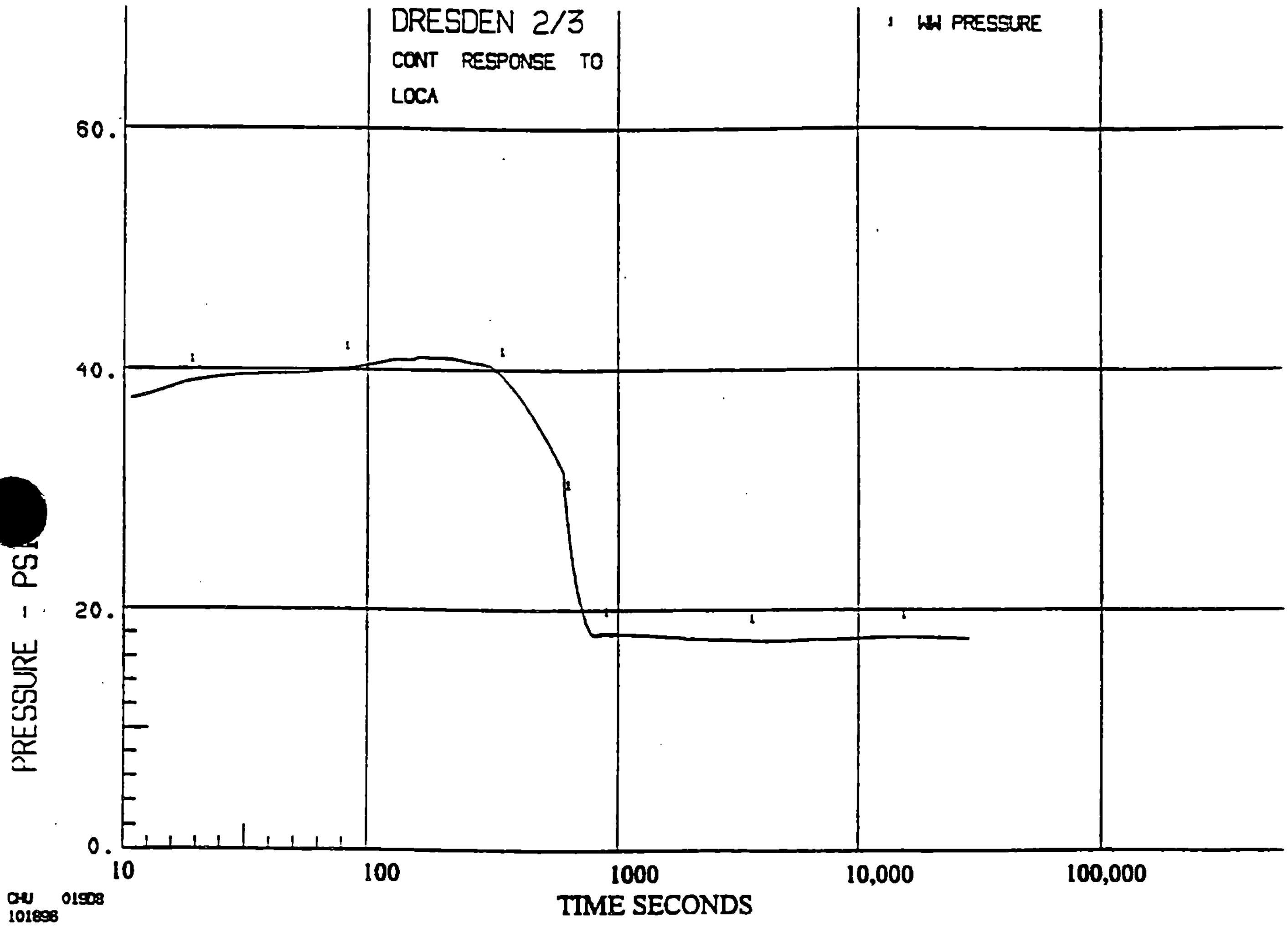

Figure 6 - DBA-LOCA Suppression Chamber Pressure Response. Case 1a - Low (20%) Mixing Efficiency

