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TMI-2 DATA SUMMARY REPORT

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ABSTRACT

This report presents all the qualified data generated during the performance of the Data Review Task as part of the TMI-2 Accident Evaluation Program. Data are in graphic form accompanied by amplitude and time base uncertainties. The main body of the report contains the data plots, definition of terms, and a brief description of the data review process. There is also a table summarizing the data qualification categories and uncertainties. Appendices give details on how the data review was performed, data sources, details of analysis methodology, and letter reports generated during the task as reference material.

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EXECUTIVE SUMMARY

The data presented in this report are the result of the Data Review task which was part of the Three Mile Island Unit-2 (TMI-2) Accident Evaluation Program. The primary goals of the Accident Evaluation Program are to:

- o Understand the physical and chemical state of the TMI-2 core and related structures and the external influences which affected the accident,
- o Understand what happened during the accident and to provide a qualified data base and analysis exercise of the TMI-2 accident to benchmark severe-accident analysis codes and methodologies,
- o Understand the relationship between the phenomena and processes controlling the accident and the important severe accident/source term technical issues, and
- o Assure that the results of the program are effectively transferred to the nuclear community.

To support the above goals, the Accident Evaluation Program is providing a qualified data base and an analysis exercise based on the TMI-2 accident in order to benchmark severe accident analysis codes and methodologies. In particular this Data Summary Report makes the data available to the nuclear community.

The data review process started with collecting the TMI-2 measurement data and support information, establishing priorities and designing a formal system for systematically performing the uncertainty analyses and establishing the quality categories of the data. This system consisted of analyzing the measurements, reviewing the results in committee, and assigning qualification levels and statements to each measurement. In analyzing the measurements, answers to the following questions were sought: (1) are the data consistent with respect to single channel analysis criteria (range, noise limits, time response, and correlation with the significant plant events and prior history)?, (2) do the data agree with other redundant information?, and (3) do the data agree with thermal-hydraulic theory? A Data Integrity Review Committee (DIRC) then reviewed all analyses, evaluations, and comparisons performed in response to the above questions. (The DIRC was composed of a panel of experienced persons, knowledgeable in TMI-2 data analysis.) Finally, the DIRC approved qualification levels and uncertainty assigned to each set of data. The data were then put into the TMI-2 Initial and Boundary Conditions Data Base.

The primary purposes for reviewing and qualifying the data were (1) to identify the uncertainties in operator actions, the sequence of events, and the measured on-line data for defining the TMI-2 analysis exercise, and (2) to provide information to improve our understanding of the accident progression and the interactions between the degraded core, reactor coolant System thermal-hydraulic response, and fission product behavior.

The basic data required for the TMI-2 analysis exercise are:

- RCS pressure and temperatures
- Reactor coolant flow rates
- RCS makeup and letdown flow rates
- Operation periods of emergency core cooling injection
- Operation periods of pilot operated relief value and block valve
- Containment radiation levels
- Source and intermediate-range detector data

INTRODUCTION

On March 28, 1979 the Unit 2 pressurized water reactor at Three Mile Island (TMI-2) underwent an accident resulting in severe damage to the reactor core. Although the accident had minimal effects on the health and safety of the public, it did cause a reevaluation of severe accidents, fission product source terms, and potential power reactor risks. For the past several years the U.S. Nuclear Regulatory Commission (NRC) and other independent research organizations[1-5] have worked to develop new insights into degraded core accidents and source terms important to nuclear safety and regulation. These research efforts have provided new information and insight, but have yet to conclusively define a methodology for determining realistic source terms for severe accidents. The specification of realistic source terms for severe accidents is one of the major unresolved technical issues facing the nuclear industry today.

The TMI-2 accident is the most severe accident that has occurred in a commercial nuclear power plant in the United States and is providing a wealth of knowledge about core damage and fission product behavior during severe accidents. The TMI-2 accident provides a unique opportunity to confirm the applicability to full scale reactors of existing severe fuel damage and fission product data, obtained from small-scale experiments. It also provides data for an analysis exercise[6] designed to benchmark current severe accident analysis codes and methodologies based upon a real severe accident in a full-scale operating power reactor.

The Department of Energy (DOE) is sponsoring the TMI-2 Accident Evaluation Program[7] to take full advantage of this unique research opportunity. To achieve this goal, the program must first develop a consistent and comprehensive physical understanding of the accident. This understanding must then be applied toward resolution of severe accident and source term issues to which the TMI-2 research is applicable. The resolution of these techical issues will contribute to the restoration of public confidence in the nuclear industry and the establishment of a sound technical basis for the desired regulatory relief. The objectives of the Accident Evaluation Program to support this overall goal are:

1. To understand the physical and chemical state of the TMI-2 core and related structures as well as the external influences which effected the accident.

2. To understand what happened during the accident and to provide a qualified data base and standard problem of the TMI-2 accident to benchmark severe-accident analysis codes and methodologies.

3. To understand the relationship between the phenomena and processes controlling the accident and the important severe accident/source term technical issues.

4. To assure that the results of the program are effectively transferred to the nuclear community.

This document is a summary of the results obtained from the Data Review Task which was part of the Accident Evaluation Program and is in support of Item 2 above and to comply with Item 4.

The purpose of the data review task was to evaluate, qualify and place in a dedicated data base the more important TMI-2 data. This Data Summary Report presents all the qualified TMI-2 data in plots along with the corresponding uncertainties. In addition, enough background information is given to understand the qualification and uncertainty analyses processes and how the information was presented in the data base. Five appendices are attached to the document to provide details for interested readers. Appendix E contains details of how the uncertainty analyses were made on specific data. This appendix consists of letter reports generated during the program to document the work. Documents generated during the data review task are referenced but are not contained in Appendix E.

2. DEFINITIONS

The data plots in the main body of this report contain terms used to describe the types of data, quality level, uncertainty, etc. This section is designed to give a brief description of these terms so that the reader can better utilize the data plots. Some data plots may contain combinations of these terms.

1. Qualified Data

This term describes the quality category of the data. Qualified data has defined uncertainties of a reasonable magnitude and it accurately represents the physical phenomena being measured or calculated. Qualified data are shown as solid lines on the data plots.

2. Trend Data

This term describes the quality category of the data. Trend data has undefined or unacceptably large uncertainties and it only approximately represents the physical phenomenon being measured or calculated but it does contain useful information. Trend data are shown as dashed lines on the data plots.

3. Composite Data

A composite data set is composed of data from two or more sources. For example, data might be from a stripchart recorder for one time period and from the reactimeter for another. A composite data set can be Qualified, Trend or a combination of Qualified and Trend.

4. Failed Data

Failed data is data which contain no useful information. This is of interest only because there may be regions within a Qualified or Trend data set where the data is failed. These failed data regions will be left blank, i.e., there will be gaps left in the data plot corresponding to the time in which the data were failed.

5. Computed Data

Computed data is a parameter which is the result of a calculation using measurement data. A computed parameter can be Qualified or Trend.

6. Estimated Data

Estimated data is a parameter which was calculated using assumptions and little real data. Estimated data can only be Trend.

7. Uncertainty

Uncertainty is the term used to express the maximum probable error in the data. It is generally given as a symetrical value surrounding the data at all times, i.e., the error value added to the data gives the upper error boundary and the error value subtracted from the data gives the minimum error boundary. In a few cases the uncertainty is itself a function of time or amplitude of the data.

8. Data Qualification

All data have been assigned a category of either Qualified (Q) or Trend (T). The purpose of these terms is to describe generically how good the data are.

3. DATA REVIEW

The purpose of the TMI-2 Data Review task was to provide a single source of data, which was of known quality, for use in understanding and analyzing the TMI-2 accident. The most immediate use of this data is in support of the TMI-2 Analysis Exercise and other ongoing analyses. Data review consisted of collecting the raw data, determining the uncertainty in and quality of the data, and storing it in a dedicated data base. The Data Review Task is described in more detail in Appendix A.

Of the approximately 3000 measurements made at TMI-2, some 170 were selected as being important to the understanding and analysis of the accident. Data at TMI were recorded on computer print outs, magnetic tapes and analog stripcharts. After the accident all such records were impounded at the site and access was allowed only for copying or study. The only source of data for this task, therefore, were microfilm, photographs, and microfiche of the hard copy data and copies of the magnetic tapes. Enlarged color photographs of some of the multipoint recorder data and support documentation to be used in the uncertainty analyses (instrument calibrations, circuit diagrams, operating manuals, etc) were obtained.

Data qualified for the TMI-2 Analysis Exercise were:

- o RCS pressures and temperatures
- o Reactor coolant flow rates

- RCS makeup and letdown flow rates
- Operation periods of ECC injection
- Operation periods of PORV and block valve
- Containment radiation levels
- Source and intermediate-range detector data

Data were extracted and stored on a main frame computer. This process was accurate for computer printouts and magnetic tapes. Stripchart data, however, had to be digitized, which was generally done on an apparatus which transferred the plot coordinates directly into the computer.

The next step was to perform an uncertainty analyses on the data. Because some important support information was not available for use in the analyses, major simplifications were made in the approach to determining uncertainties. All errors were treated as bias errors as a function of instrument range. This approach simplified both the uncertainty analyses and the presentation of uncertainty in the data base by eliminating the need for calculation and presentation of the statistical part of the total error. Conservative substitutions were made for the small number of errors which could not be treated as bias (i.e., statistical errors). Most of the error information was taken from instrument calibration sheets which gave errors as a tolerance value which is a bias. Treating any errors as a function of range rather than reading has the effect of making the results more conservative.

Each data set was studied to determine if an analysis could or should be performed. If the preanalysis study revealed problems that precluded calculating measurement uncertainties of a reasonable magnitude, an uncertainty analysis was not performed. The uncertainty analyses provided the error bounds for the data, i.e., the maximum and minimum probable error with a 95% confidence. Because of the simplified approach taken, uncertainties were generally expressed as a symetrical value which applies to the data at all times. In only a few cases were uncertainties calculated which had to be expressed as functions of time or data amplitude. Details of the uncertainty analyses are given in Appendix D.

After the uncertainty was established for the data it was possible to determine the quality category of the data. All data were given a quality category of either Qualified or Trend. The criterion for Qualified data was that it have reasonably sized uncertainty and be well behaved. The criterion for Trend data was that the uncertainties were unreasonably large or uncalculable and that the data only approximate the phenomenon being measured. Data classified as Failed was not presented in this report or in the data base but was retained in the main frame computer raw data file.

After the data had been categoriezed, an internal review was made of the data, the uncertainty analysis, and any underlying assumptions made. A group called the Data Integrity Review Committee (DIRC) reviewed the data put into the TMI-2 Data Base. The size and composition of the DIRC varied according to the type of data being reviewed, but generally consisted of members of the TMI-2 Accident Evaluation Program. For some specific measurements, outside experts participated in the DIRC.

Calculated and estimated parameter data were generated and stored on the main frame computer. These data went through the DIRC process in the same manner as did the measurement data.

4. SUMMARY OF DATA QUALIFICATION AND CERTAINTY

The purpose of this section of the report is summarize the TMI-2 data qualification categories, uncertainties values and plot page numbers for the data plots contained in Section 5. The data summary is contained in Table 1 where data is listed by type (i.e., flow, temperature, pressure, etc.) and within type in alphabetical order. Table 1 also lists measurement data qualification and uncertainty for the once through steam generator (OTSG) feedwater which is valid only prior to turbine trip (time zero of the accident) and therefore are not plotted. Table 2 contains the averaged value for these data immediately prior to the accident.

TABLE 1

SUMMARY OF DATA QUALIFICATION AND UNCERTAINTY

Measurement Identifier	Measurement Description	Amplitude Qualification* Category & Uncertainty	Time Qualification* Category & Uncertainty	Qualification Reference	Plot Page Number
		F L O W	R A T E		
AFW-SG-A	Auxiliary Feedwater Secondary Injection Rate, Based upon Secondary Mass Inventory - Steam Generator A	T Estimate	T	EGG-TMI-7481	26
AFW-SG-B	Auxiliary Feedwater Secondary Injection Rate, Based upon Secondary Mass Inventory - Steam Generator B	T Estimate	T	EGG-TMI-7481	27
HPI-MUP1	HPI/Makeup Estimate Based on Expected Results (Multi-valued Function), ICBC name is HPI/MAKEUP FLOW 1	T Estimate	T	EGG-TMI-7833	28
LETDOWN FLOW	Letdown Cooler Volumetric Flowrate	Q ± 24.6% Reading	Q ± 2.5 min	Letter YN-3-86 & YN-4-87	29
PORV Flow Rate	Calculated Mass Flow Rate Thru PORV	Q ± 20% Reading	Q	EGG-TMI-7825	30
RC-14A-FT-CALC	Hot Leg Calculated Loop A Mass Flow Rate	Q Note 1	Q Note 1	EGG-TMI-7485	31
RC-14B-FT-CALC	Hot Leg Calculated Loop B Mass Flow Rate	Q Note 1	Q Note 1	EGG-TMI-7485	32
SP-8A-FT-R	OTSG Feedwater Flow Rate	Q ± 0.106 Mph, Note 2	Q ± 3 sec	Letter RDMc-15-86	No plot
SP-8B-FT-R	OTSG Feedwater Flow Rate	Q ± 0.106 Mph Note 2	Q ± 3 sec	Letter RDMc-15-86	No plot

Measurement Identifier	Measurement Description	Amplitude Qualification* Category & Uncertainty	Time Qualification* Category & Uncertainty	Qualification Reference	Plot Page Number
		LEVELS MEASUREMENTS			
RC-1-LT1-L-R	Pressurizer Level	Q ± 24 in.	Q ± 3 sec	EGG-TMI-7100	33
SG-A-LEVEL	Steam Generator A - Composite Level	Q ± 9 cm	Q ± 3 sec	EGG-TMI-7359	34
SG-B-LEVEL	Steam Generator B - Composite Level	Q ± 9 cm	Q ± 3 sec	EGG-TMI-7359	35
		NUCLEAR RADIATION MEASUREMENTS			
DC-R-3399-M	Decay Heat Closed A Loop Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	36
DC-R-3400-M	Decay Heat Closed B Loop Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	37
HP-R-207-M	Intermediate Cooling Pump Area Radiation Monitor - in the Auxiliary Building	T	Q ± 10 min	EGG-TMI-7376	38
HP-R-219-M	Station Vent Rad Monitor - Gas	T	Q ± 2 min	EGG-TMI-7376	39
HP-R-222-G-M HP-R-222-I-M HP-R-222-P-M	Auxiliary Bldg Purge Air Exhaust Rad Monitor Upstream of Filter - Gas - Iodine - Particulate	T	Q ± 2 min	EGG-TMI-7376	40
HP-R-225-G-M HP-R-225-I-M HP-R-225-P-M	Reactor Building Purge Air Exhaust, Duct A, Rad Monitor - Gas - Iodine - Particulate	T	Q ± 2 min	EGG-TMI-7376	41 42 43
HP-R-226-G-M HP-R-226-I-M HP-R-226-P-M	Reactor Bldg Purge Air Exhaust, Duct B, Rad Monitor - Gas, - Iodine, -Particulate	T	Q ± 2 min	EGG-TMI-7376	44 45 46

Measurement Identifier	Measurement Description	Amplitude Qualification* Category & Uncertainty	Time Qualification* Category & Uncertainty	Qualification Reference	Plot Page Number
HP-R-228-G-M HP-R-228-I-M HP-R-228-P-M	Auxiliary Bldg Purge Air Exhaust Rad Monitor Downstream of Filter - Gas, - Iodine, - Particulate	T	Q ± 2 min	EGG-TMI-7376	49 50 51
HP-R-229-G-M	Hydrogen Purge Rad Monitor - Gas	T	Q ± 2 min	EGG-TMI-7376	52
HP-R-3236-M	Reactor Building Purge Unit Area Radiation Monitor	T	Q ± 15 min	EGG-TMI-7376	53
HP-R-3238-M	Auxiliary Building Exhaust Unit Area Radiation Monitor	T	Q ± 15 min	EGG-TMI-7376	54
HP-R-3240-M	Fuel Handling Exhaust Unit Area Radiation Monitor	T	Q ± 15 min	EGG-TMI-7376	55
IC-R-1091-M	Intermediate Coolant Letdown, Cooler B Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	56
IC-R-1092-M	Intermediate Coolant Letdown, Cooler A Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	57
IC-R-1093-M	Intermediate Coolant Letdown, Inlet Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	58
MU-R-720H-M	Primary Coolant Letdown HI Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	59
MU-R-720L-M	Primary Coolant Letdown LO Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	60
NI-ND-1-P	Source Range Power Level	Q Note 3	Q -30/+0 sec	EGG-TMI-7174	61
NI-ND-1-S	Source Range Power Level	Q Note 3	Q -45/+10 sec	EGG-TMI-7174	62
NI-ND-2-P	Source Range Power Level	Q Note 3	Q -30/+0 sec	EGG-TMI-7174	63
NI-ND-3-S	Intermediate Range Power Level	T	Q - 45/+10 sec	EGG-TMI-7174	64
NI-ND-4-S	Intermediate Range Power Level	T	Q - 45/+10 sec	EGG-TMI-7174	65