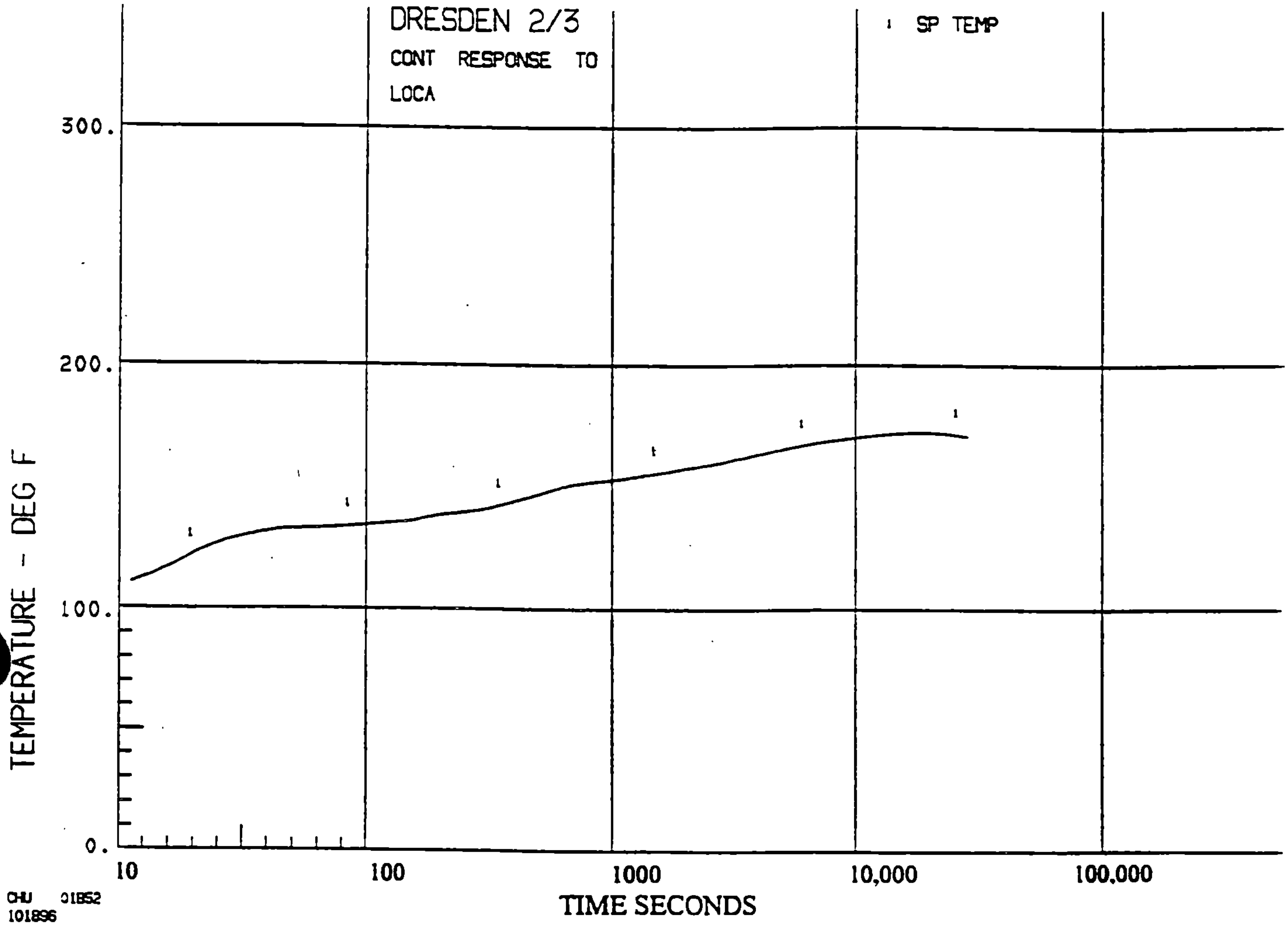

Figure 7 - DBA-LOCA Suppression Pool Temperature Response. Case 2

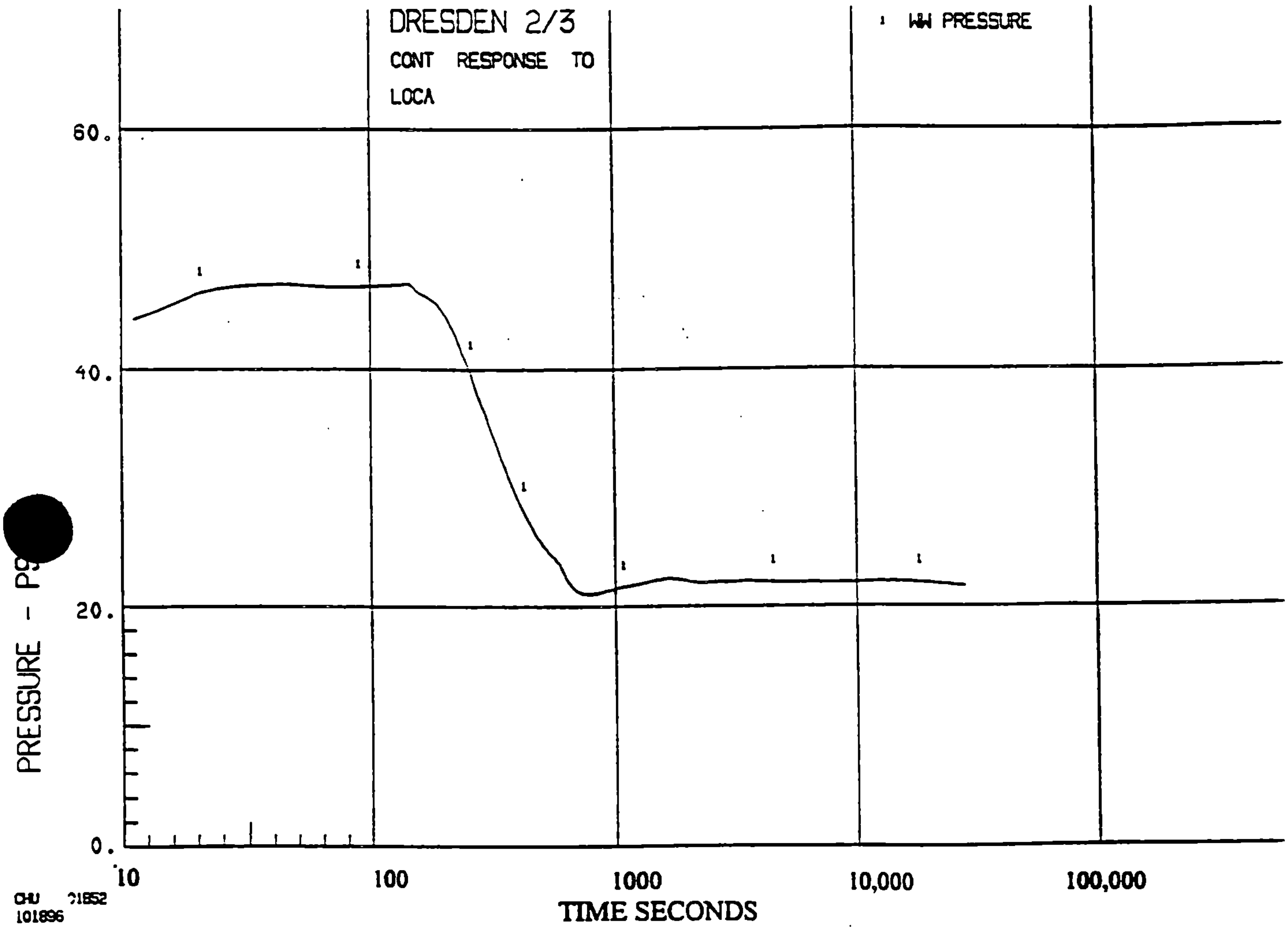

Figure 8 - DBA-LOCA Suppression Chamber Pressure Response. Case 2

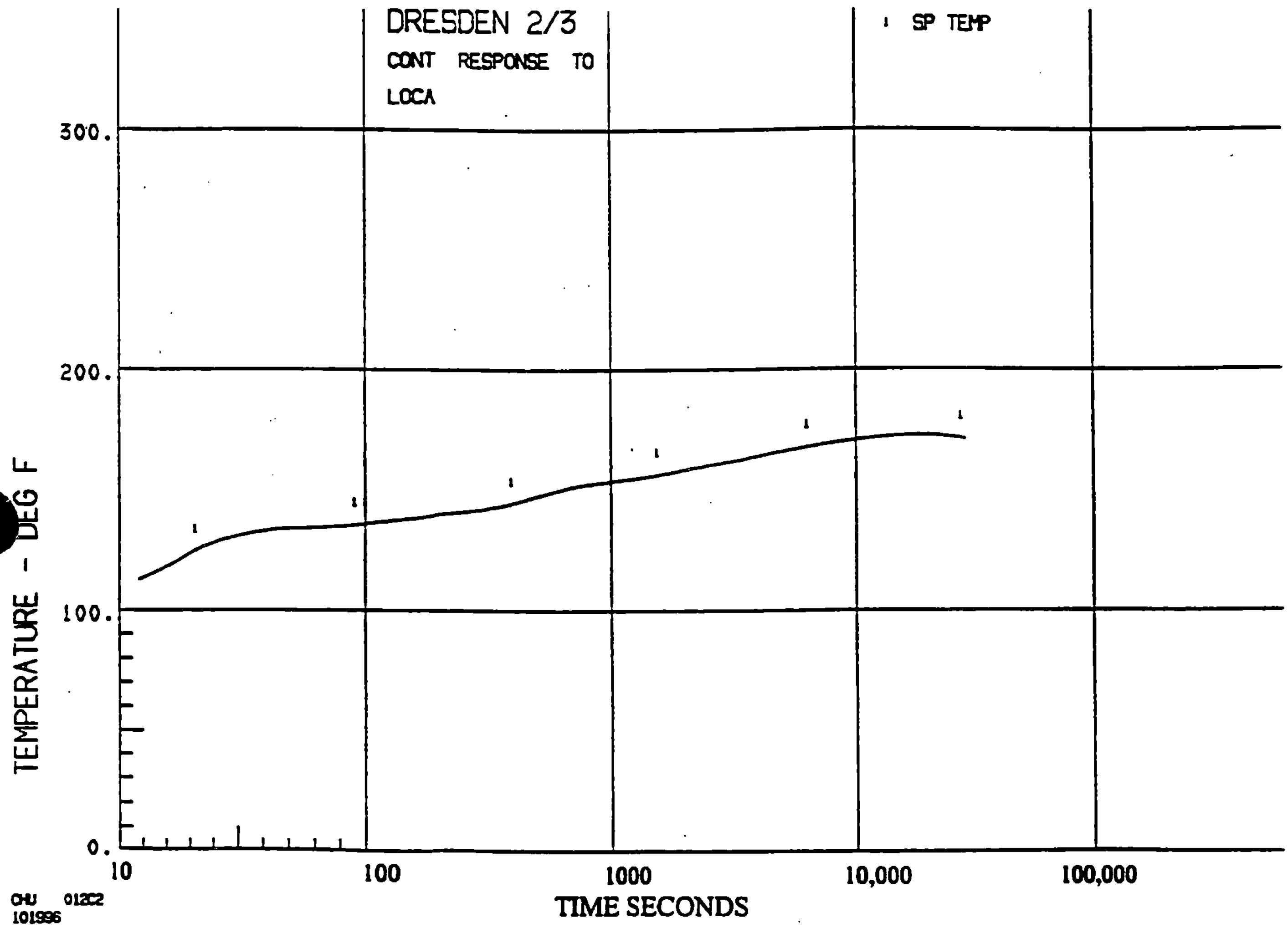

Figure 9 - DBA-LOCA Suppression Pool Temperature Response. Case 2a - High (100%) Mixing Efficiency

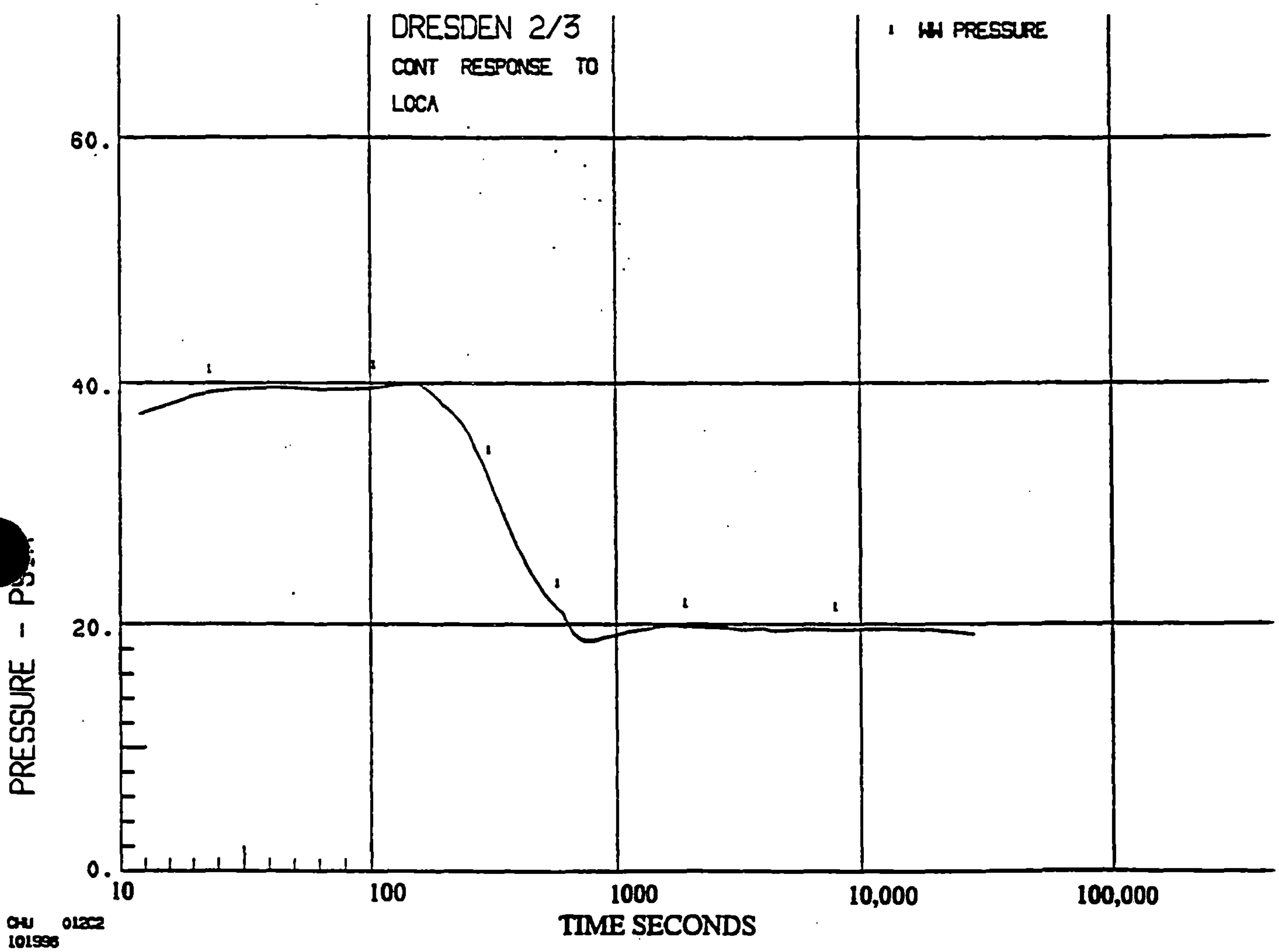

Figure 10 - DBA-LOCA Suppression Chamber Pressure Response. Case 2a - High (100%) Mixing Efficiency

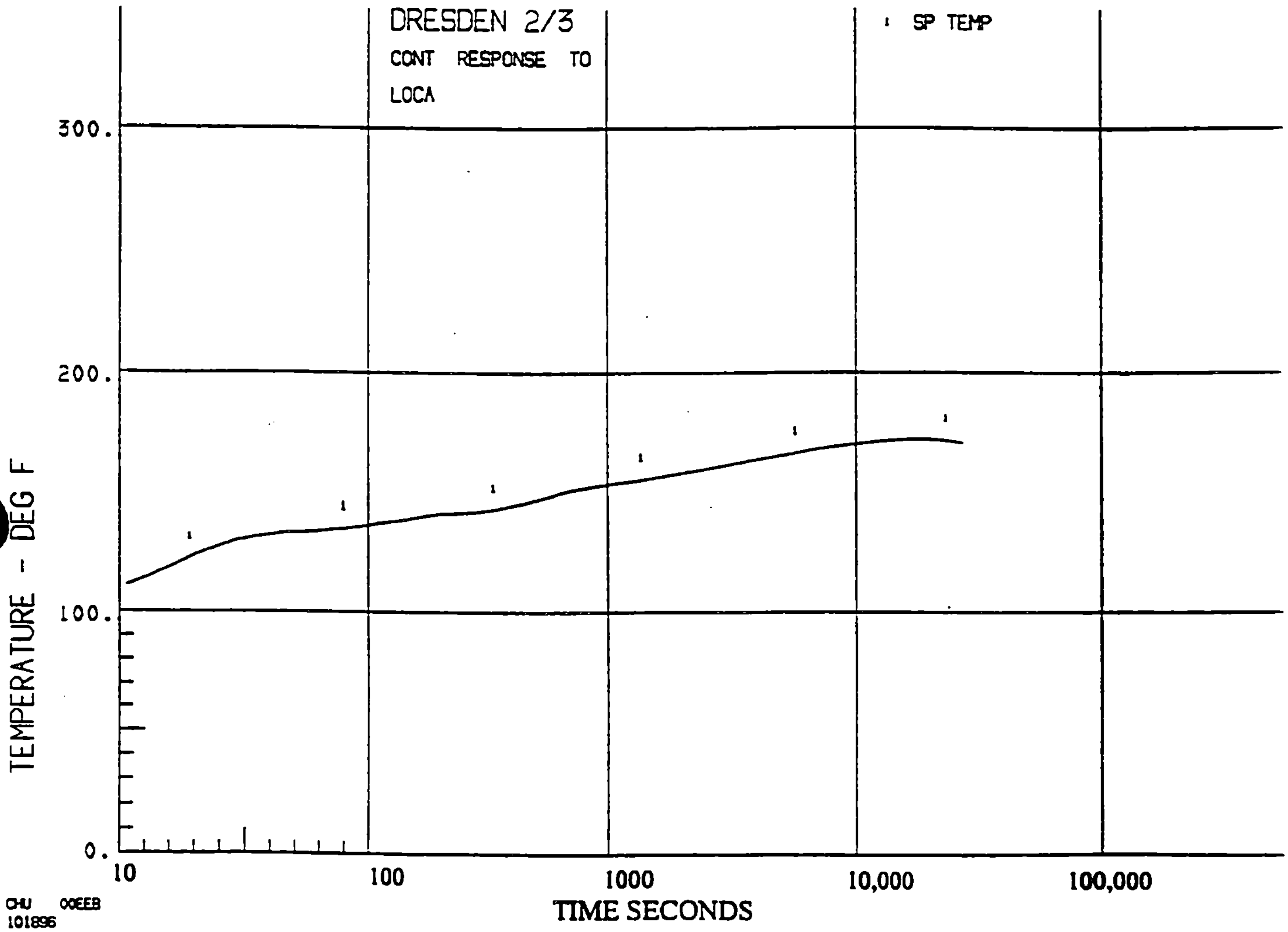

Figure 11 - DBA-LOCA Suppression Pool Temperature Response. Case 2a -Low (20%) Mixing Efficiency

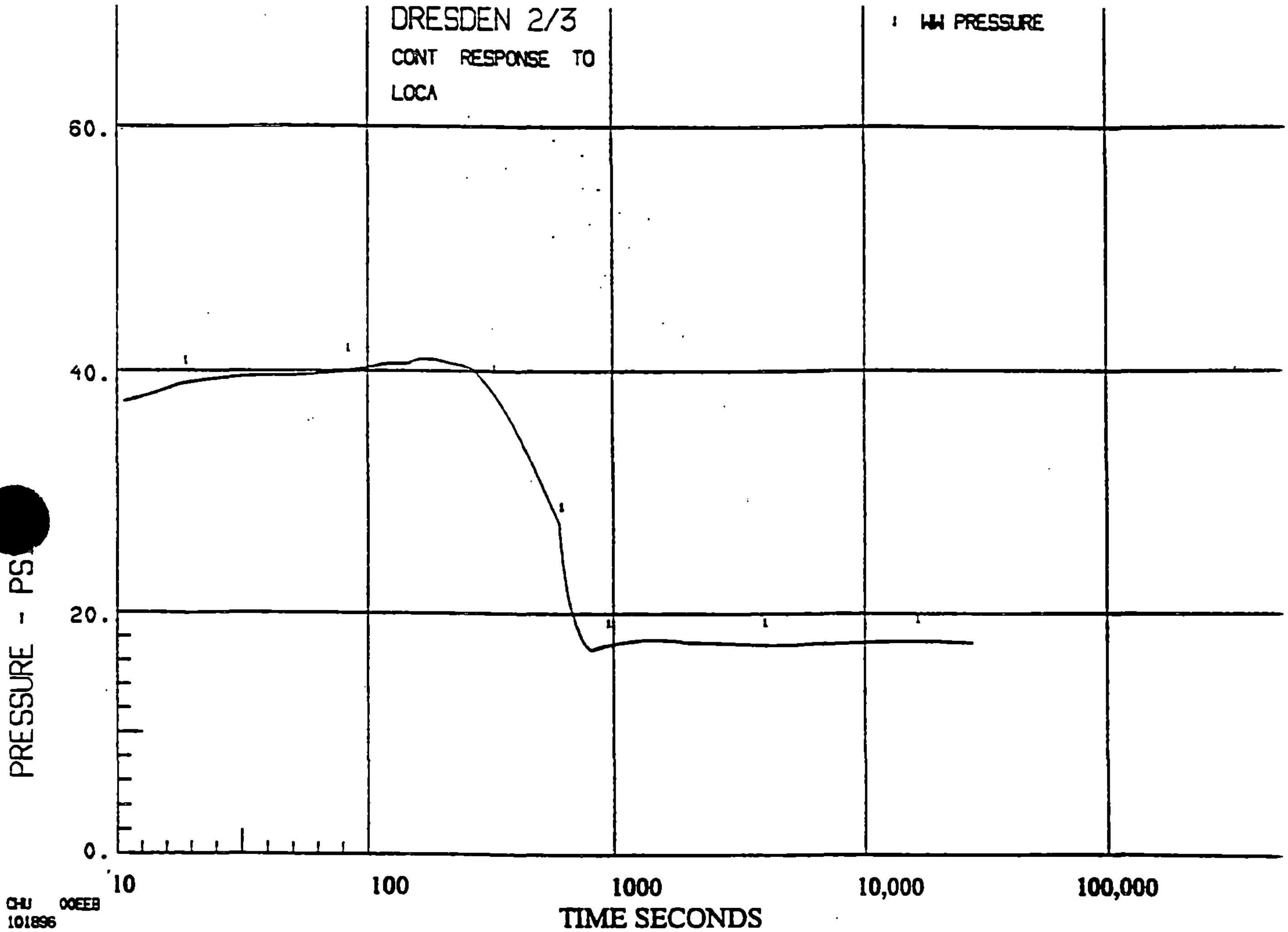

Figure 12 - DBA-LOCA Suppression Chamber Pressure Response. Case 2a - Low (20%) Mixing Efficiency