Measurement Identifier	Measurement Description	Amplitude Qualification* Category & Uncertainty	Time Qualification* Category & Uncertainty	Qualification Reference	Plot Page Number
SF-R-3402-M	Spent Fuel Cooling Area Radiation Monitor	T	Q ± 5 min	EGG-TMI-7376	66
WDL-R-1311-M	Plant Effluent Radiation Monitor, Unit 2	T	Q ± 5 min	EGG-TMI-7376	67
WGD-R-1480-G-M	Waste Gas Discharge Duct Radiation Monitor - Gas	T	Q ± 2 min	EGG-TMI-7376	68
		PRESSURE			
PRESS.-PRIMARY	Reactor Coolant Composite Pressure	Q ± 40 psi	Q	Letter JA-16-86	69
BS-PT-4388-S	Containment Building Pressure	Q ± 0.32 psig Note 4	Q ± 1.2 min	Letter JA-4-87	70
SP-10A-PT1-R	Turbine Header Pressure - Loop A	Q ± 8.2 psig	Q ± 3 sec	Letter JA-2-87	71
SP-6A-PT1-R	Steam Generator A - Steam Pressure	Q ± 16.1 psi	Q ± 3 sec	Letter JA-18-86	72
SP-6B-PT1-R	Steam Generator B - Steam Pressure	Q ± 16.1 psi	Q ± 3 sec	Letter JA-18-86	73
WDL-PT-1202-R	Reactor Coolant Drain Tank (RCDT) Pressure	Q ± 3.9 psi	Q ± 3 sec	Letter JA-1-87	74
		TEMPERATURE			
AH-TE-5011-M	Ambient Temperature, Letdown Cooler Area	Q/T ± 3.3 F	Q ± 90 sec	Letter RDMc-5-87	75

Measurement Identifier	Measurement Description	Amplitude Quality* Category & Uncertainty	Time Quality* Category & Uncertainty	Qualification Reference	Plot Page Number
AH-TE-5012-M	Ambient Temperature, Drain Tank Area	Q/T ± 3.3 F	Q ± 90 sec	Letter RDMc-5-87	76
FW-TE-1131-P	Feedwater Heater B Outlet Temperature	Q ± 2.2 F Note 2	Q - 1.5/+1 min	Letter RDMc-1-87	No plot
MU-TE-739-M	Letdown Cooler 1A Outlet Temperature	Q ± 10% Reading	Q ± 2.5 min	Letter RDMc-15-87	77
MU-TE-740-M	Letdown Cooler 1B Outlet Temperature	Q ± 10% Reading	Q ± 2.5 min	Letter RDMc-15-87	78
RC-2-TE1/2-P	Pressurizer Temperature	Q ± 2.5 F	Q ± 1 min	Letter RDMc-11-87	79
RC-9-TE-P	Pressurizer Surge Line Temperature	T	Q ± 1 min	Letter RDMc-11-87	80
RC-15A-TE1-M	Hot Leg Temperature - Loop A: Wide Range (Elev 355'2")	T	Q ± 2.5 min	Letter RDMc-12-87	81
RC-15A-TE3-M	Cold Leg Temperature - Pump 2A Inlet: Wide Range (Elev 310'2")	T	Q ± 2.5 min	Letter RDMc-12-87	82
RC-15B-TE1-M	Hot Leg Temperature - Loop B: Wide Range	T	Q ± 2.5 min	Letter RDMc-12-87	83
RC-15B-TE3-M	Cold Leg Temperature - Pump 2B Inlet: Wide Range (Elev 310"2")	T	Q ± 2.5 min	Letter RDMc-12-87	84
RC-5A-TE2-R	Cold Leg Temperature - Pump 1A Inlet: Wide Range	Q ± 1.91 F	Q ± 3 sec	Letter RDMc-17-86	85
RC-5B-TE2-R	Cold Leg Temperature - Pump 1B	Q ± 1.91 F	Q ± 3 sec	Letter RDMc-17-86	86

Measurement Identifier	Measurement Description	Amplitude Quality* Category & Uncertainty	Time Quality* Category & Uncertainty	Qualification Reference	Plot Page Number
SP-2A-TE1-P	OTSG Shell Temperature	Q ± 8.1 F	Q ± 1 min	Letter RDMc-10-87	87
SP-2A-TE2-P					88
SP-2A-TE3-P					89
SP-2A-TE4-P					90
SP-2A-TE5-P					91
SP-2B-TE1-P					92
SP-2B-TE2-P					93
SP-2B-TE3-P					94
SP-2B-TE4-P					95
SP-2B-TE5-P					96
SP-3A-TE1/2-P	OTSG Downcomer Temperature	Q ± 2.2 F	Q ± 1 min	Letter RDMc-11-87	97
SP-3B-TE1/2-P					98
SP-4A-TE-P	Main Stream Temperature	Q ± 2.72 F	Q ± 1 min	Letter RDMc-1-87	99
SP-4B-TE-P					100
SP-5A-TE1/2-R	Feedwater Inlet Temperature	Q ± 1.71 F Note 2	Q ± 3 sec	Letter RDMc-1-87	No plot
SP-12A-TE1-P	OTSG Upper Downcomer Temperature	Q ± 2.2 F	Q ± 1 min	Letter RDMc-11-87	101
SP-12A-TE2-P					102
SP-12B-TE1-P					103
SP-12B-TE2-P					104
TE-HL-A	Reactor Coolant Composite Temperature - Loop A Hot Leg	Q/T ± 1.14 F	Q ± 3 sec & + 2 min	Letter RDMc-9-87, RDMc-17-86, RDMC-7-87	105
TE-HL-B	Reactor Coolant Composite Temperature - Loop B Hot Leg	Q/T ± 1.14 F	Q ± 3 sec & + 2 min	Letter RDMc-9-86, RDMc-17-86, RDMc-7-87	106
TSAT-PRIMARY	Reactor Coolant Saturation Temperature	Q ± 4.8 F		Letter JA-16-86	107

Measurement Identifier	Measurement Description	Amplitude Quality* Category & Uncertainty	Time Quality* Category & Uncertainty	Qualification Reference	Plot Page Number
TSAT-SG-A	Saturation Temperature from Pressure, Steam Generator A	Q ± 5.5 F	Q ± 3 sec	EGG-TMI-7482	108
TSAT-SG-B	Saturation Temperature from Pressure, Steam Generator B	Q ± 5.5 F	Q ± 3 sec	EGG-TMI-7482	109
WDL-TE-1200-P	Reactor Coolant Drain Tank (RCDT) Temperature	Q ± 1.7 F	Q - 30/+ 0 sec	Letter JA-1-87	110
		BINARY MEASUREMENTS			
PCP1A	Primary Coolant Pump 1A (Start/Stop Times), Binary Function	T			111
PCP1B	Primary Coolant Pump 1B (Start/Stop Times), Binary Function	T			112
PCP2A	Primary Coolant Pump 2A (Start/Stop Times), Binary Function	T			113
PCP2B	Primary Coolant Pump 2B (Start/Stop Times), Binary Function	T			114

Measurement Identifier	Measurement Description	Amplitude Quality* Category & Uncertainty	Time Quality* Category & Uncertainty	Qualification Reference	Plot Pag Number
RC-V1-R	Pressurizer Spray Valve Position, Binary Function, ICBC name is Spray Valve	Q NA	Q $\pm$ 3 sec	Letter DWG-5-86	115
RC-V2	Pressurizer Block Valve Position (Open/Closed), Binary Function, ICBC name is Block Valve	Q NA	Q $\pm$ 0.5 min	Letter DWG-7-86	116

*Definitions of these terms are found in Section 2 of this report.
Q = Qualified, T = Trend, NA = Not Applicable.

NOTES:

1. The uncertainty in the RC-14 A&B-FT data is a function of time and is expressed by a curve on the data plot.
2. These values are valid for initial conditions i.e., prior to accident time zero.
3. The uncertainty of the source range monitor is $\pm 8\times10^{-4} \times (\text{Reading})^2 + 10^6)^{1/2}$.
4. The pressure spike has an uncertainty of $\pm$ 2.2 psig.

TABLE 2

OTSG FEEDWATER INITIAL CONDITION

Measurement Identifier	Pre-Turbine Trip Value	Comment
SP-8A-FT-R	5.74 Mph	Average of two minutes.
SP-8B-FT-R	5.69 Mph	Average of two minutes.
SP-5A-TE1/2-R	463.8^{o}F	1.5 min average.
FW-TE-1131-P	461^{o}F	Hourly log reading Heater output Single point

Mph - Millions of pounds per hour.

REFERENCES

1. M. Silberberg, et. al., Reassessment of the Technical Bases for Estimating Source Terms (Draft report for comments), NUREG-0956, July 1985.

2. A. Buhl, et. al., "IDCOR '85 -- The Severe Accident Issues, Individual Plant Examinations and Source Term Reductions," paper presented at the Atomic Industrial Forum Conference on New Directives in Licensing, Dallas, Texas, May 1985.

3. Report of the Special Committee on Source Terms, American Nuclear Society, September 1984.

4. Radionuclide Release from Severe Accidents at Nuclear Power Plants, American Physical Society, February 1985.

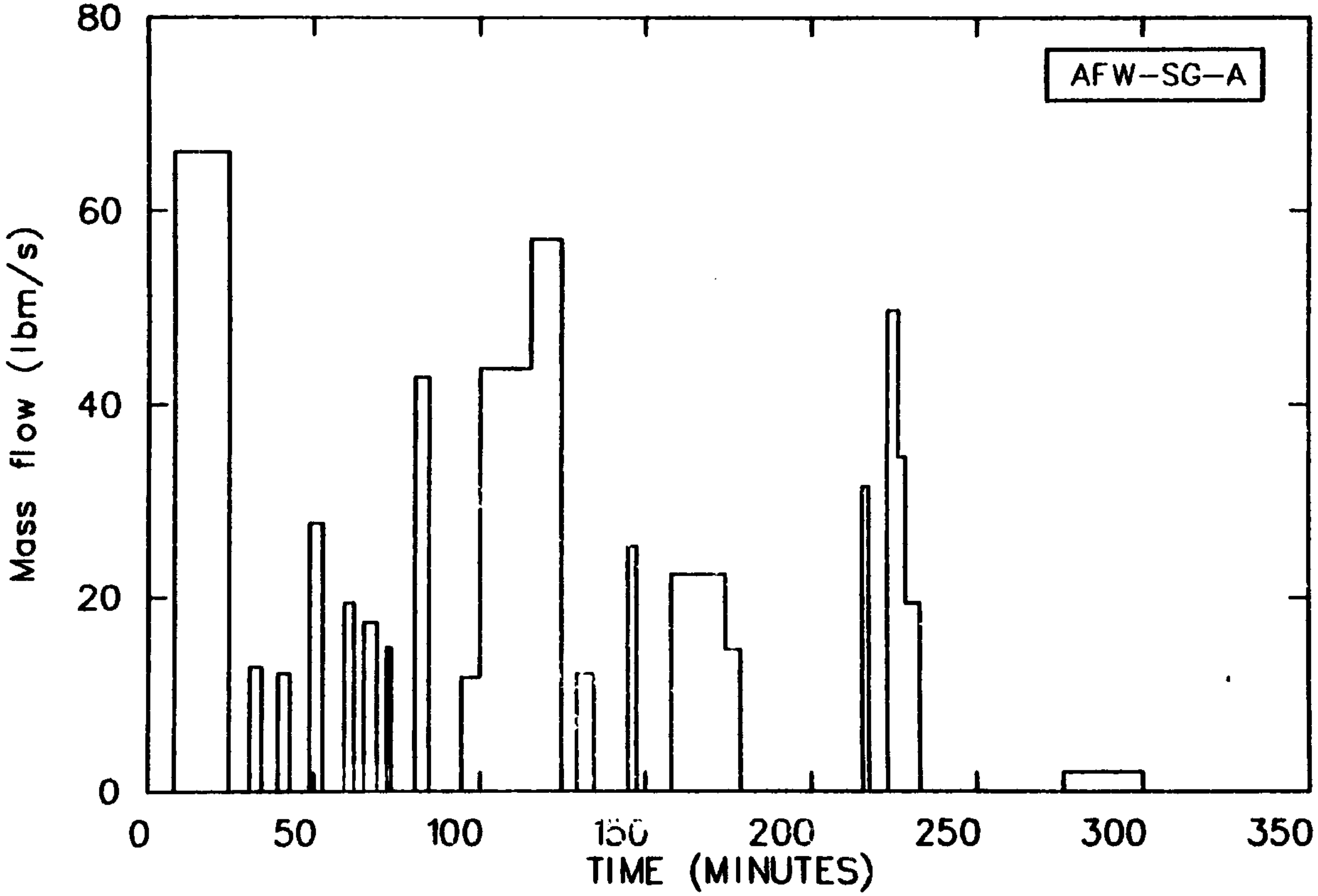
5. Assessment of Radionuclide Source Terms Research, DOE-ID-10126, March 1985.

6. Golden, D. W., et. al., TMI-2 Standard Problem Package, EGG-TMI-7382, September 1986.

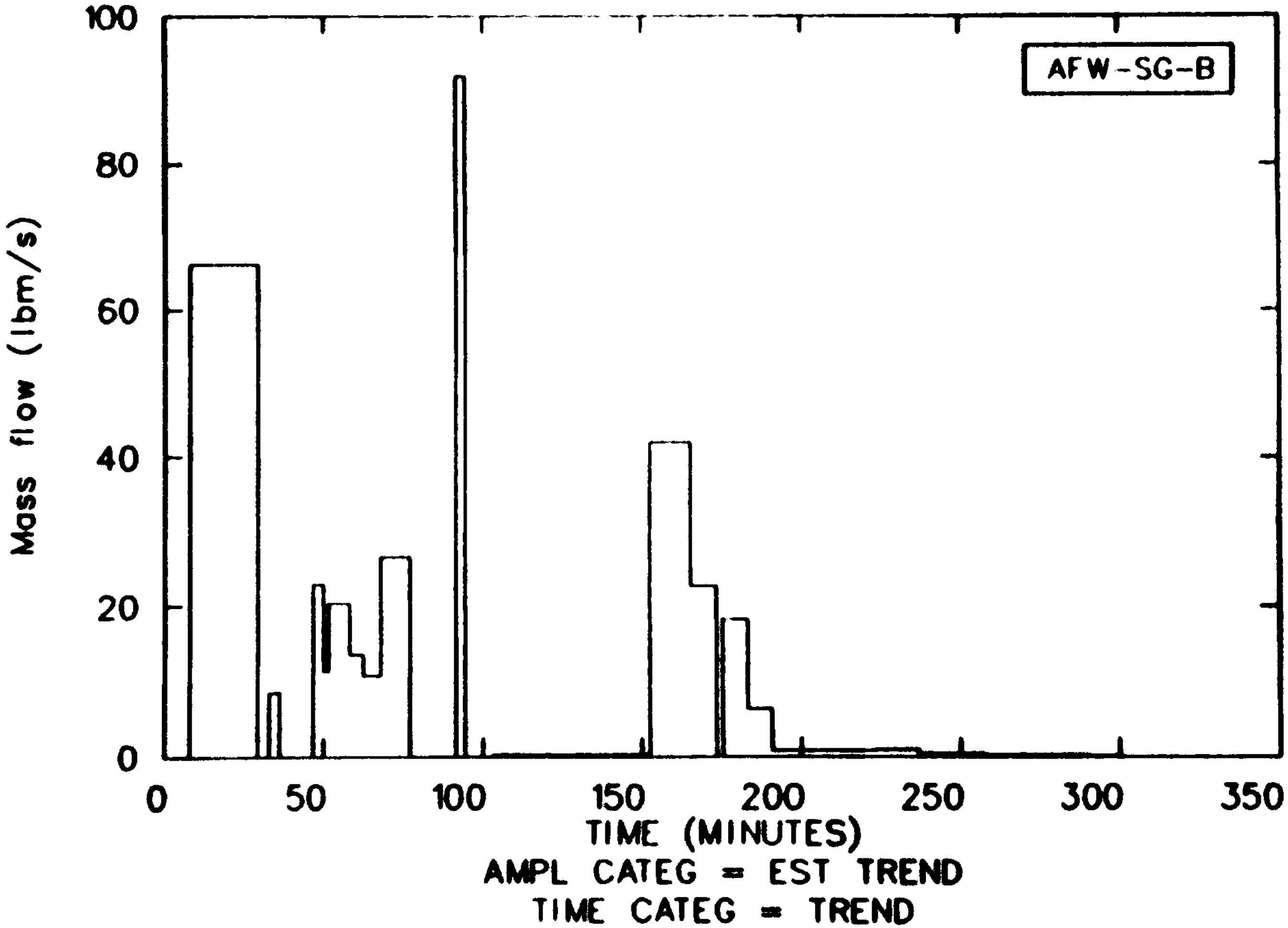
7. Tolman, E. L., et. al., "TMI-2 Accident Evaluation Program," EGG-TMI-7048, February 1986.