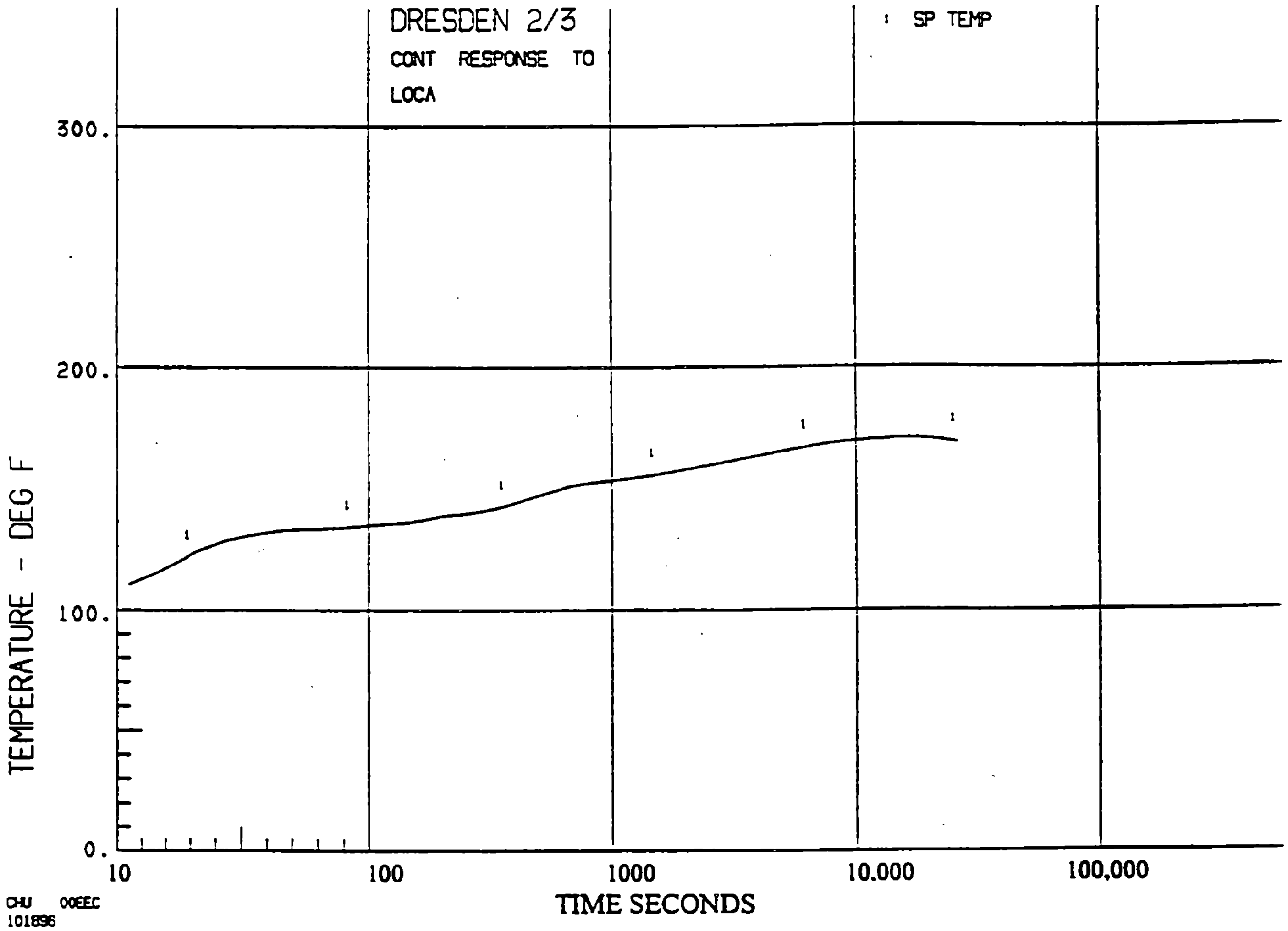

Figure 13 - DBA-LOCA Suppression Pool Temperature Response. Case 3

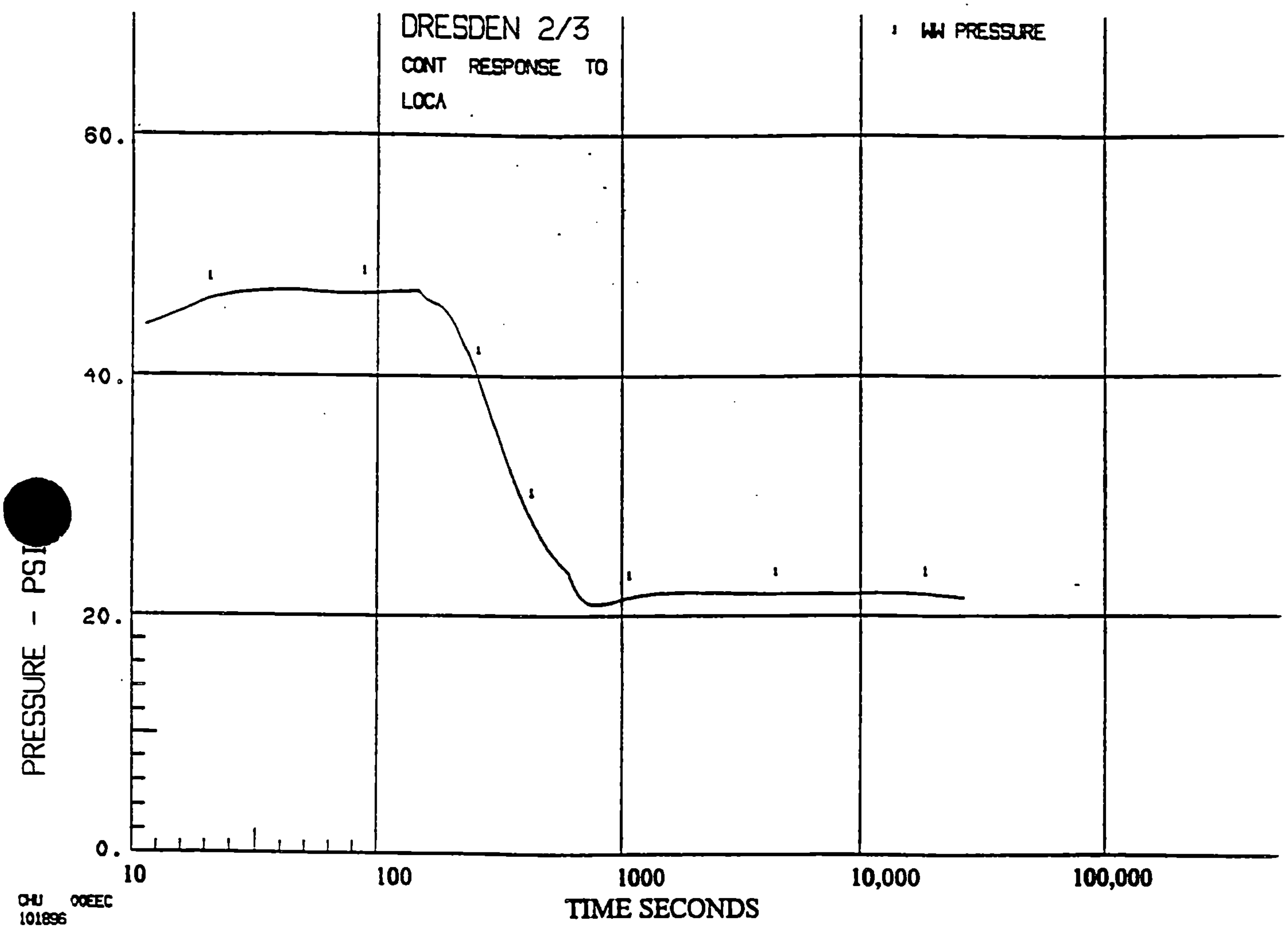

Figure 14 - DBA-LOCA Suppression Chamber Pressure Response. Case 3

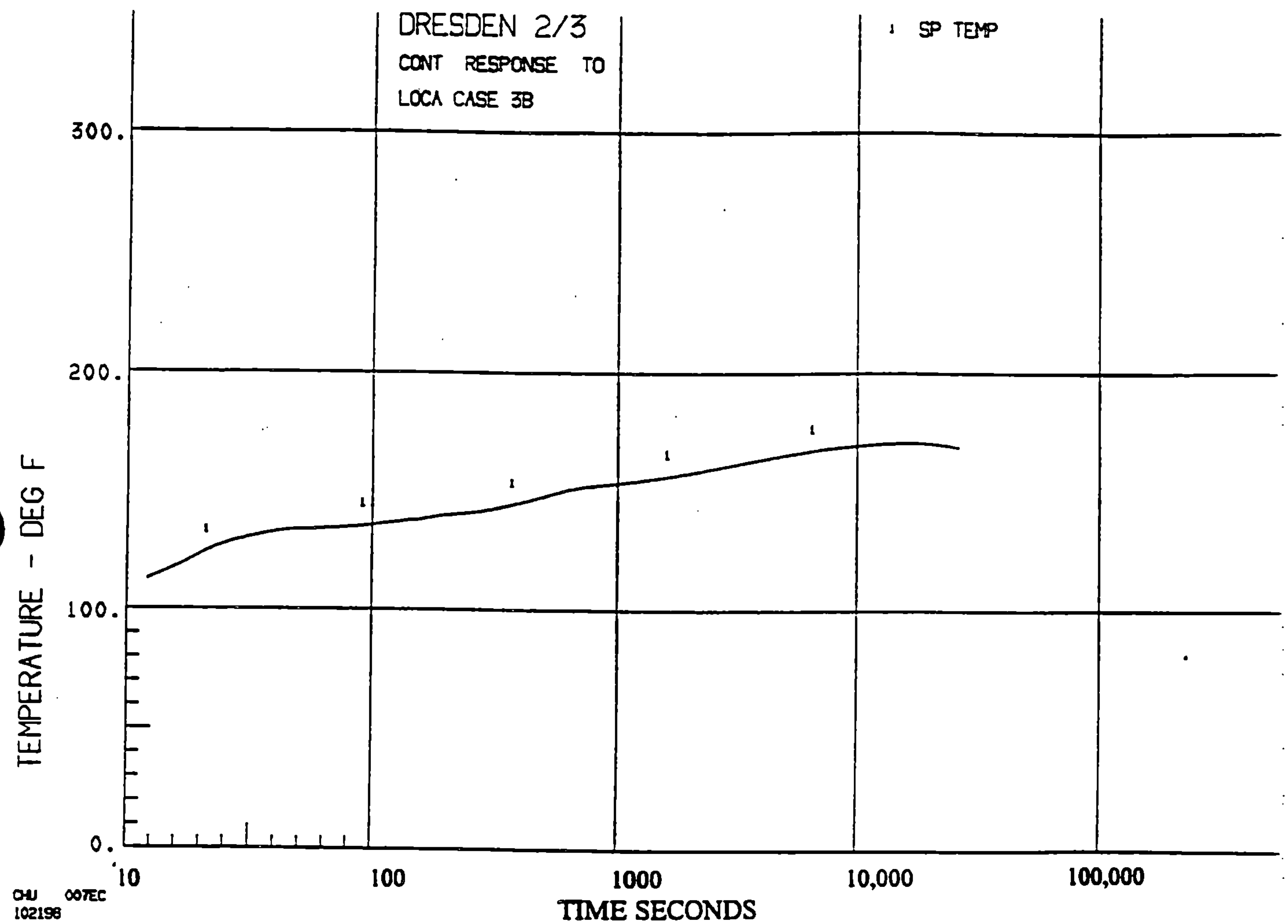

Figure 15 - DBA-LOCA Suppression Pool Temperature Response. Case 3a - High (100%) Mixing Efficiency