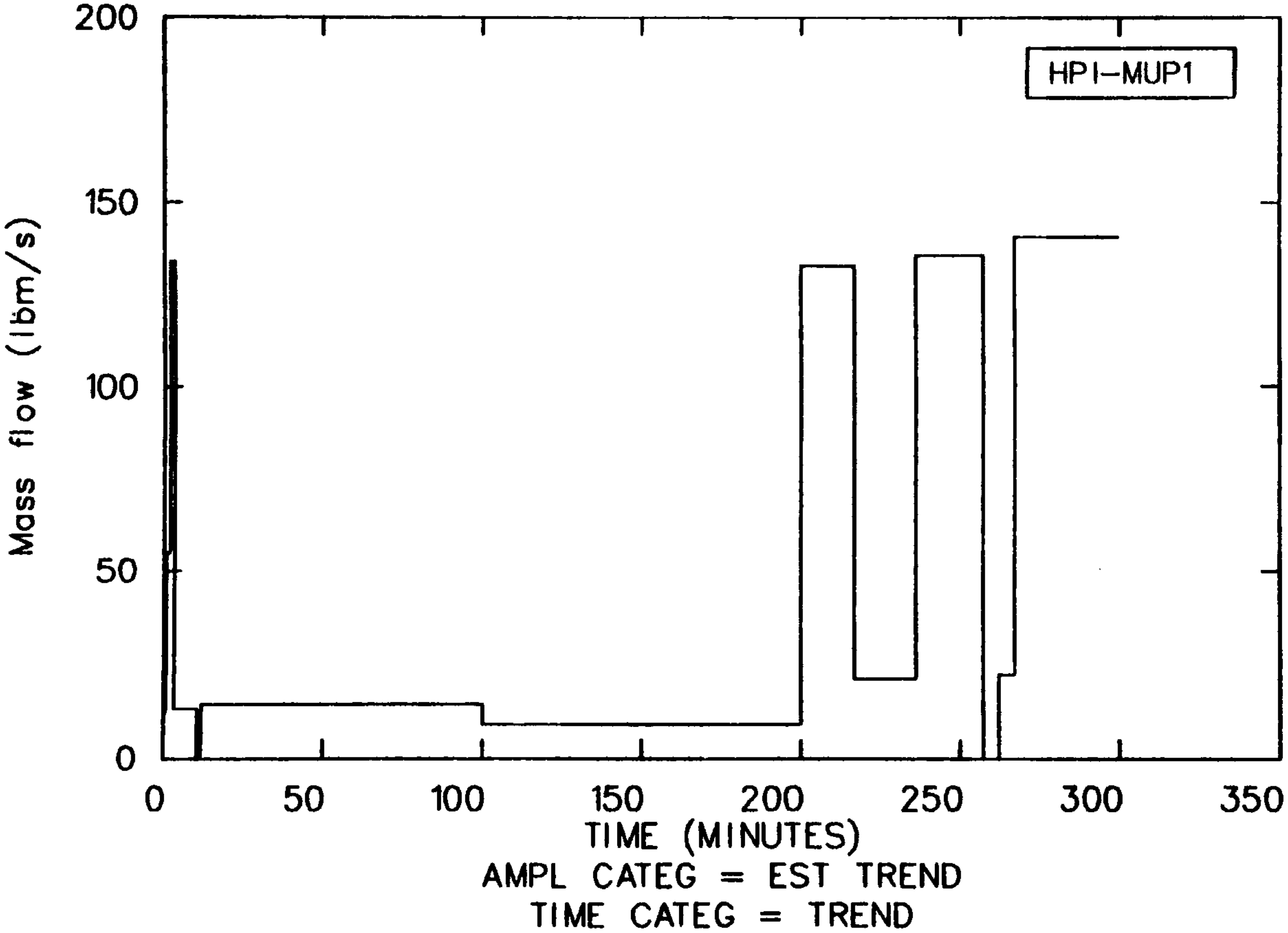
5. DATA PLOTS

This section of the report contains the plots of the data listed in Table 1.

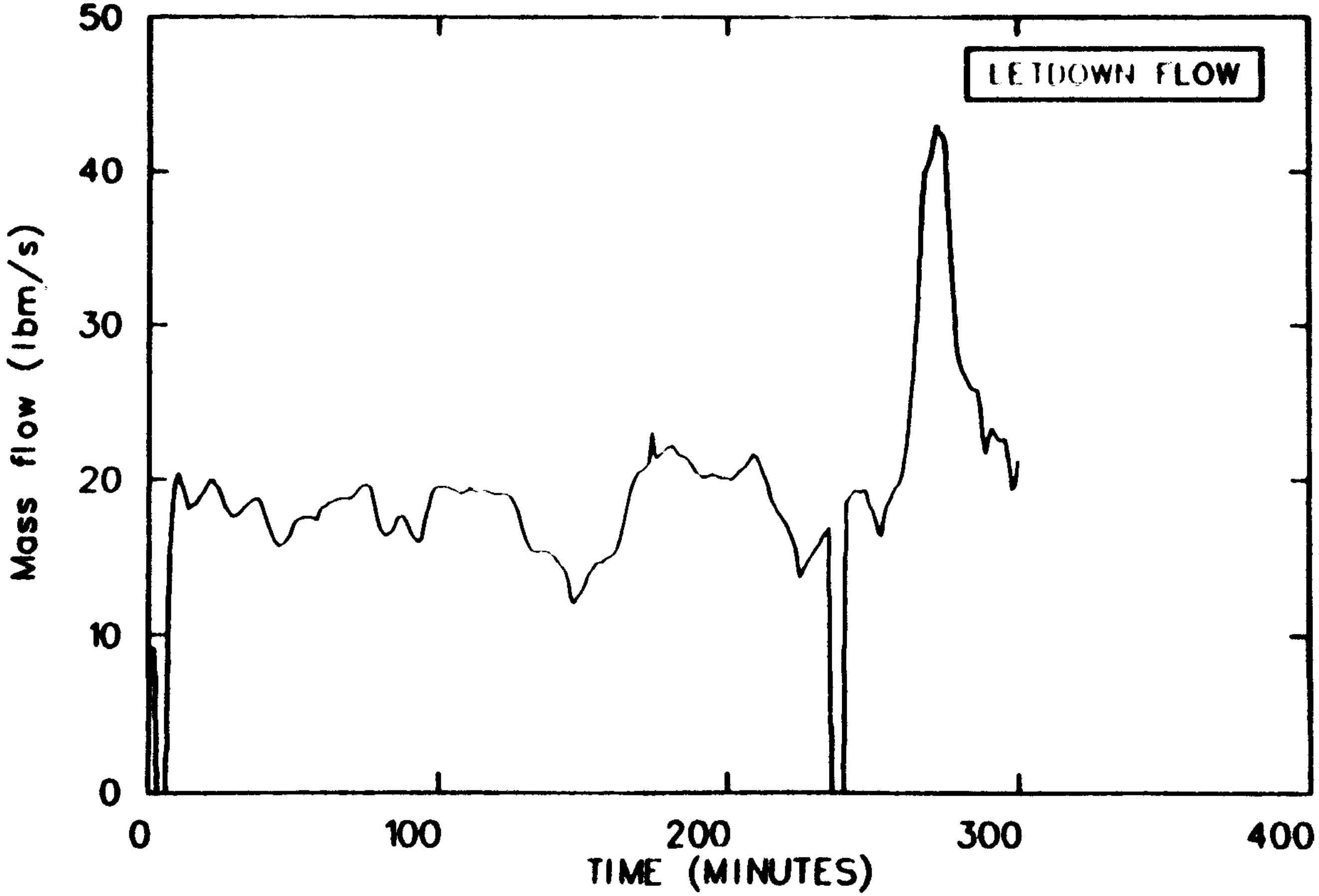


AMPL CATEG = EST TREND
TIME CATEG = TREND

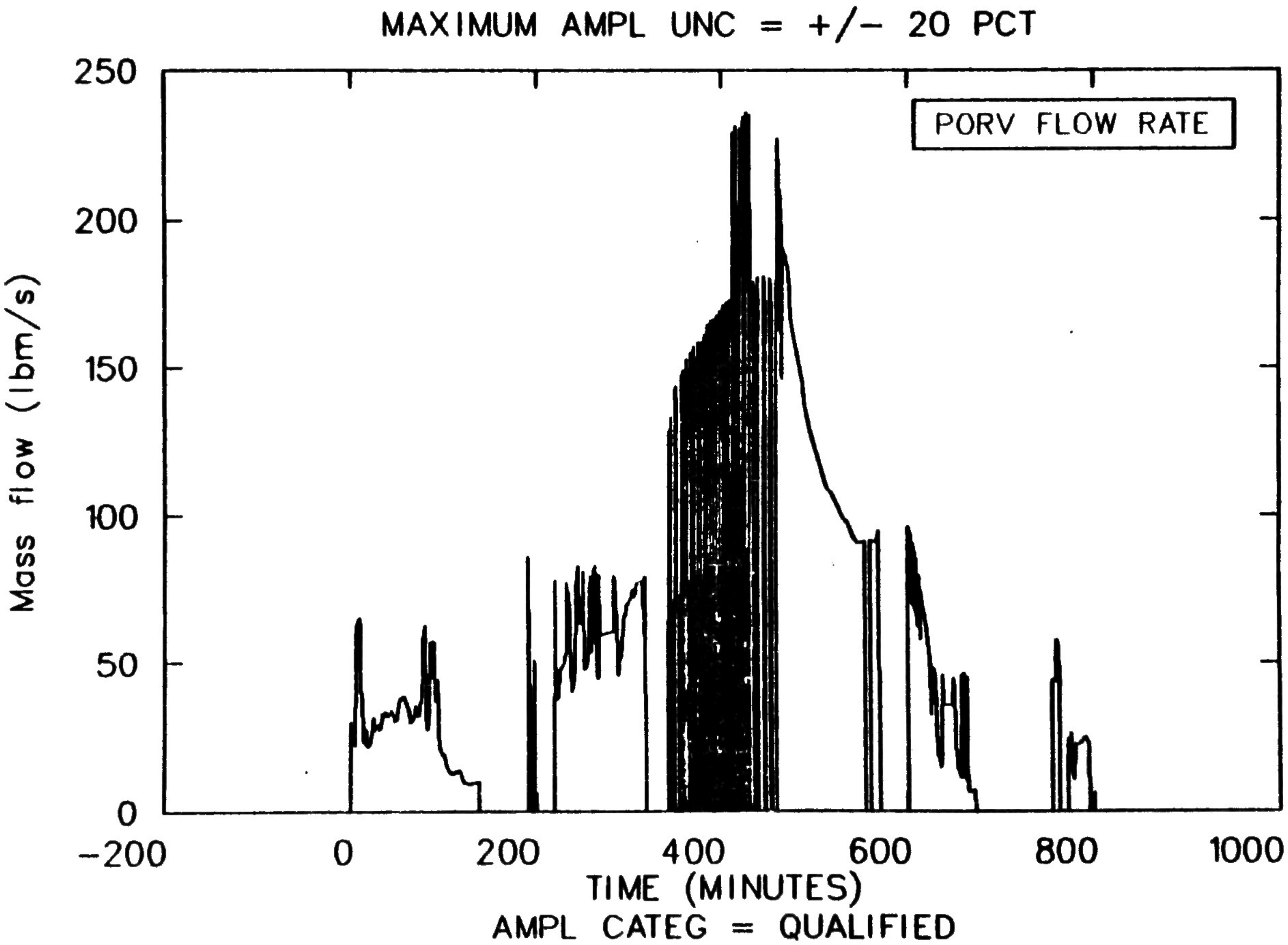

AFW-SG-B
Mass flow (lbm/s)
0
20
40
60
80
100
0
50
100
150
200
250
300
350
TIME (MINUTES)
AMPL CATEG = EST TREND
TIME CATEG = TREND


HPI-MUP1
Mass flow (lbm/s)
0
50
100
150
200
0
50
100
150
200
250
300
350
TIME (MINUTES)
AMPL CATEG = EST TREND
TIME CATEG = TREND

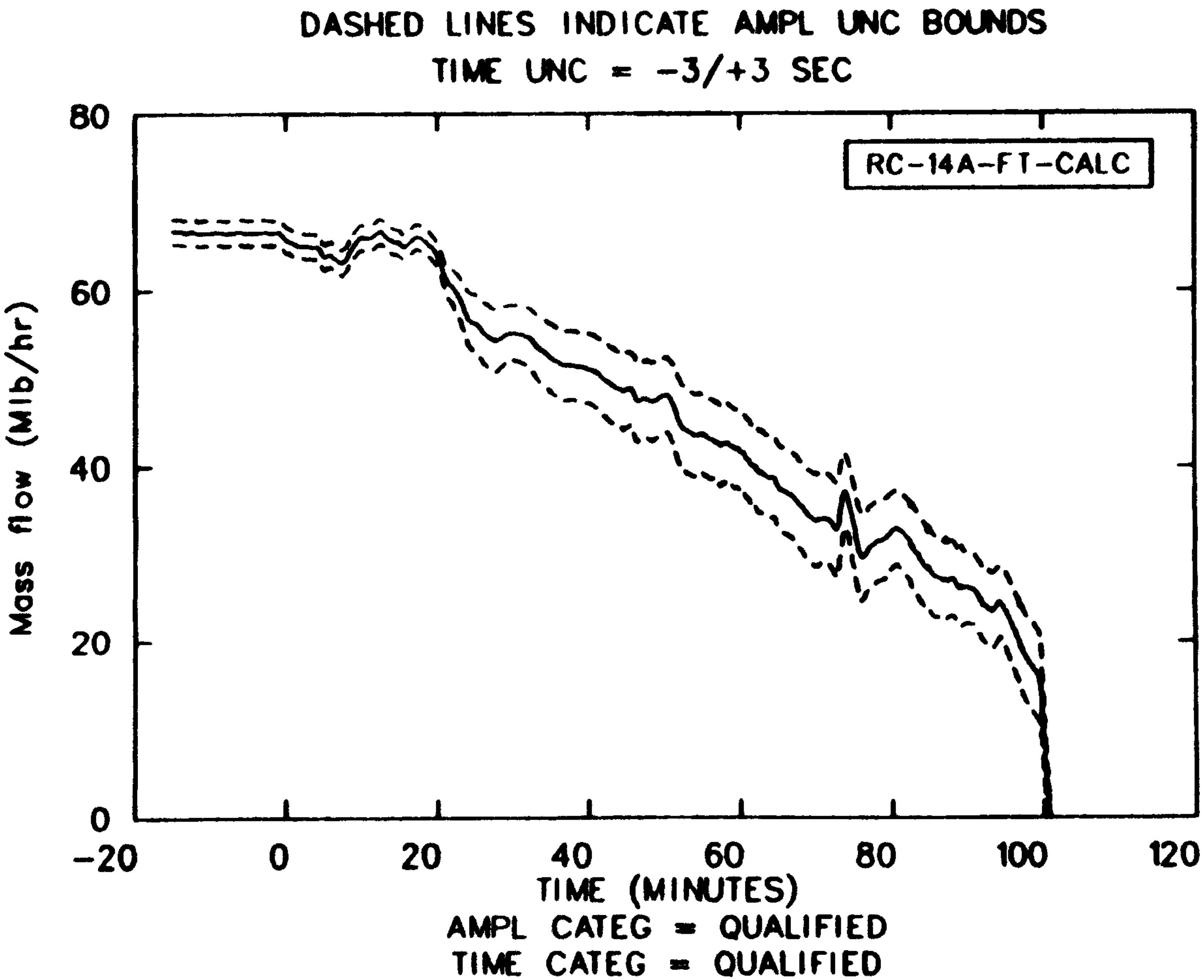
AMPL UNC = +/- 24.6 PCT
TIME UNC = -2.5/+2.5 MIN

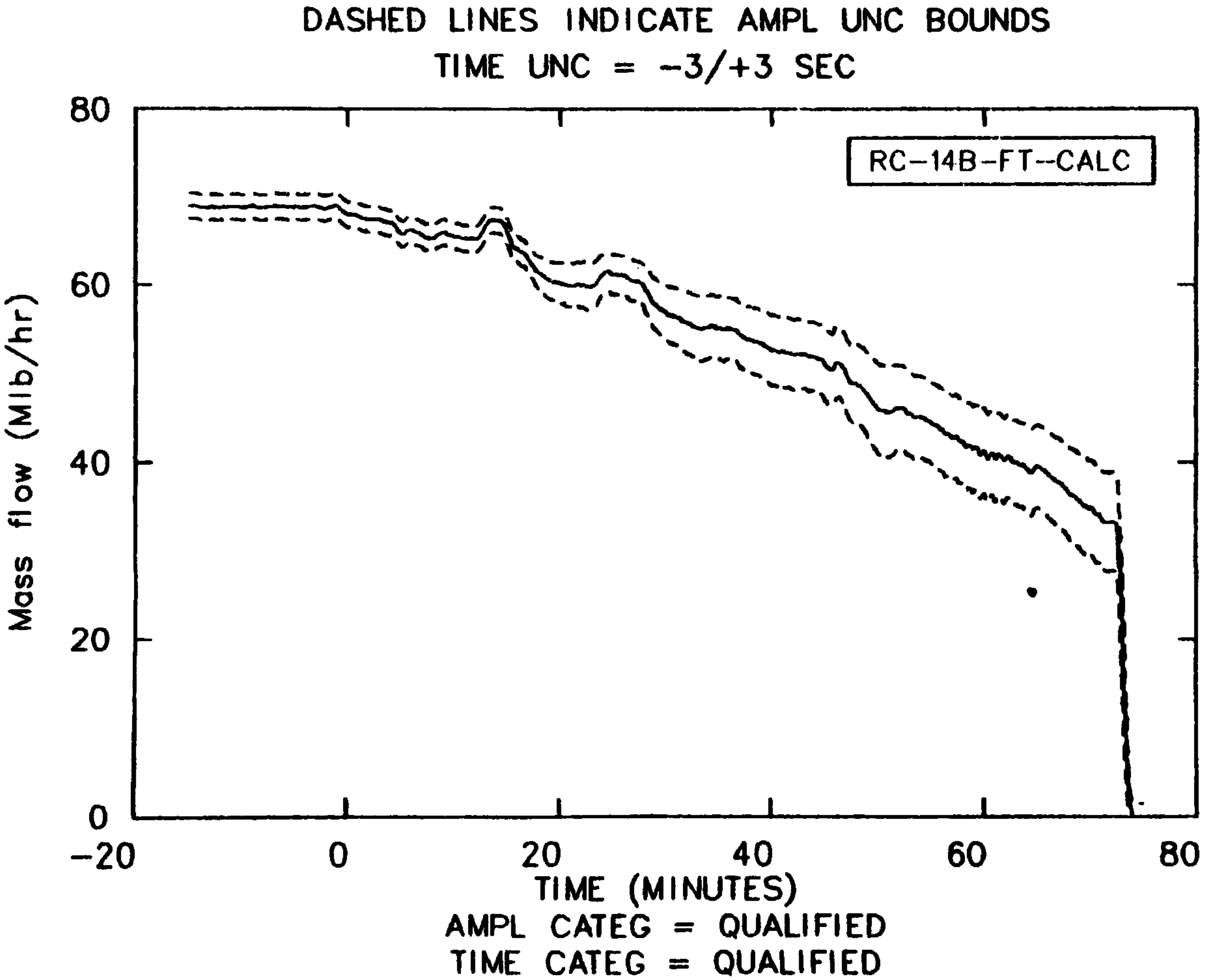


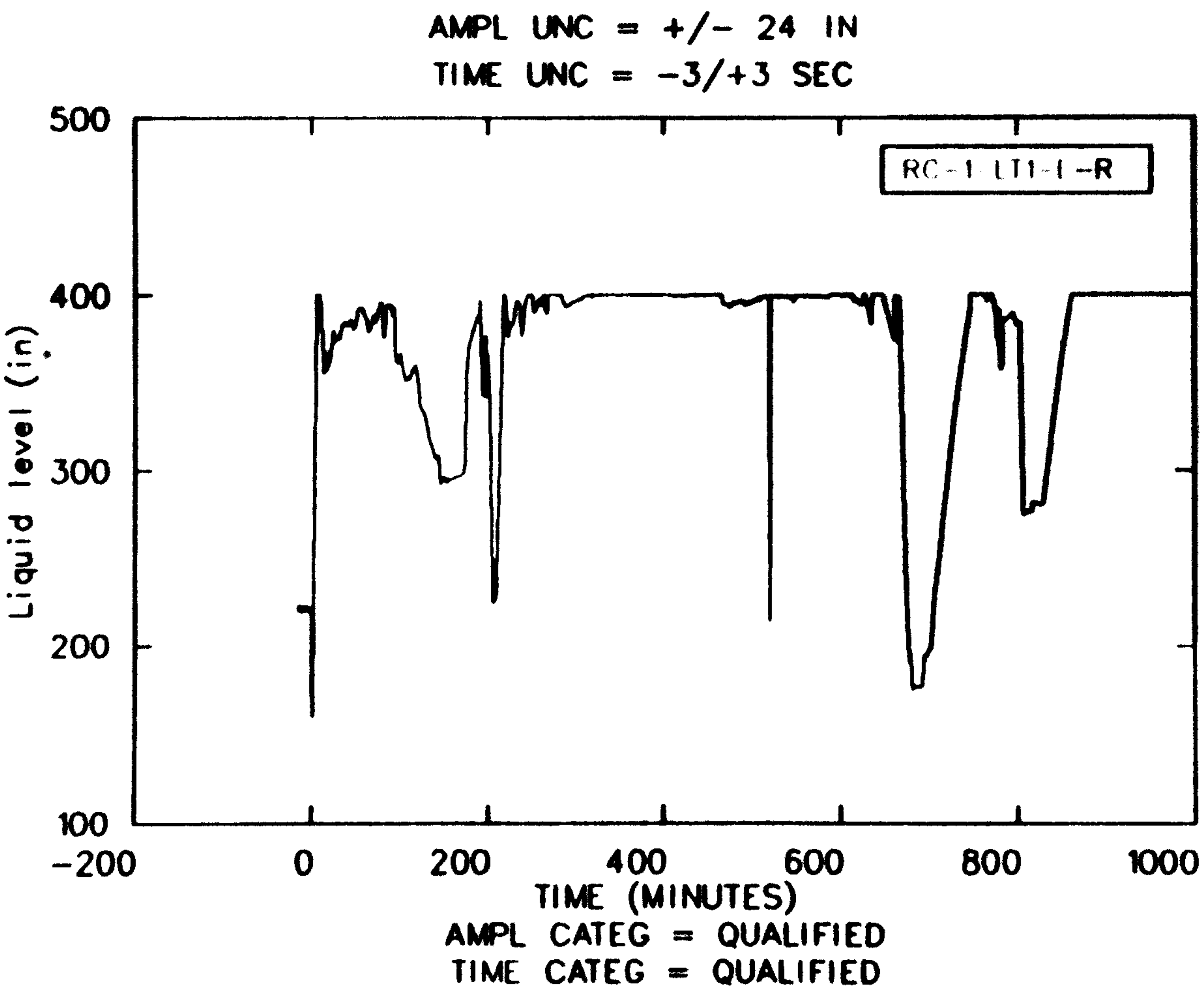
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED



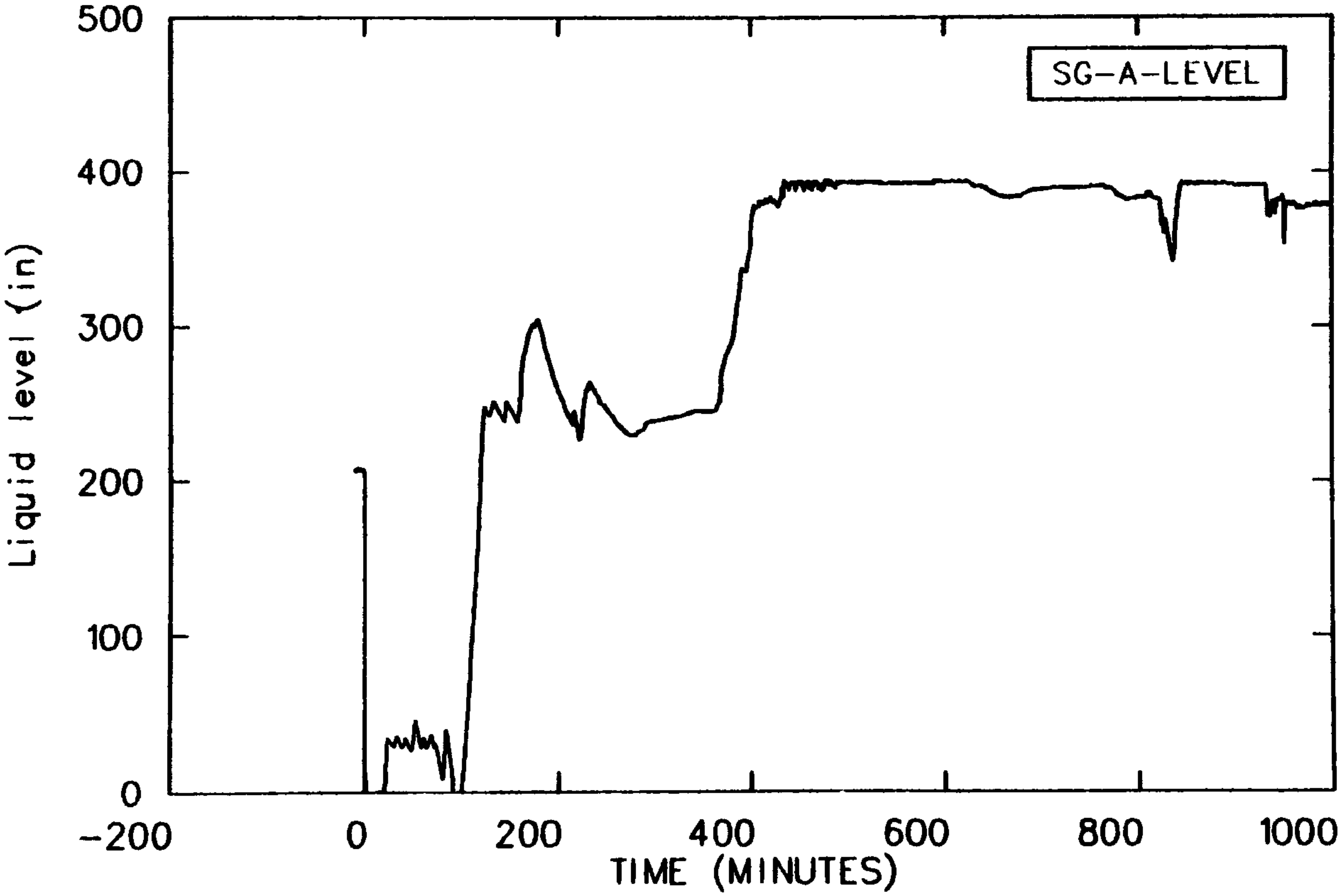
MAXIMUM AMPL UNC = +/- 20 PCT
PORV FLOW RATE
Mass flow (lbm/s)
250
200
150
100
50
0
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED


DASHED LINES INDICATE AMPL UNC BOUNDS
TIME UNC = -3/+3 SEC
RC-14A-FT-CALC
Mass flow (Mlb/hr)
80
60
40
20
0
-20
0
20
40
60
80
100
120
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

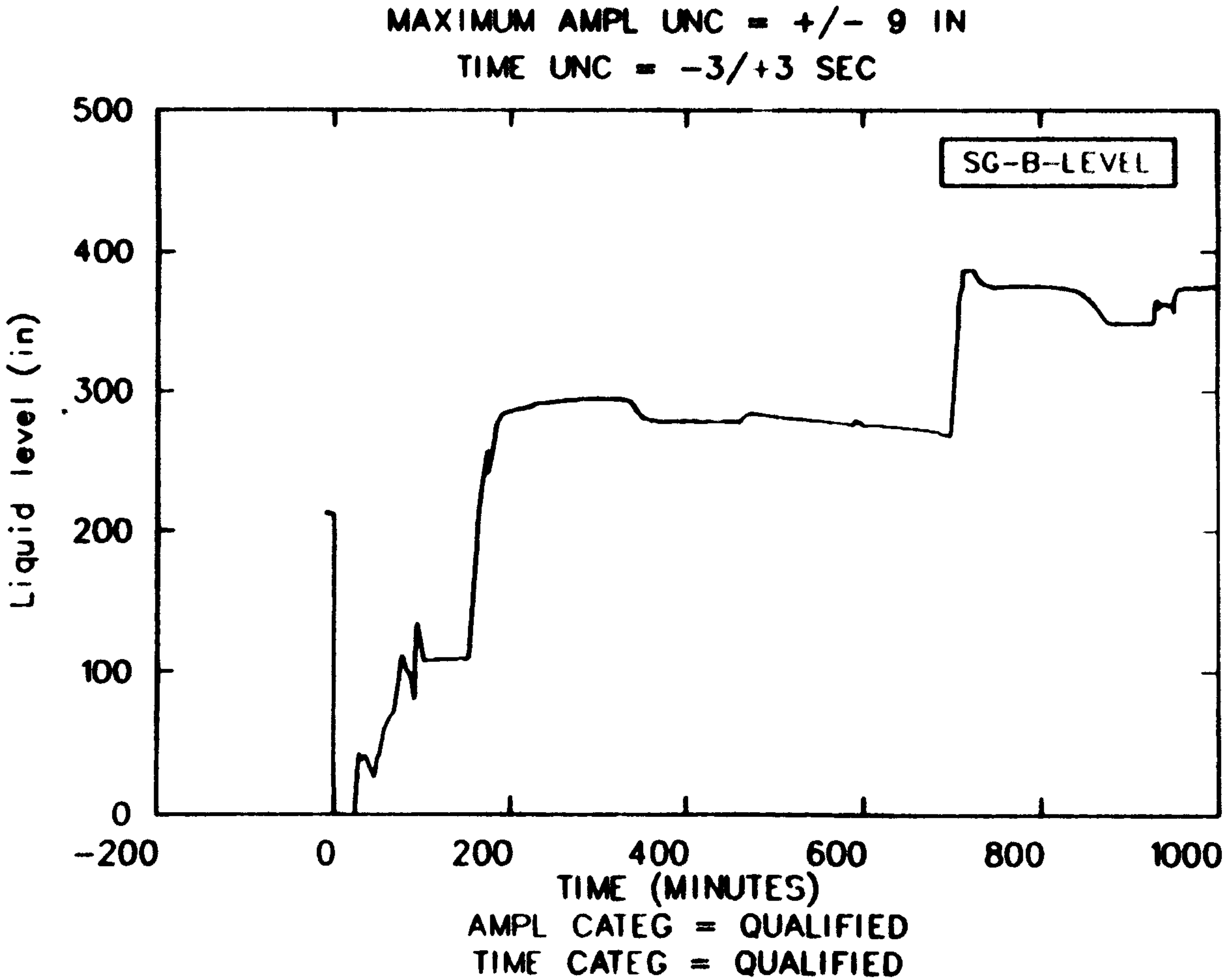

DASHED LINES INDICATE AMPL UNC BOUNDS
TIME UNC = -3/+3 SEC
RC-14B-FT--CALC
Mass flow (Mlb/hr)
80
60
40
20
0
-20
0
20
40
60
80
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

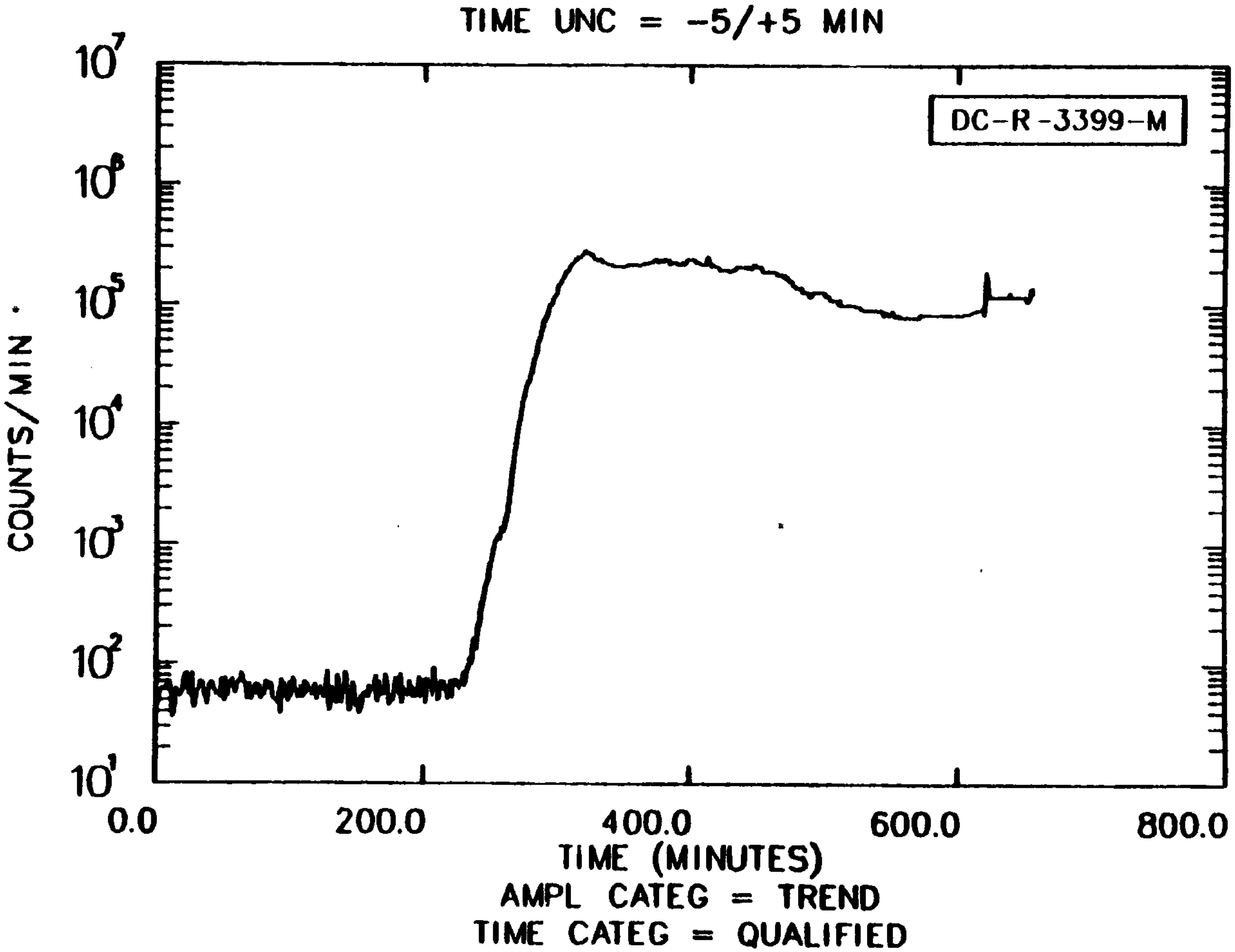

AMPL UNC = +/- 24 IN
TIME UNC = -3/+3 SEC
RC-1-LT1-1-R
Liquid level (in)
500
400
300
200
100
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