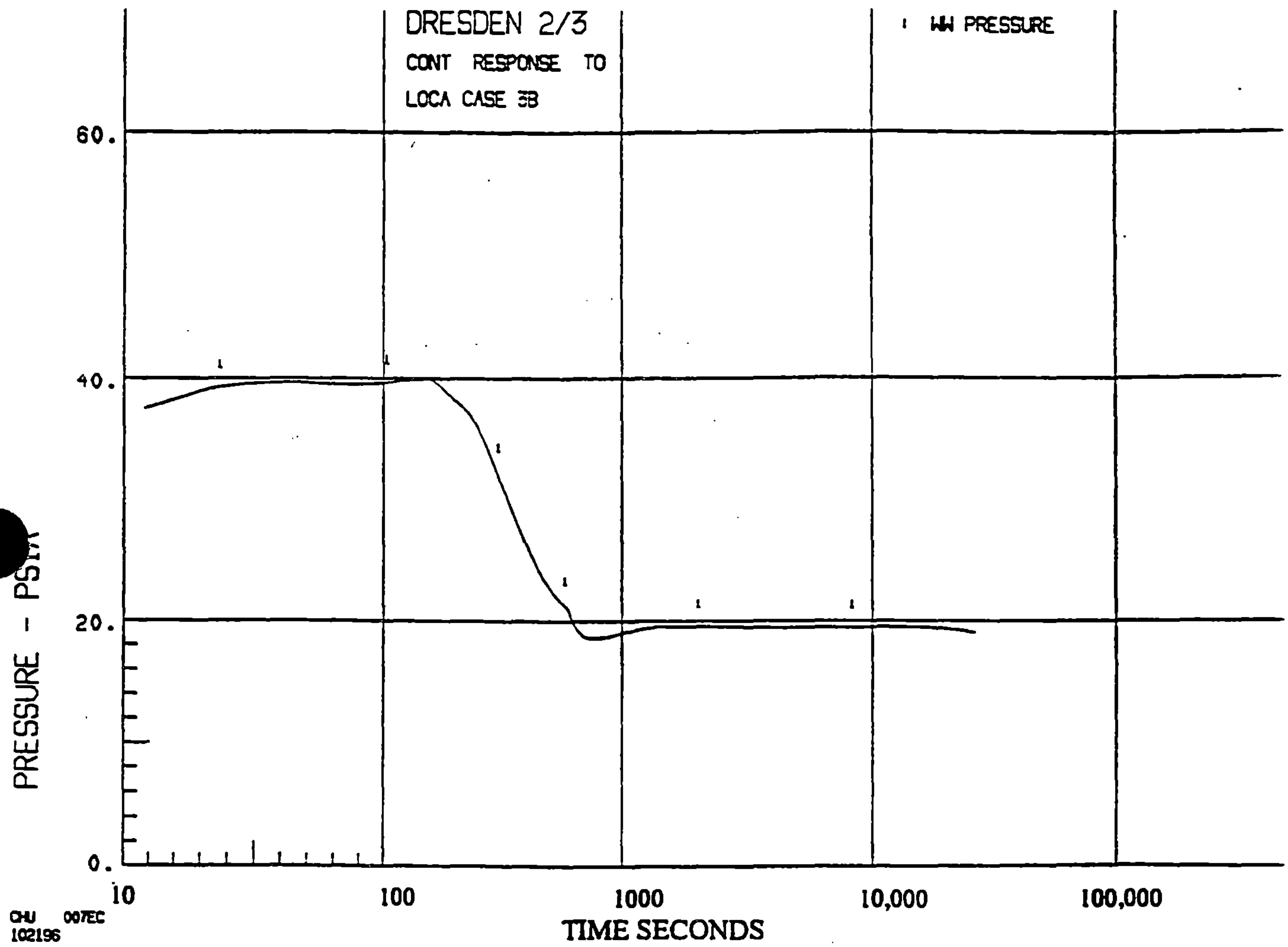

Figure 16 - DBA-LOCA Suppression Chamber Pressure Response. Case 3a - High (100%) Mixing Efficiency

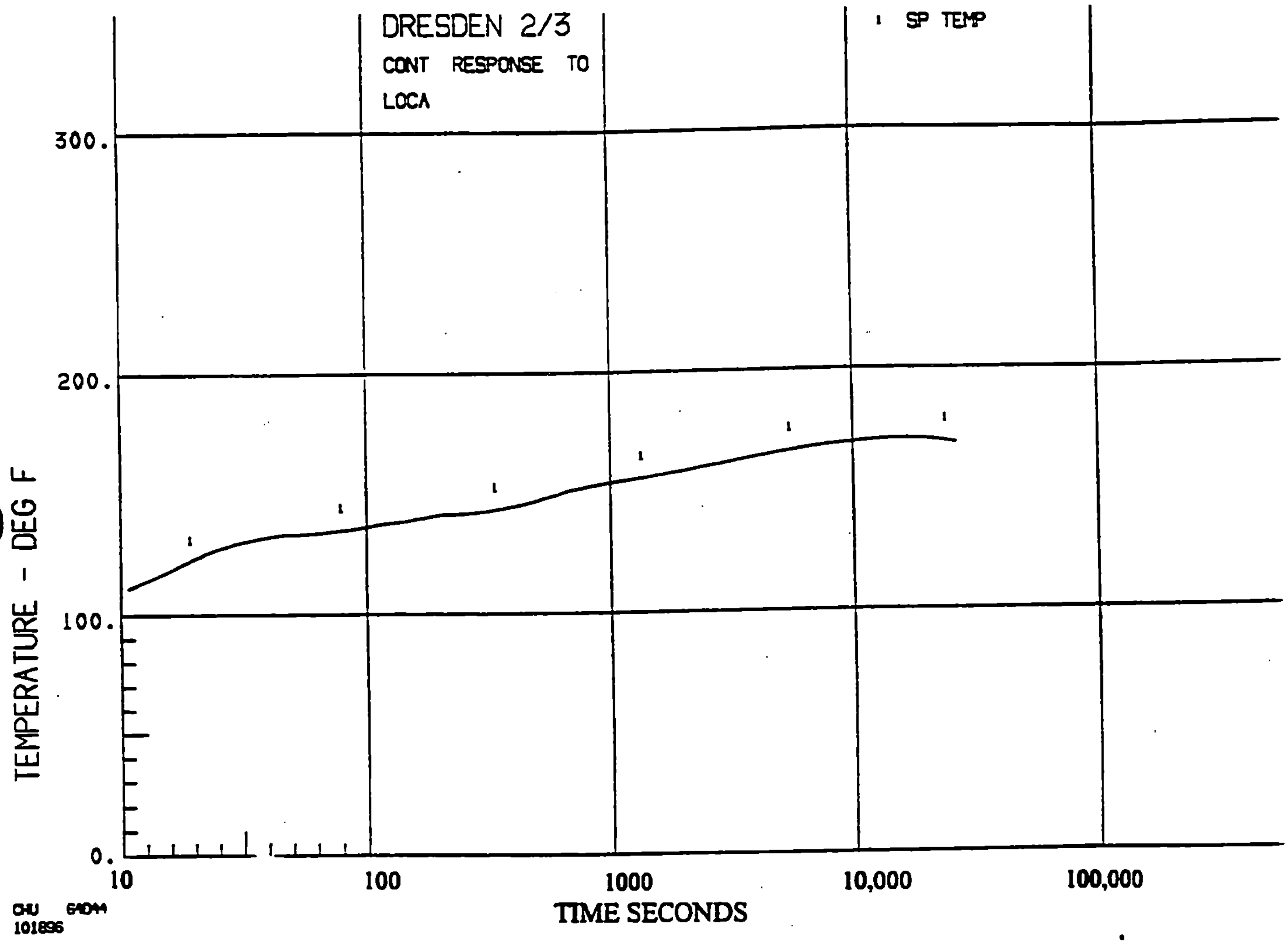

Figure 17 - DBA-LOCA Suppression Pool Temperature Response. Case 3a -Low (20%) Mixing Efficiency

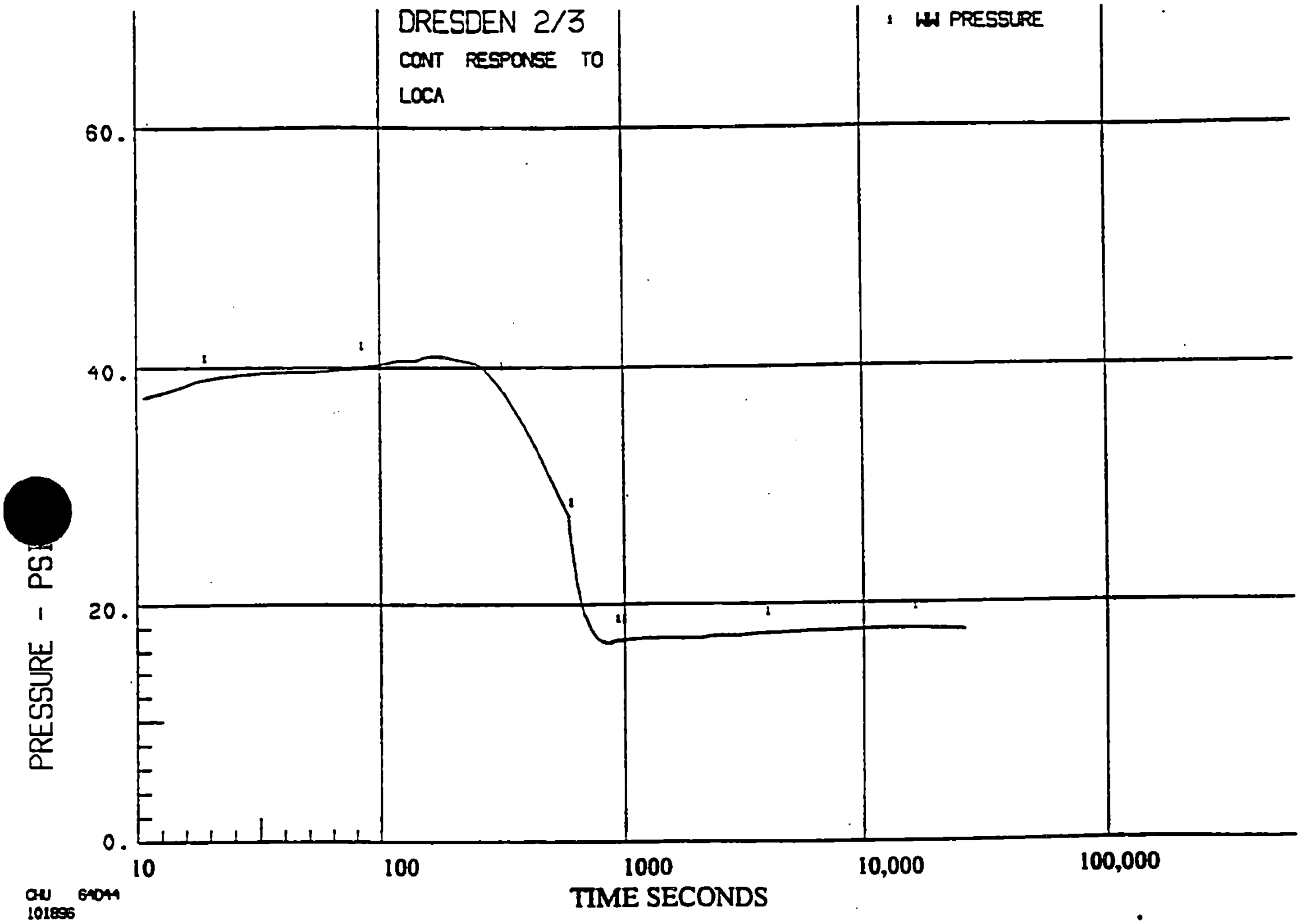

Figure 18 - DBA-LOCA Suppression Chamber Pressure Response. Case 3a - Low (20%) Mixing Efficiency