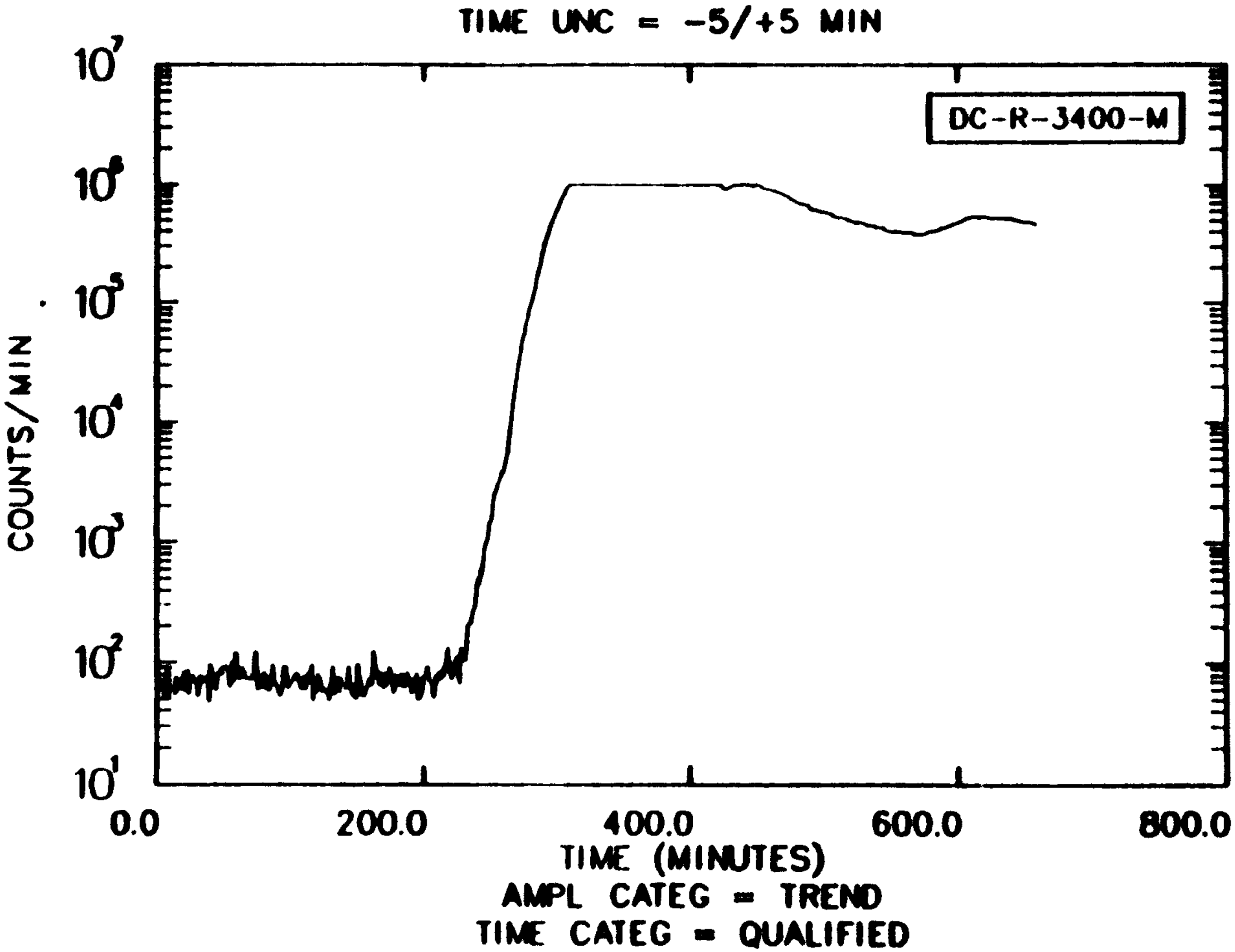
MAXIMUM AMPL UNC = +/- 9 IN
TIME UNC = -3/+3 SEC



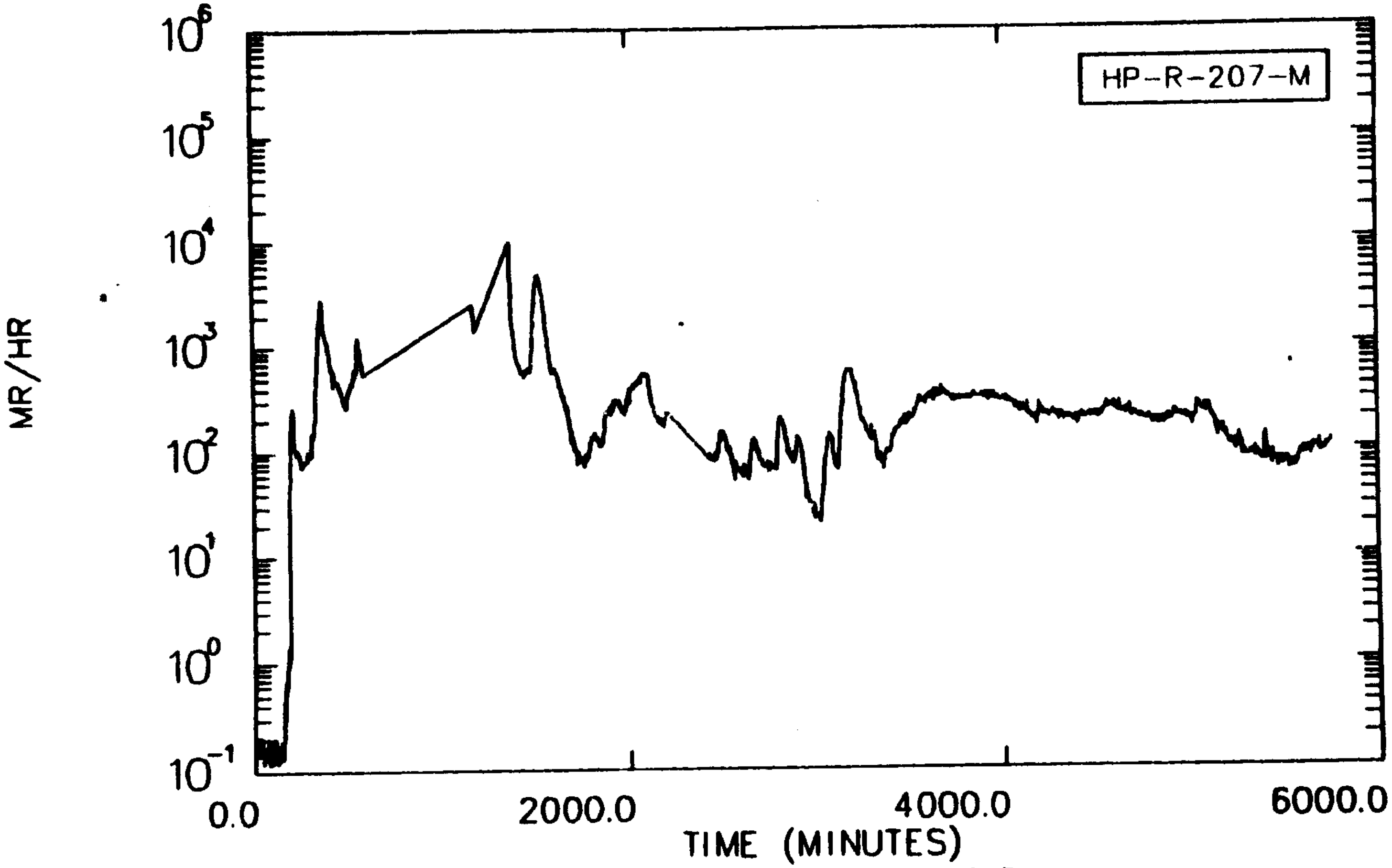
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


MAXIMUM AMPL UNC = +/- 9 IN
TIME UNC = -3/+3 SEC
SG-B-LEVEL
Liquid level (in)
500
400
300
200
100
0
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

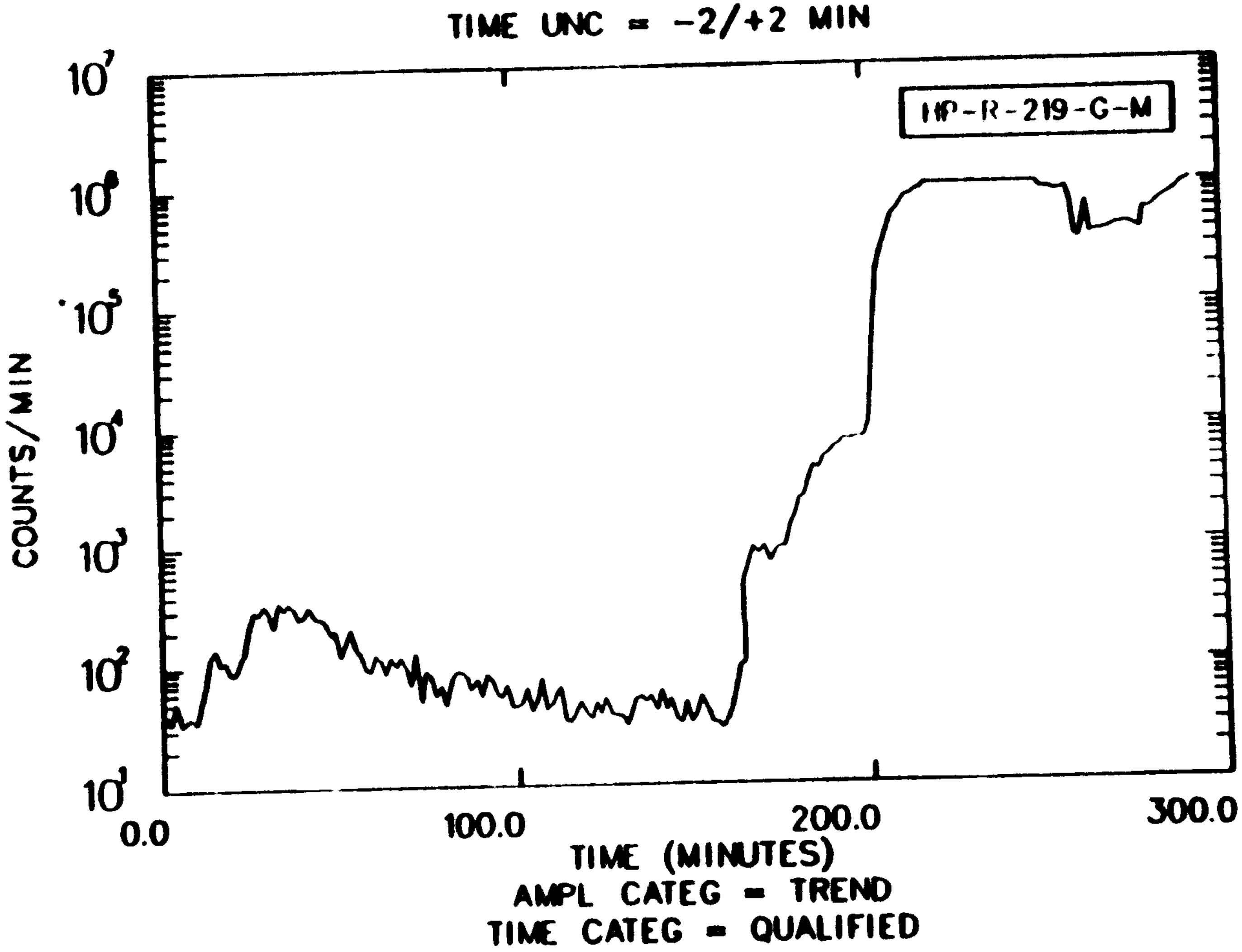

TIME UNC = -5/+5 MIN
DC-R-3399-M
COUNTS/MIN
10^1
10^2
10^3
10^4
10^5
10^6
10^7
0.0
200.0
400.0
600.0
800.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

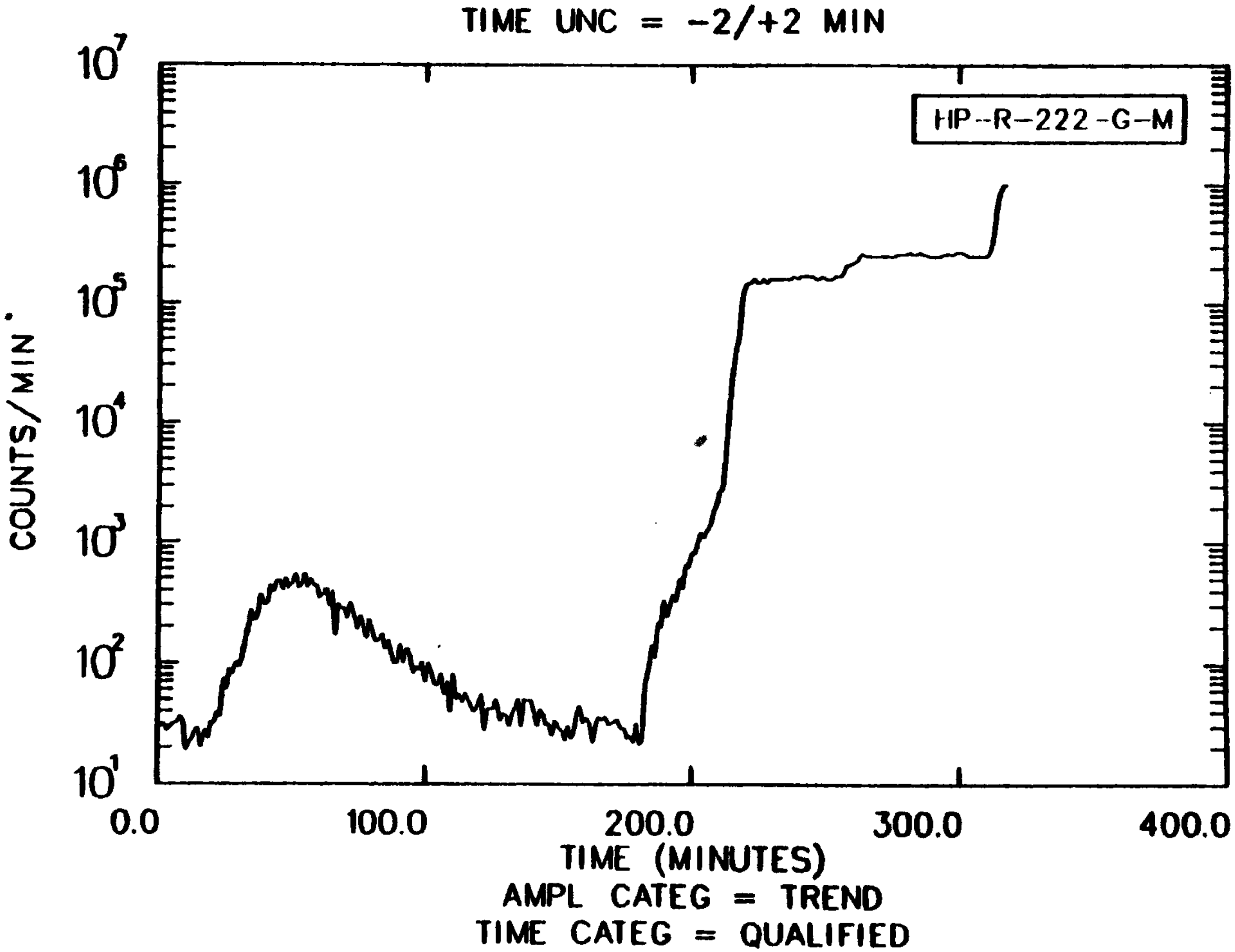

TIME UNC = -5/+5 MIN
DC-R-3400-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
200.0
400.0
600.0
800.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

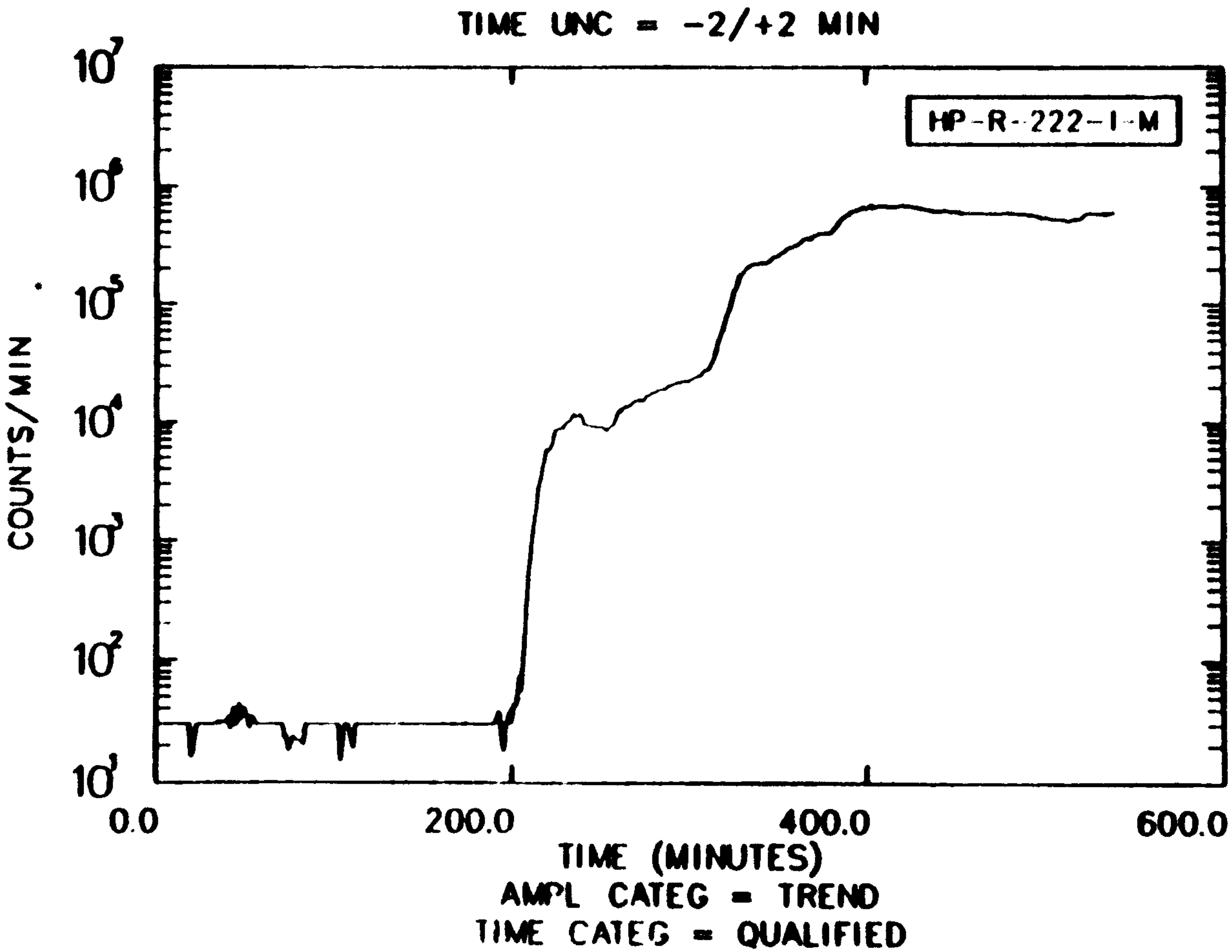
TIME UNC = -10/+10 MIN

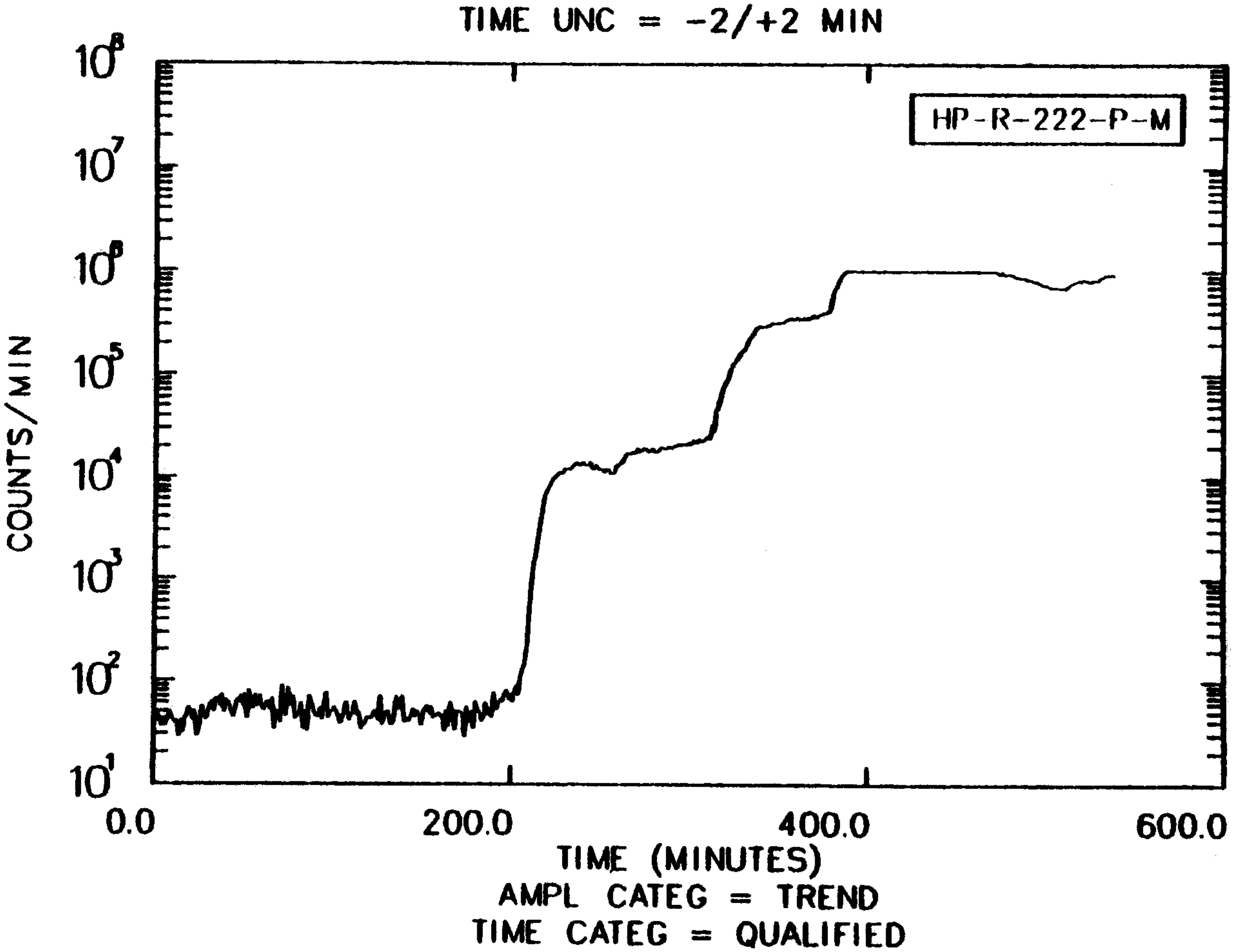


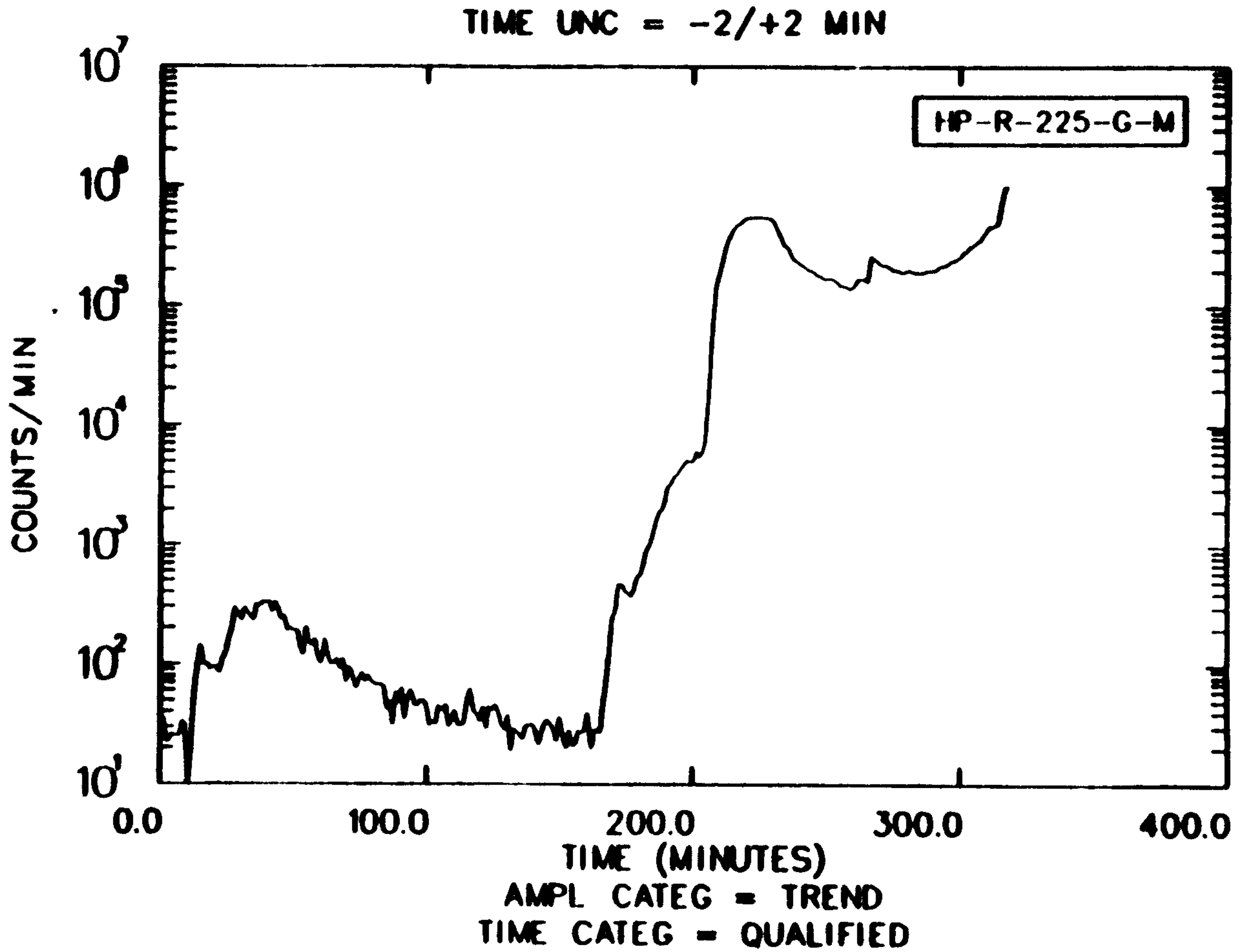
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

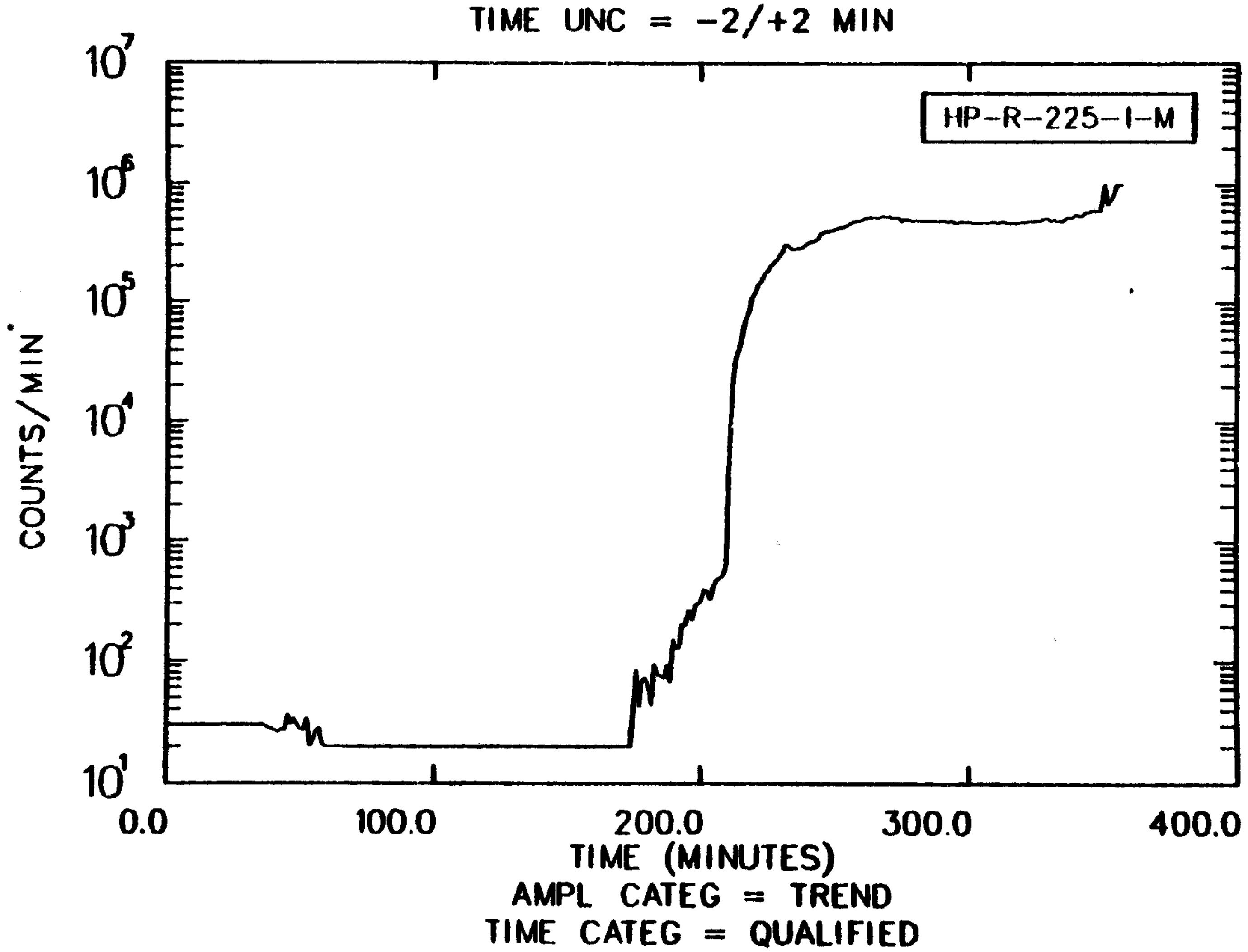

TIME UNC = -2/+2 MIN
HP-R-219-G-M
COUNTS/MIN
10^1
10^2
10^3
10^4
10^5
10^6
10^7
0.0
100.0
200.0
300.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

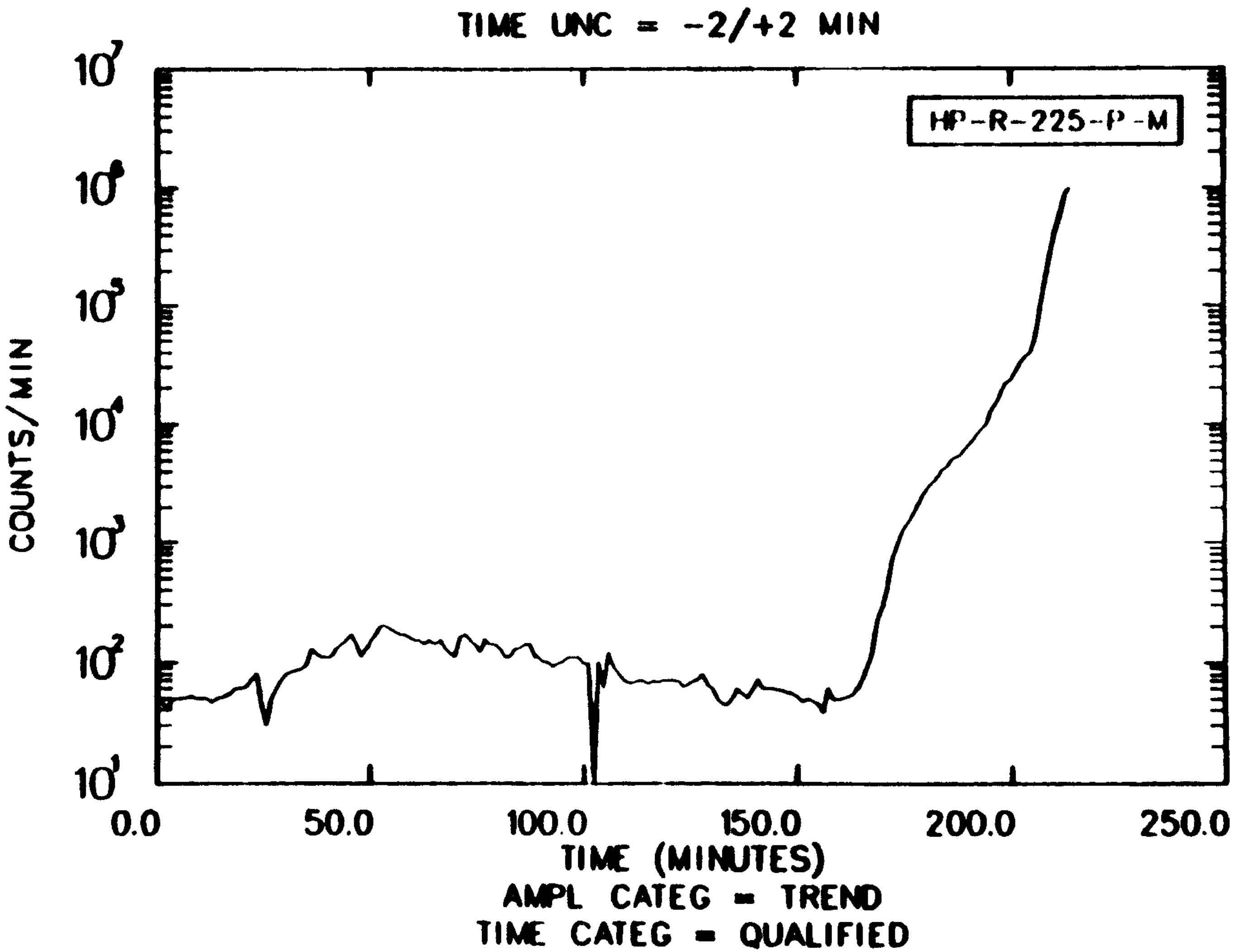

TIME UNC = -2/+2 MIN
HP--R-222-G-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

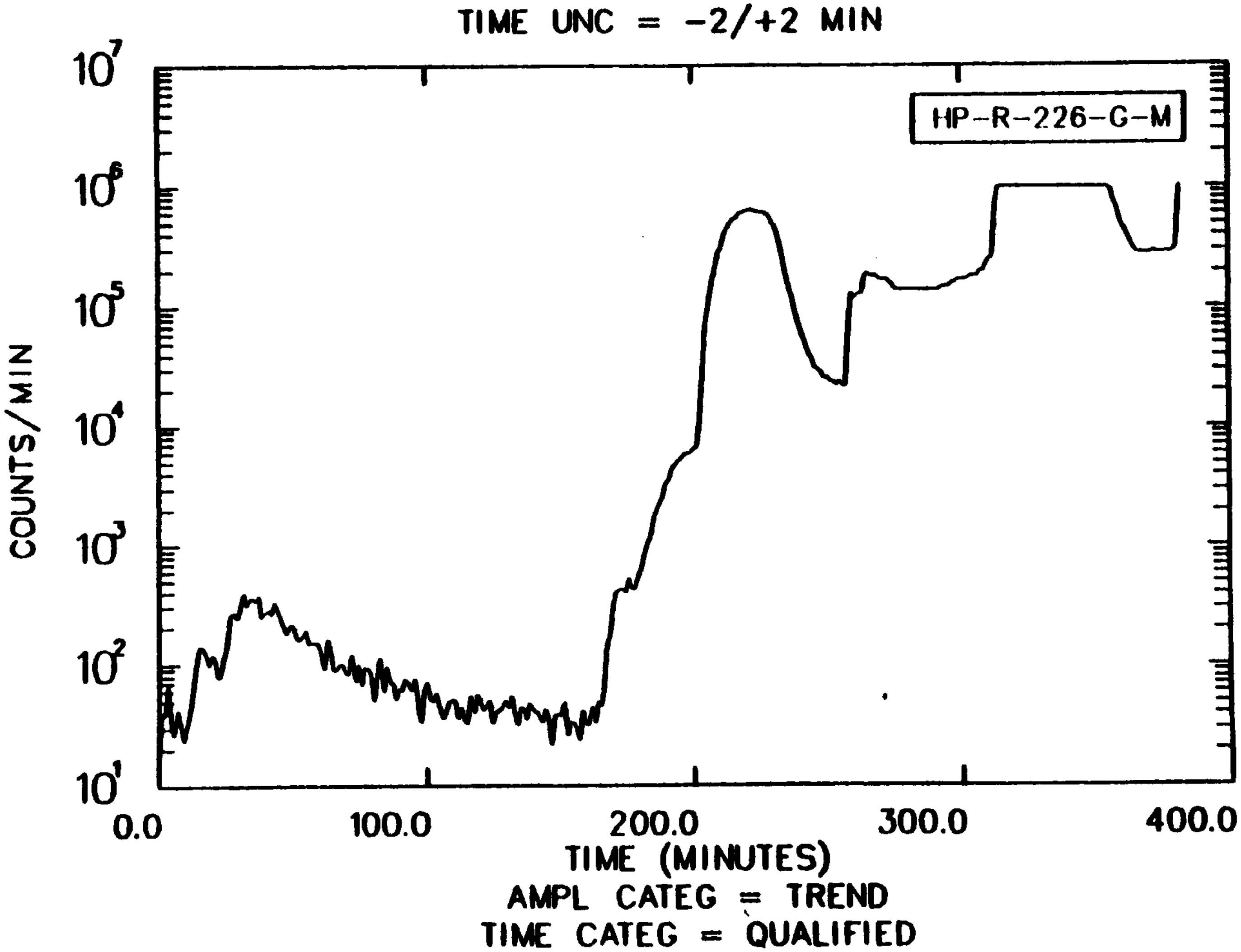

TIME UNC = -2/+2 MIN
HP-R-222-I-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
200.0
400.0
600.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