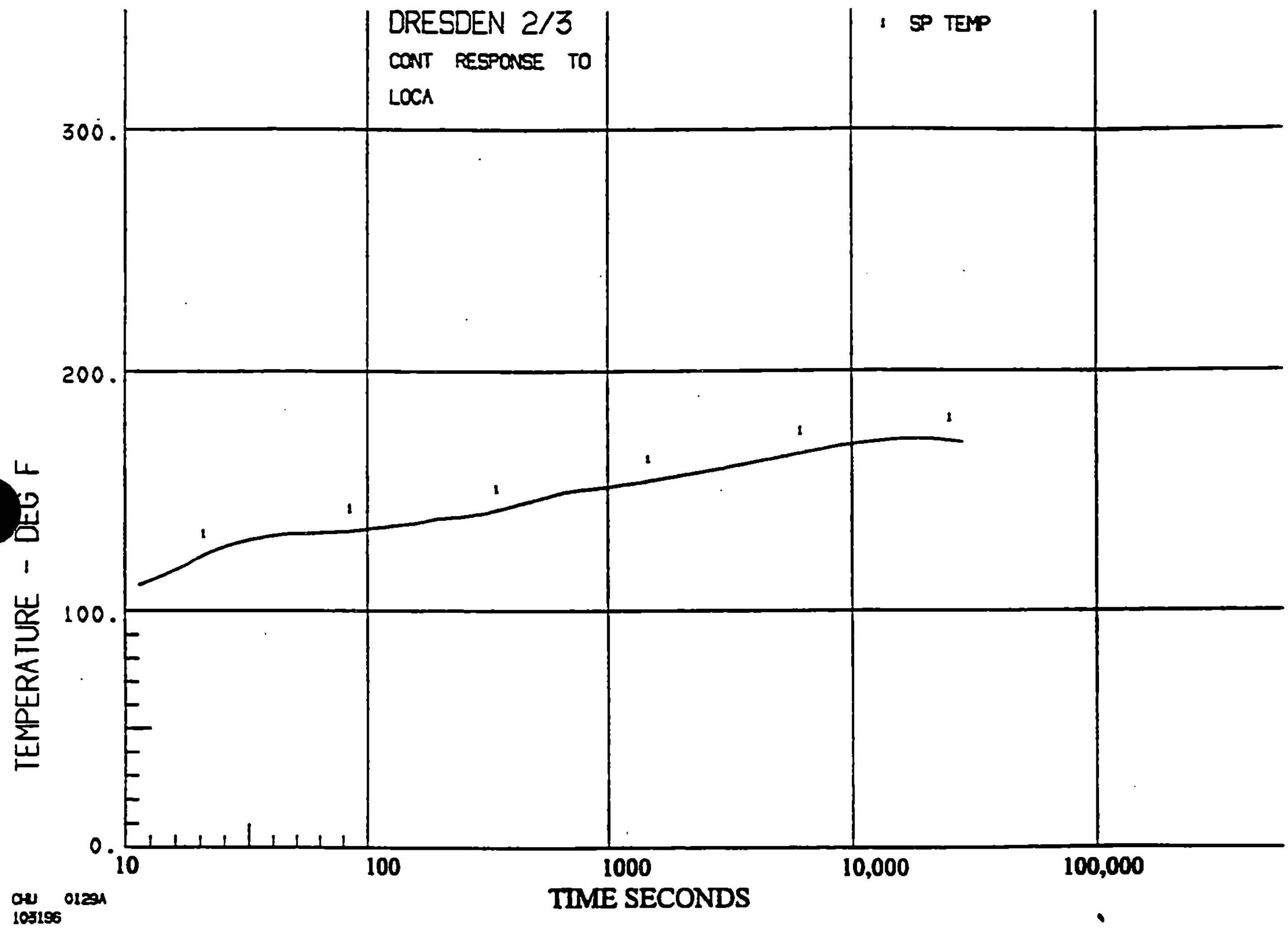

Figure 19 - DBA-LOCA Suppression Pool Temperature Response. Case 2a1 - High (100%) Mixing Efficiency

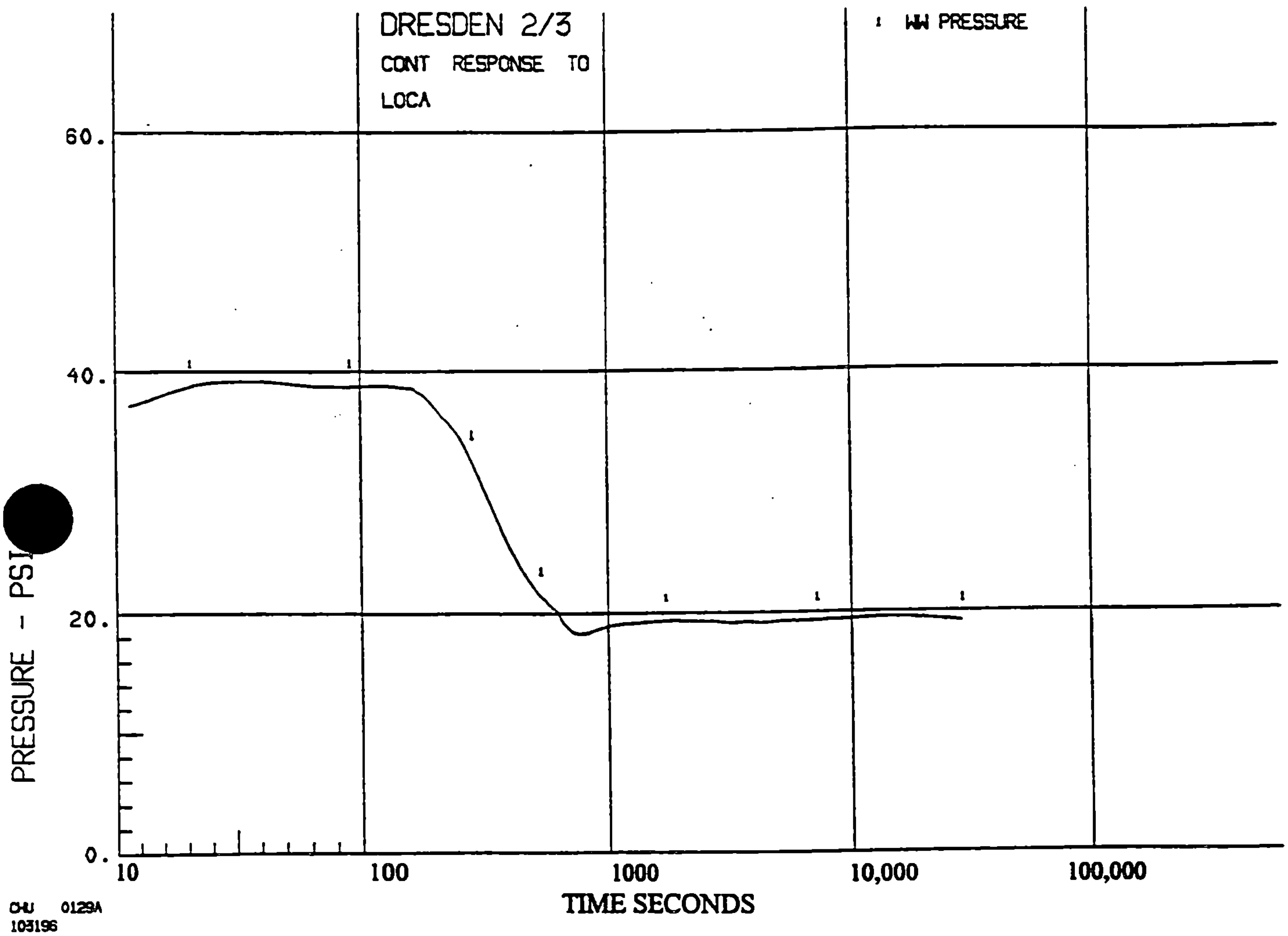

Figure 20 - DBA-LOCA Suppression Chamber Pressure Response. Case 2a1 - High (100%) Mixing Efficiency

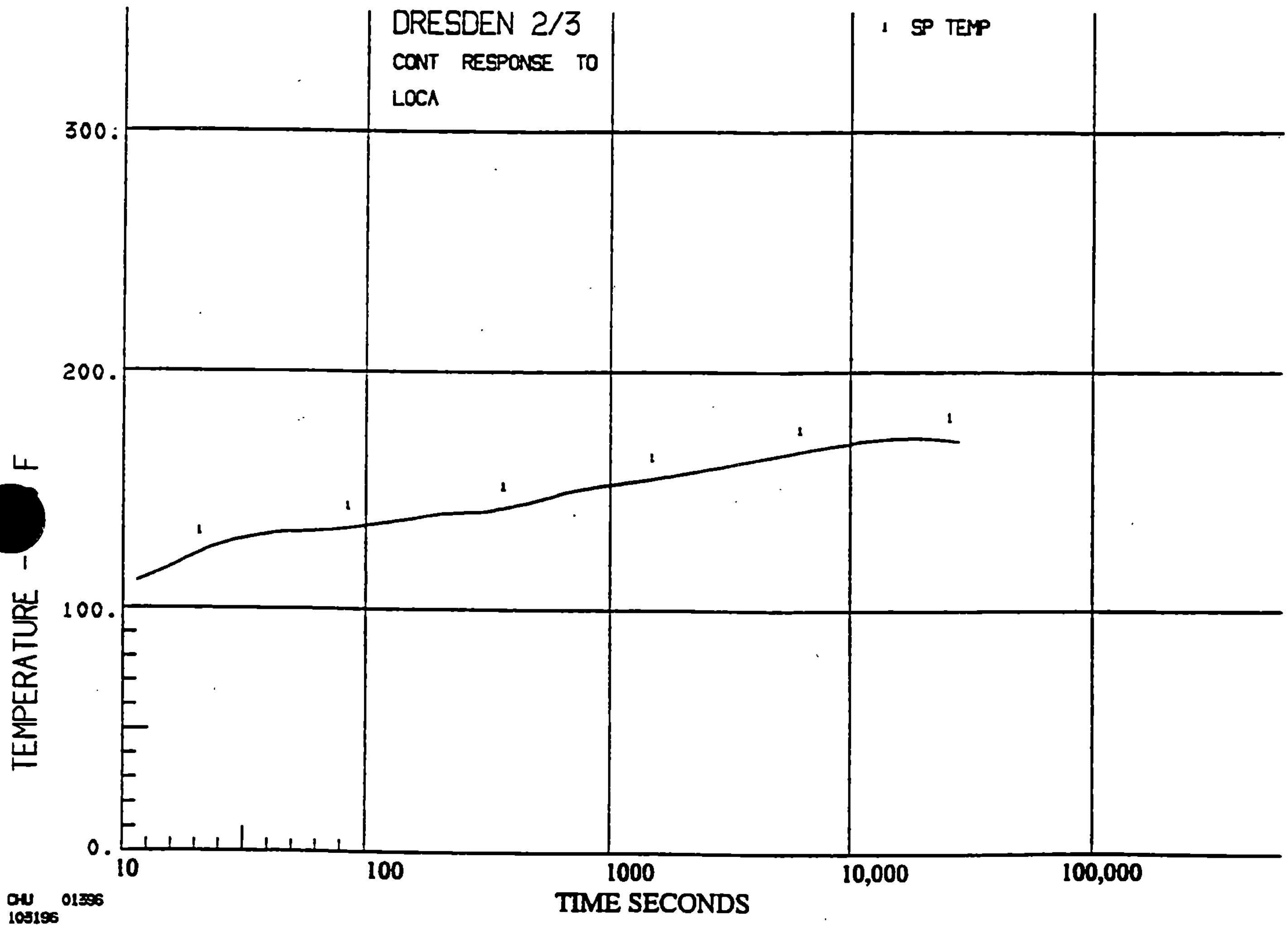

Figure 21 - DBA-LOCA Suppression Pool Temperature Response. Case 2a1 -Low (20%) Mixing Efficiency