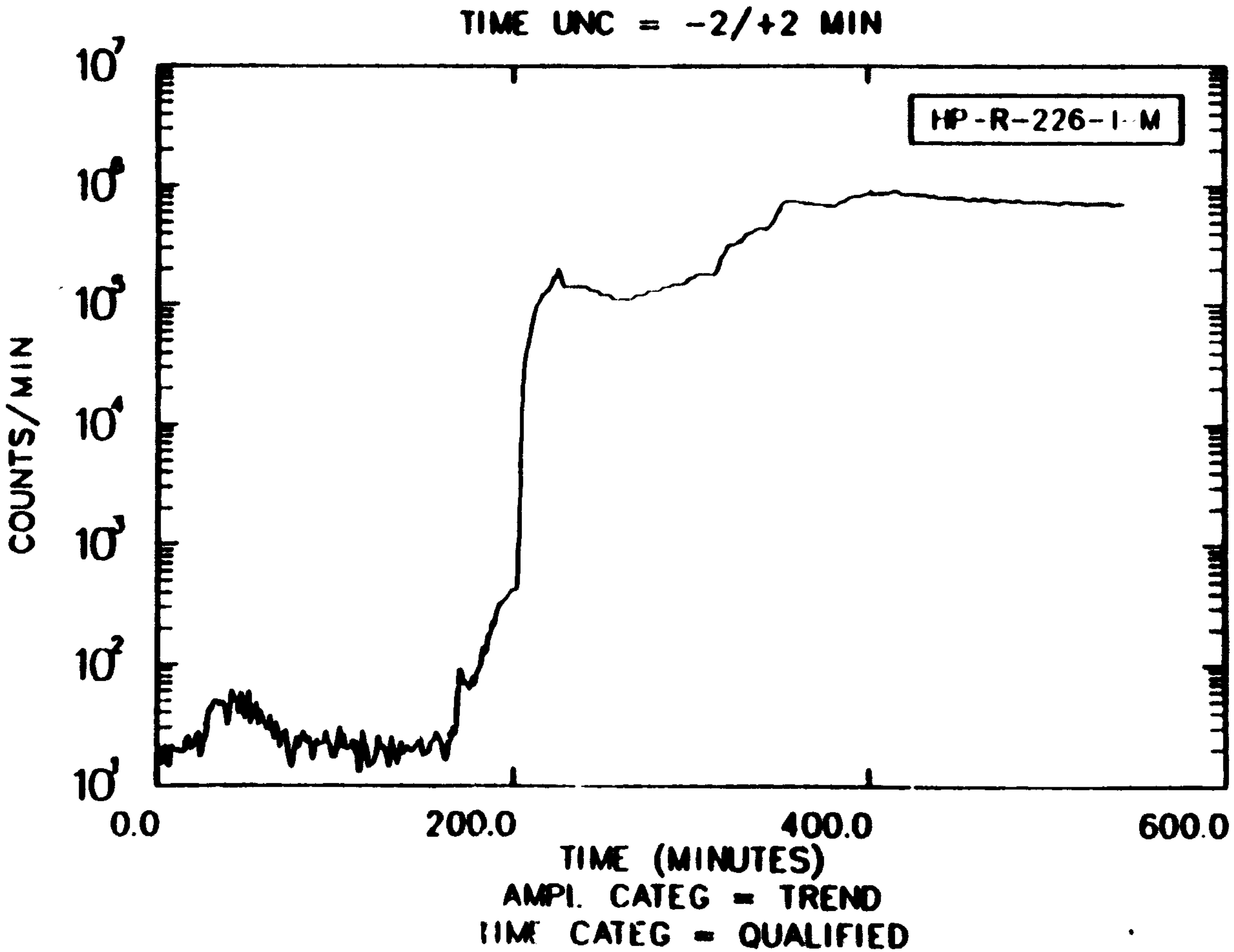

TIME UNC = -2/+2 MIN
HP-R-222-P-M
COUNTS/MIN
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
0.0
200.0
400.0
600.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

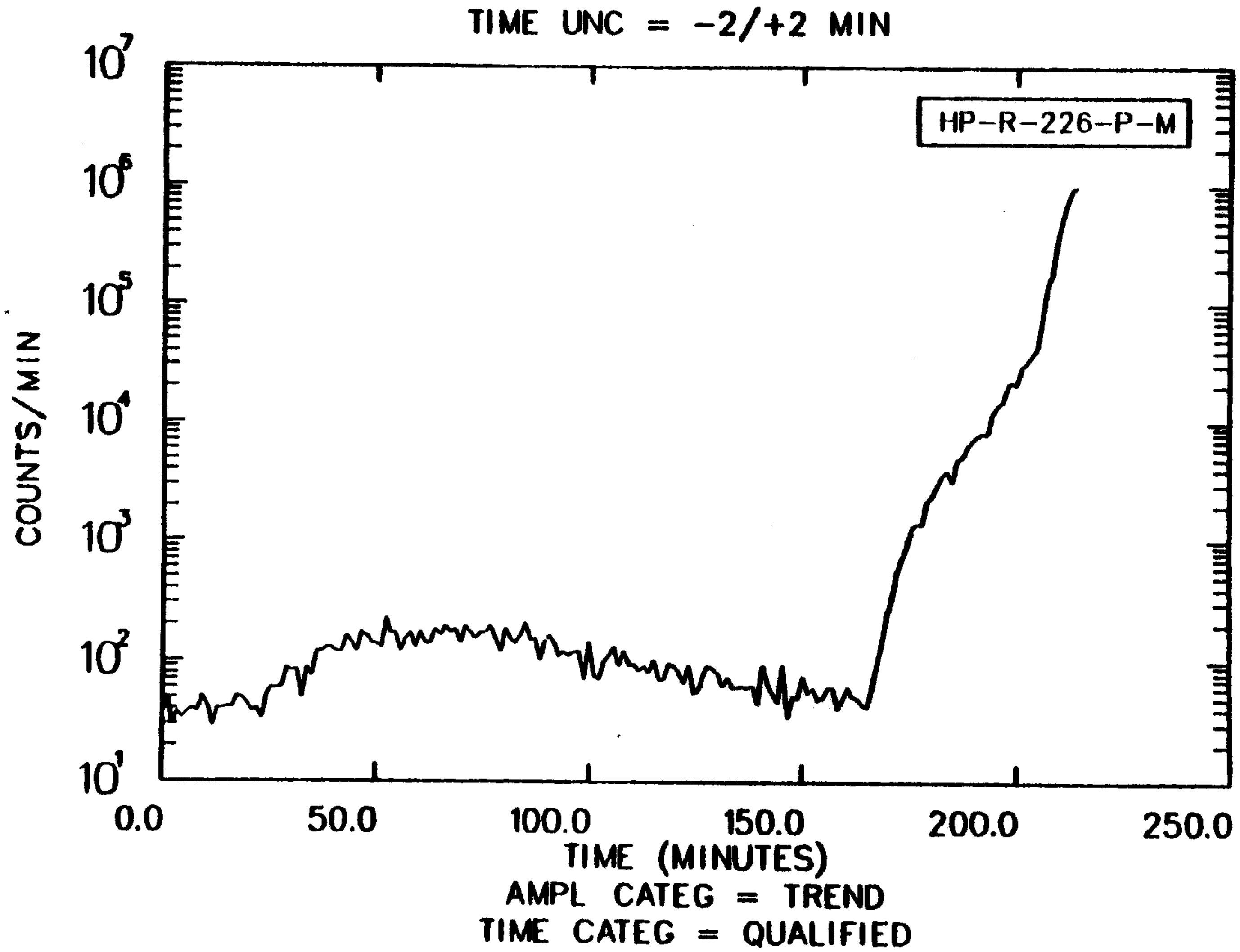

TIME UNC = -2/+2 MIN
HP-R-225-G-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

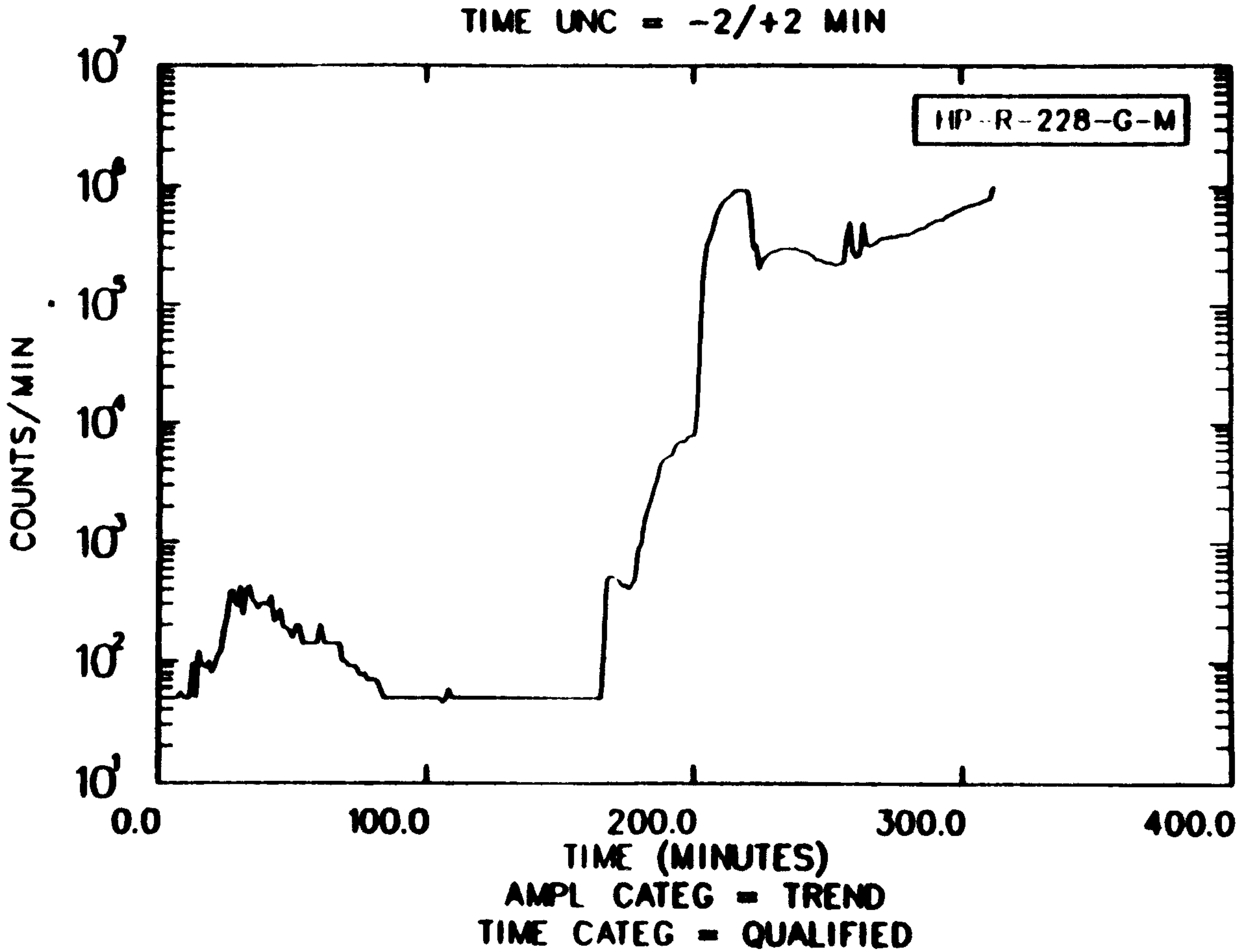

TIME UNC = -2/+2 MIN
HP-R-225-I-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = -2/+2 MIN
HP-R-225-P-M
COUNTS/MIN
10^1
10^2
10^3
10^4
10^5
10^6
10^7
0.0
50.0
100.0
150.0
200.0
250.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

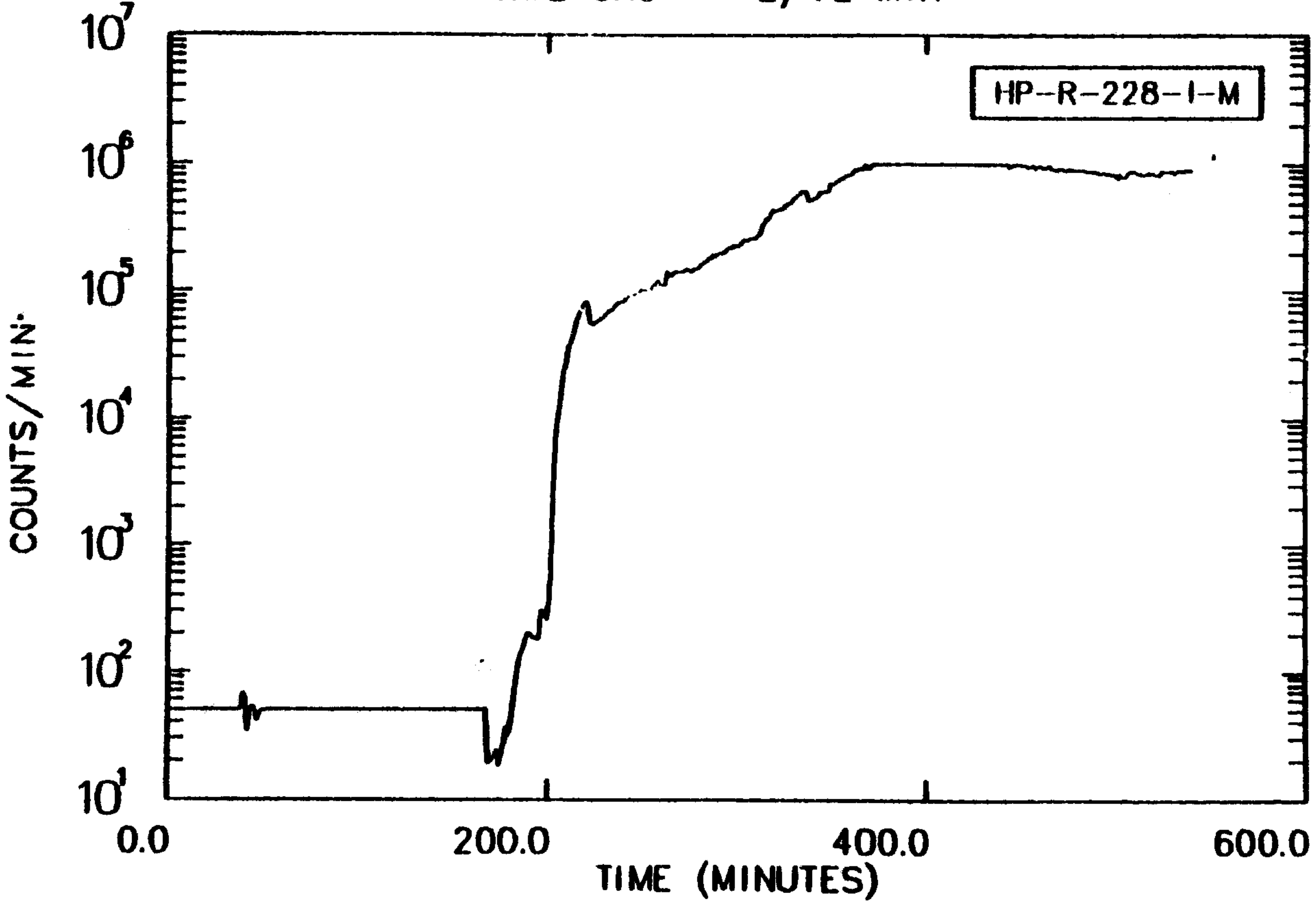

TIME UNC = -2/+2 MIN
HP-R-226-G-M
COUNTS/MIN
10^1
10^2
10^3
10^4
10^5
10^6
10^7
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = -2/+2 MIN
HP-R-226-I-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
200.0
400.0
600.0
TIME (MINUTES)
AMPL. CATEG = TREND
TIME CATEG = QUALIFIED