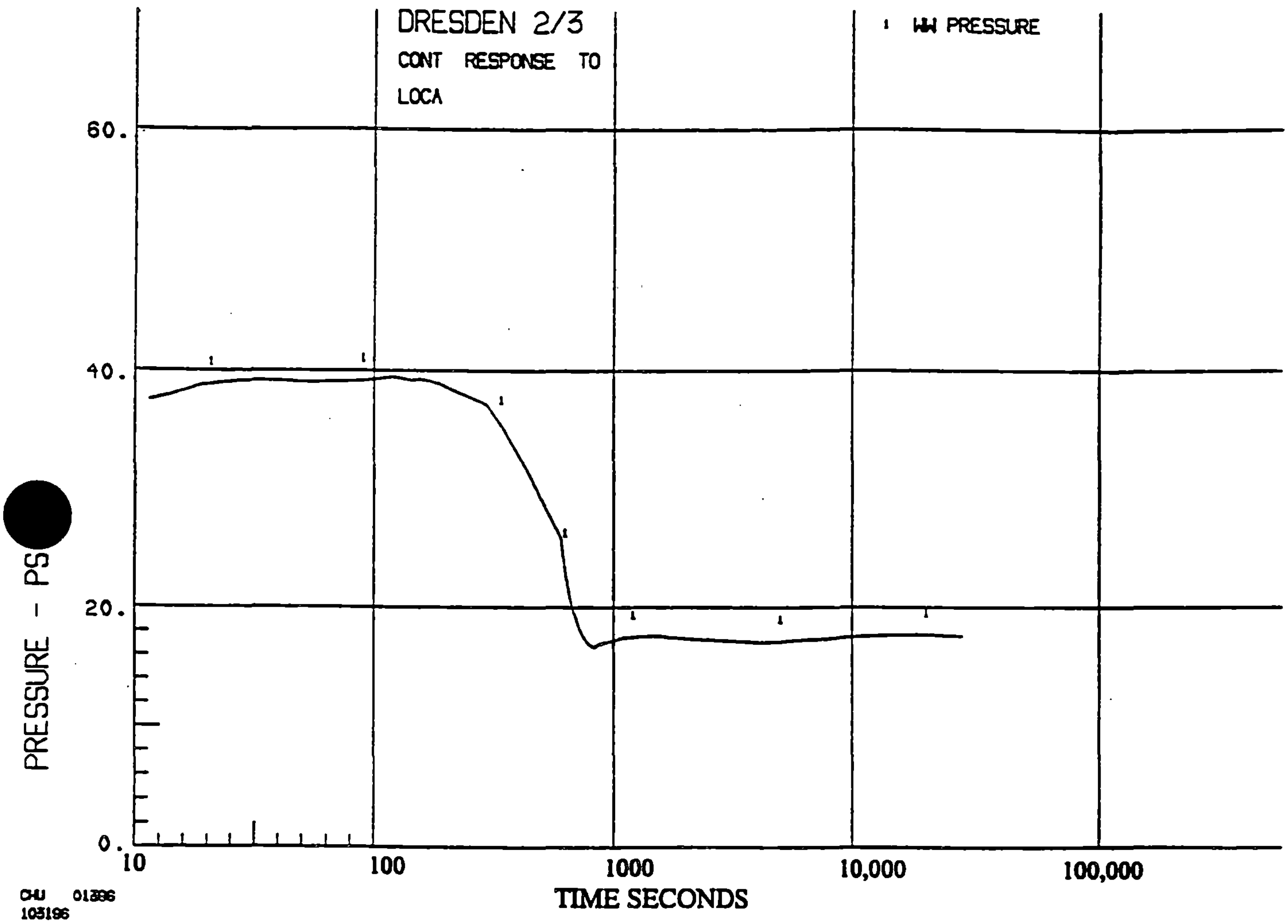

Figure 22 - DBA-LOCA Suppression Chamber Pressure Response. Case 2a1 - Low (20%) Mixing Efficiency

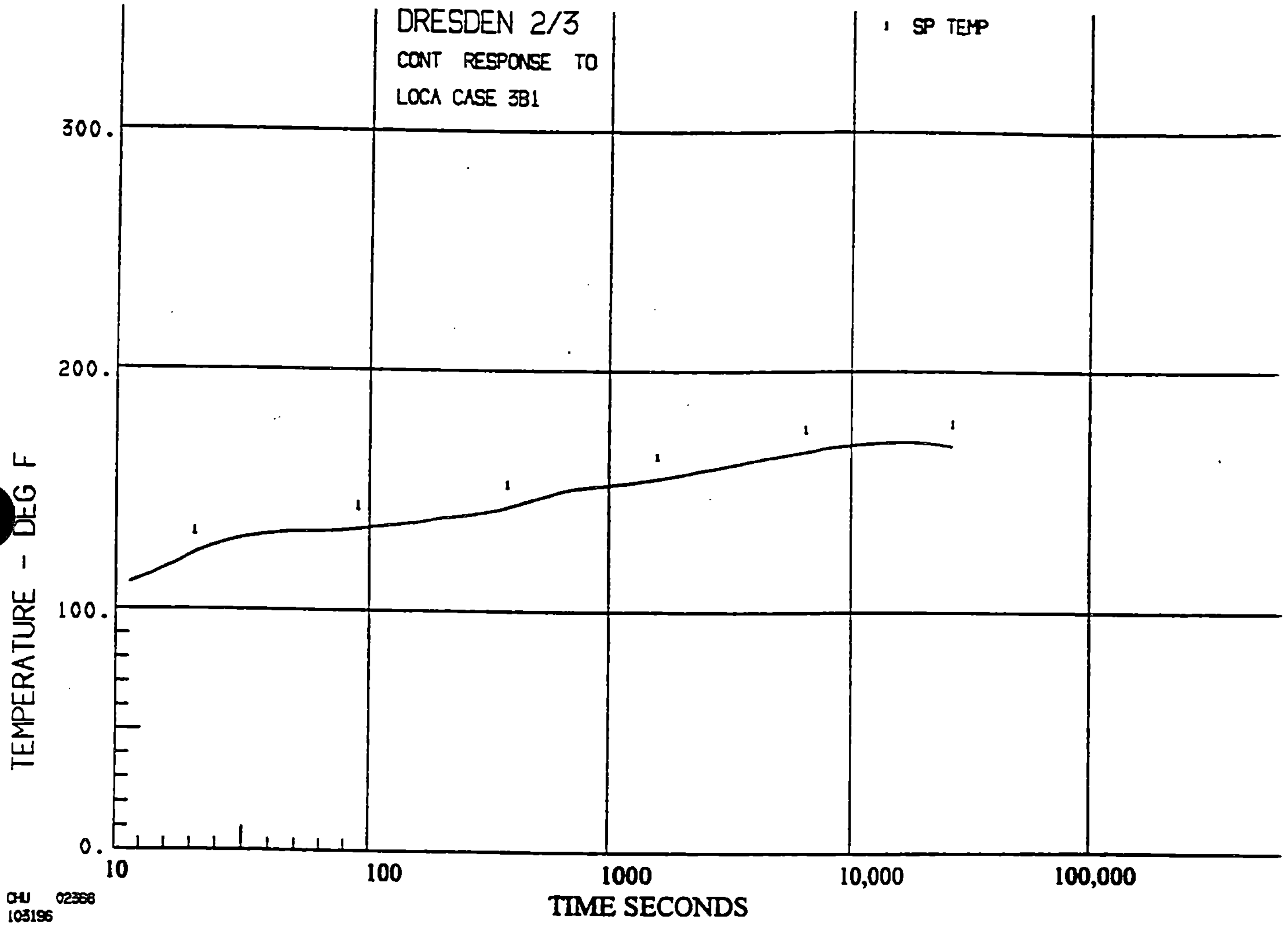

Figure 23 - DBA-LOCA Suppression Pool Temperature Response. Case 3a1 - High (100%) Mixing Efficiency

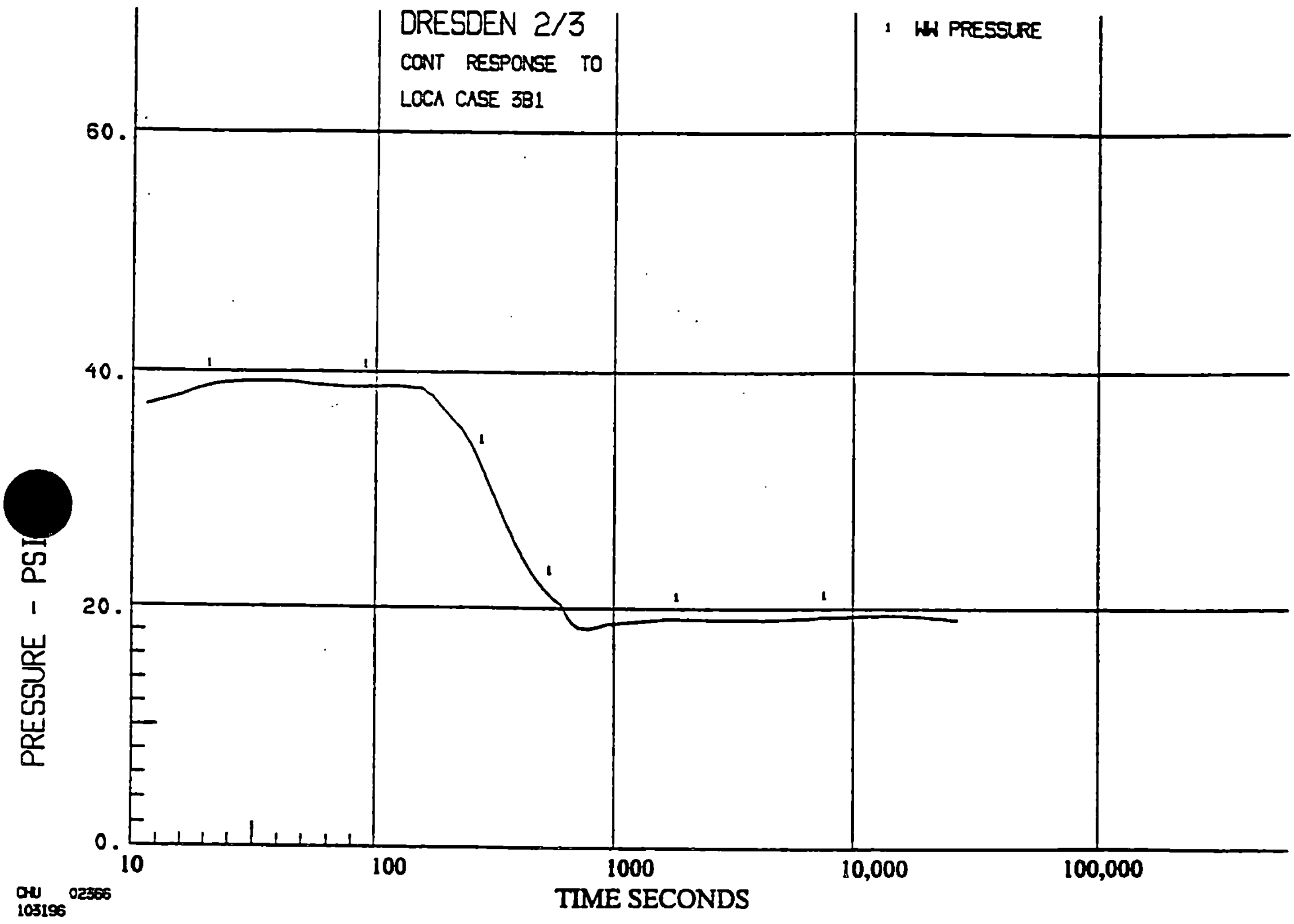

Figure 24 - DBA-LOCA Suppression Chamber Pressure Response. Case 3a1 - High (100%) Mixing Efficiency

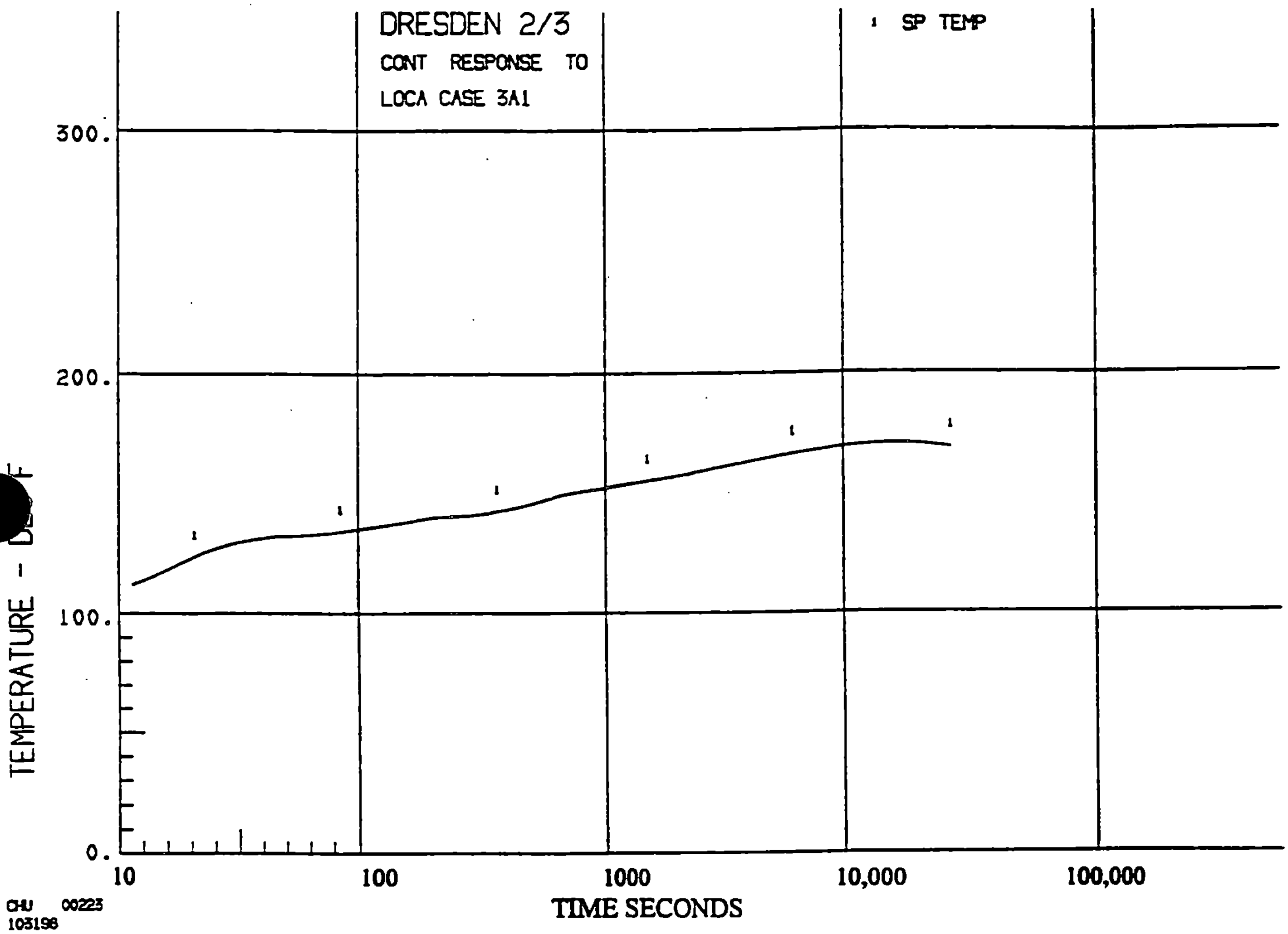

Figure 25 - DBA-LOCA Suppression Pool Temperature Response. Case 3a1 -Low (20%) Mixing Efficiency

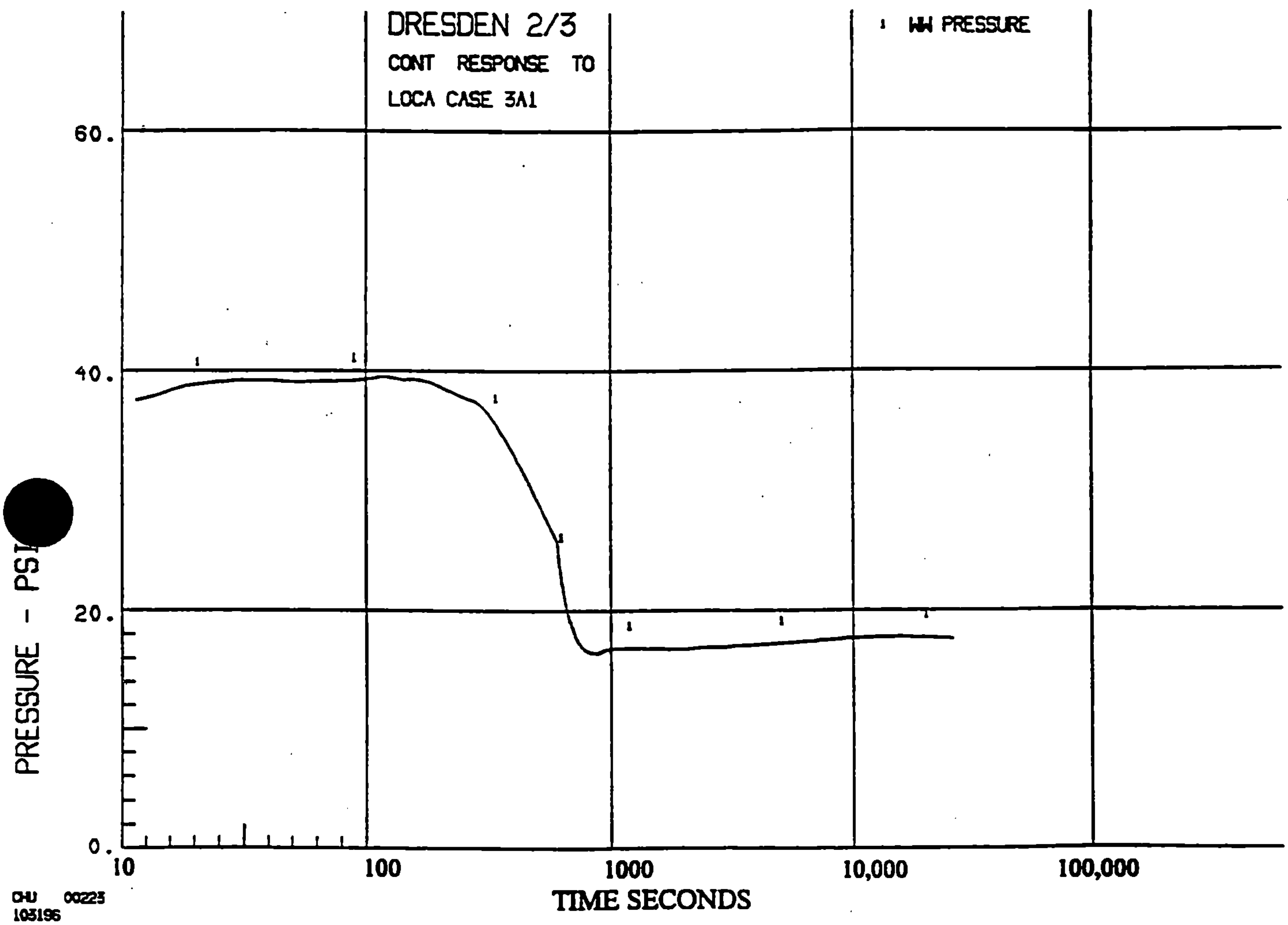

Figure 26 - DBA-LOCA Suppression Chamber Pressure Response. Case 3a1 - Low (20%) Mixing Efficiency

10.0 APPENDICES

A. CORE HEAT DATA

APPENDIX A
CORE DECAY HEAT DATA

Table A.1 provides the core heat (Btu/sec) based on the ANS 5.1 (Reference A.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.

Appendix A References:

1) NEDO-10625, "Power Generation in a BWR Following Normal Shutdown or Loss-Of-Coolant Accident Conditions," March 1973.

2) "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 ANS 5.1

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.