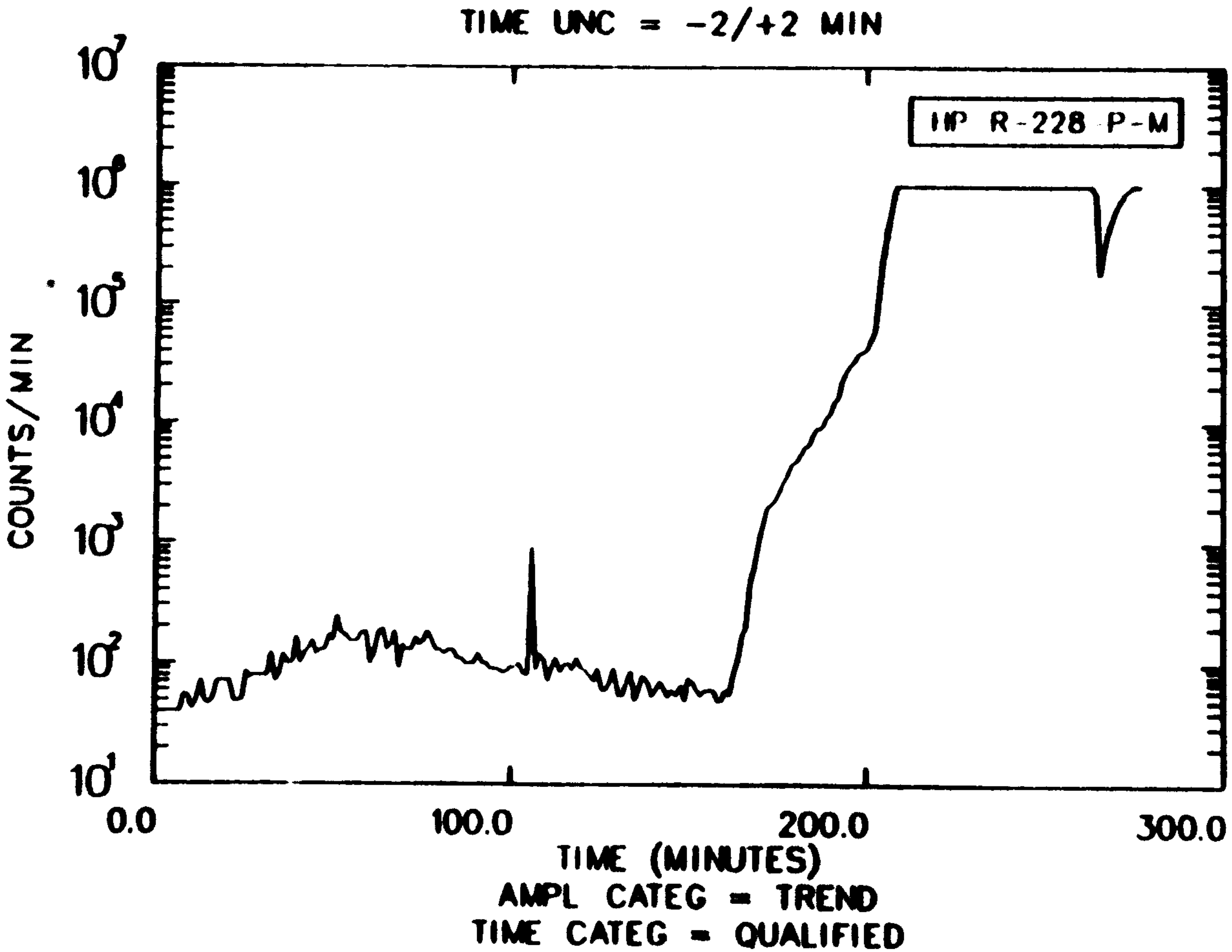

TIME UNC = -2/+2 MIN
HP-R-226-P-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
50.0
100.0
150.0
200.0
250.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

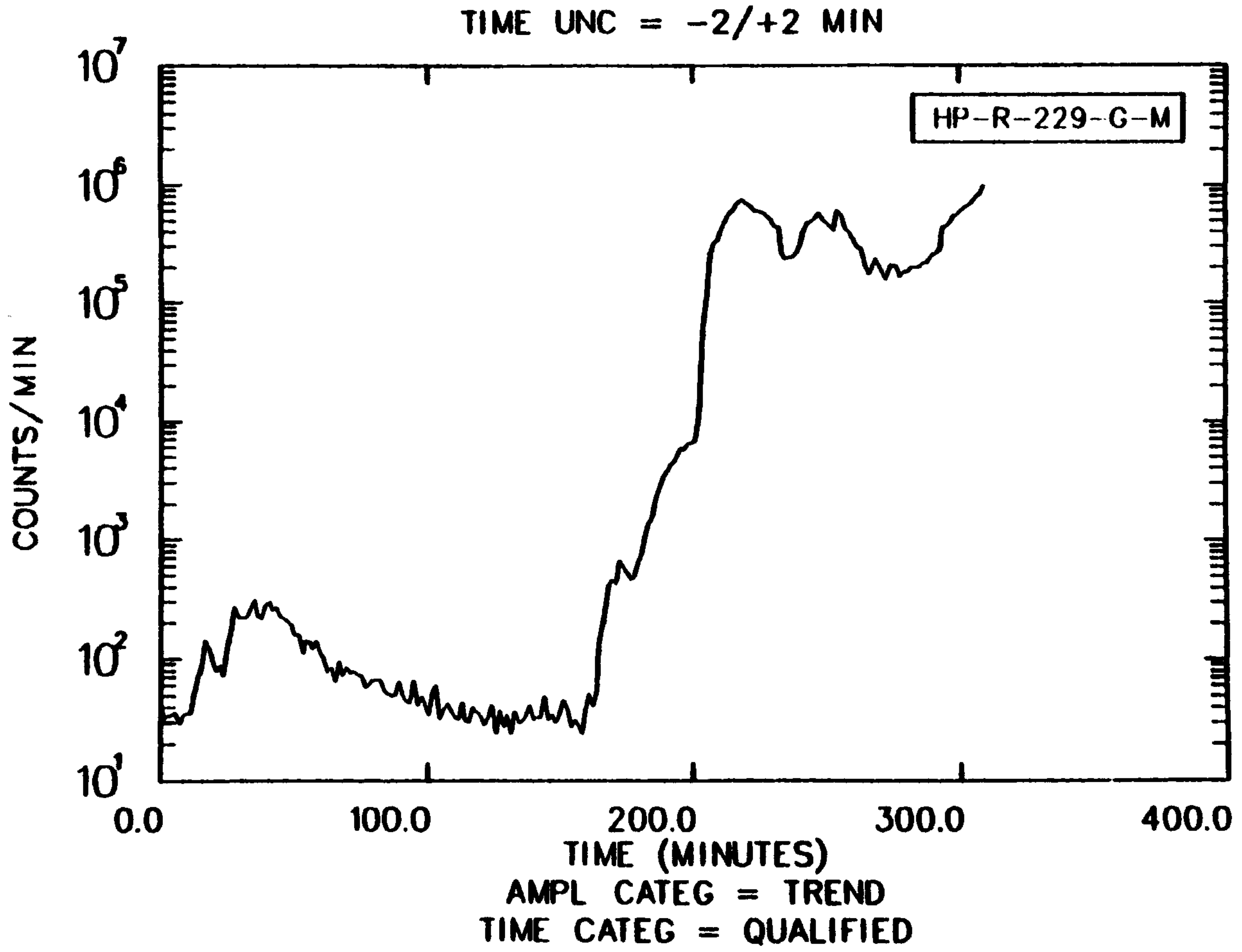

TIME UNC = -2/+2 MIN
HP-R-228-G-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

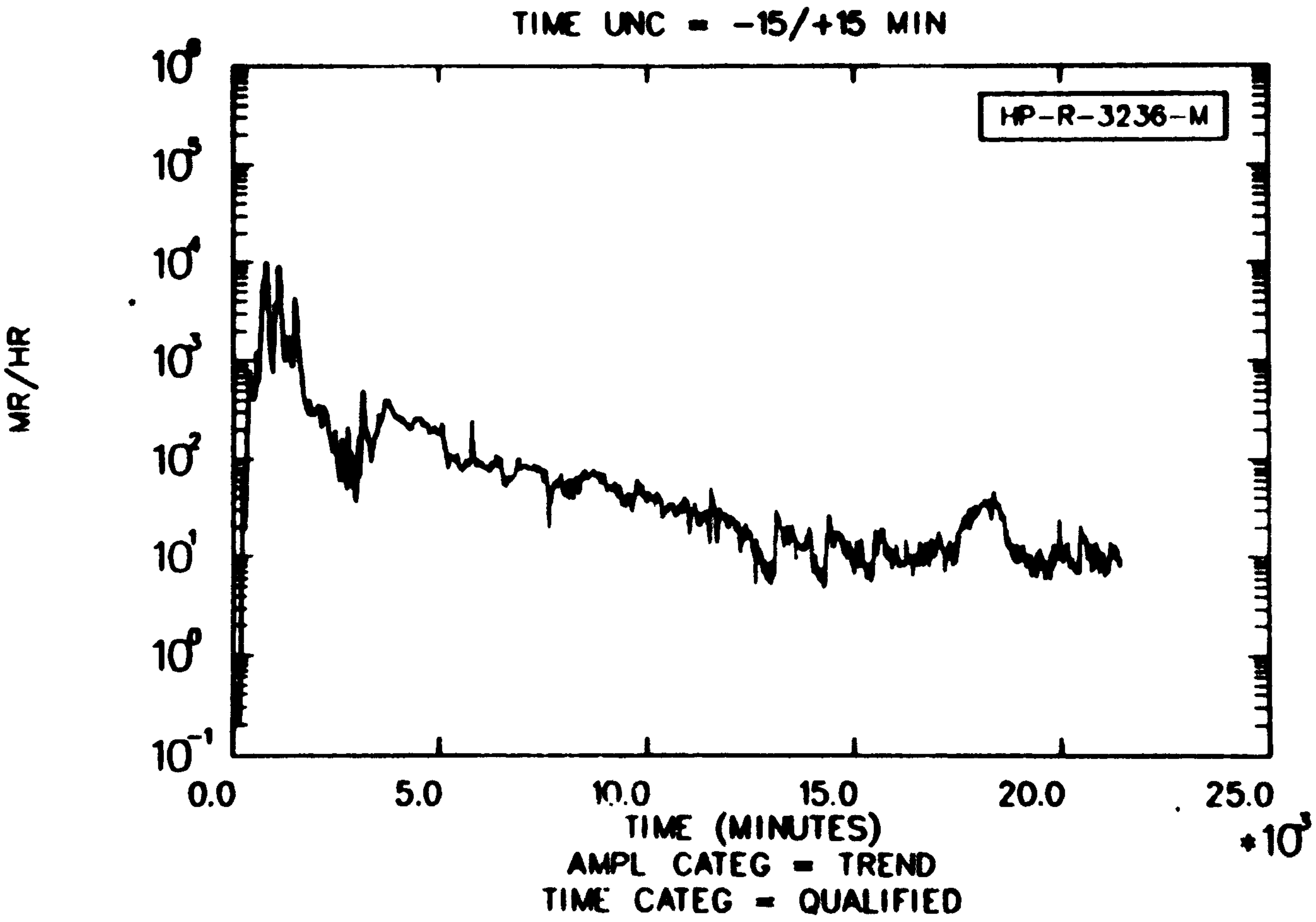
TIME UNC = -2/+2 MIN

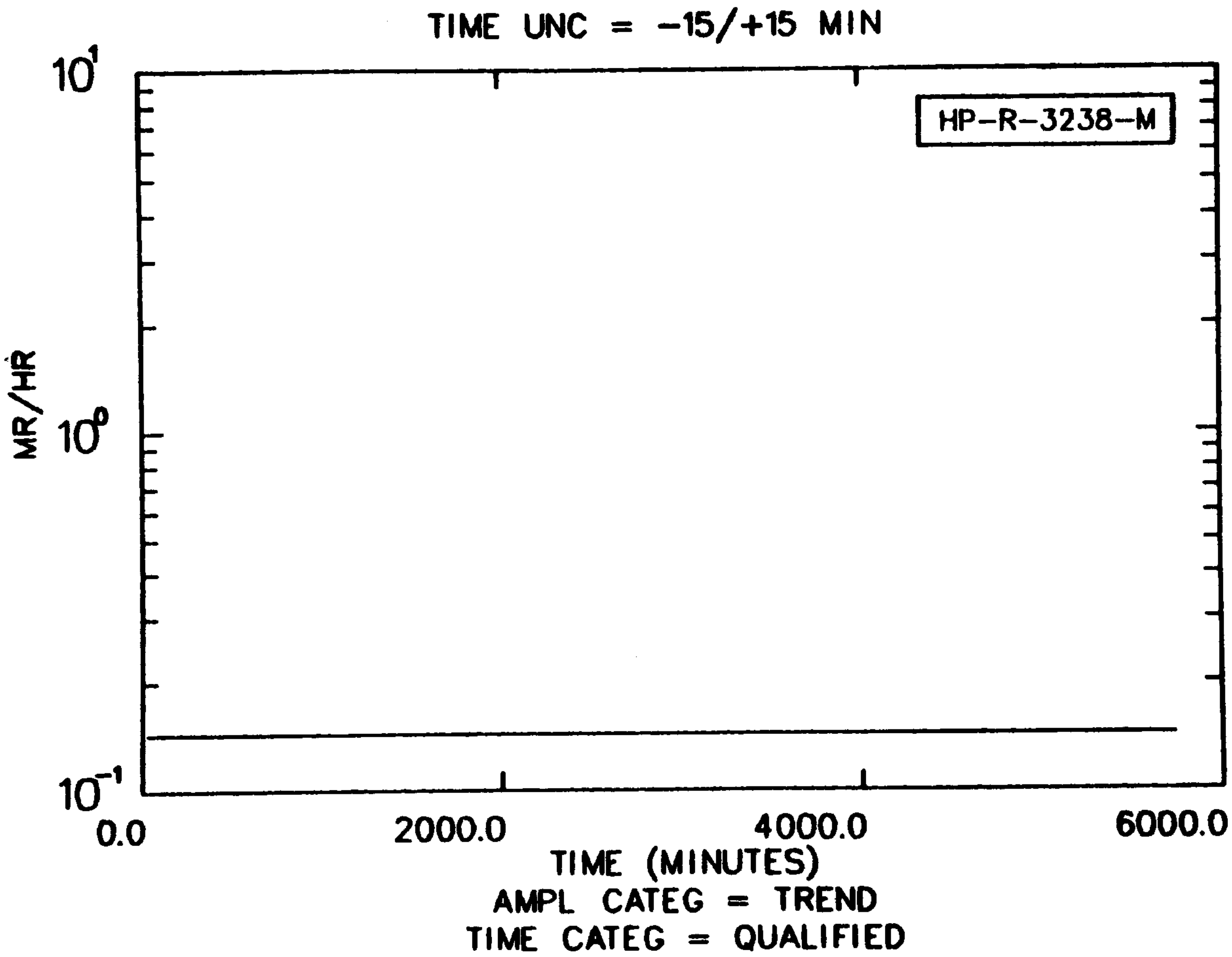


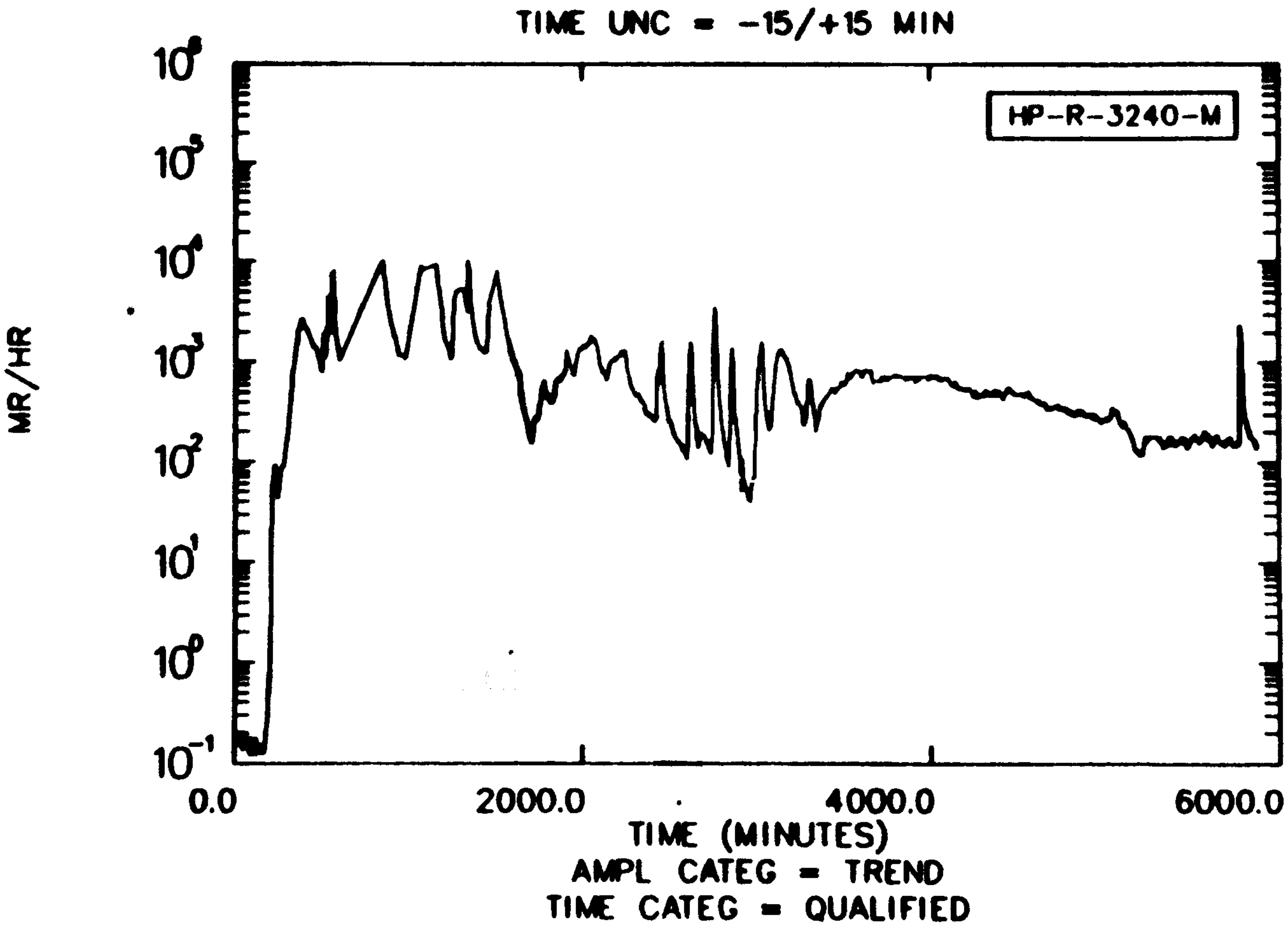
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

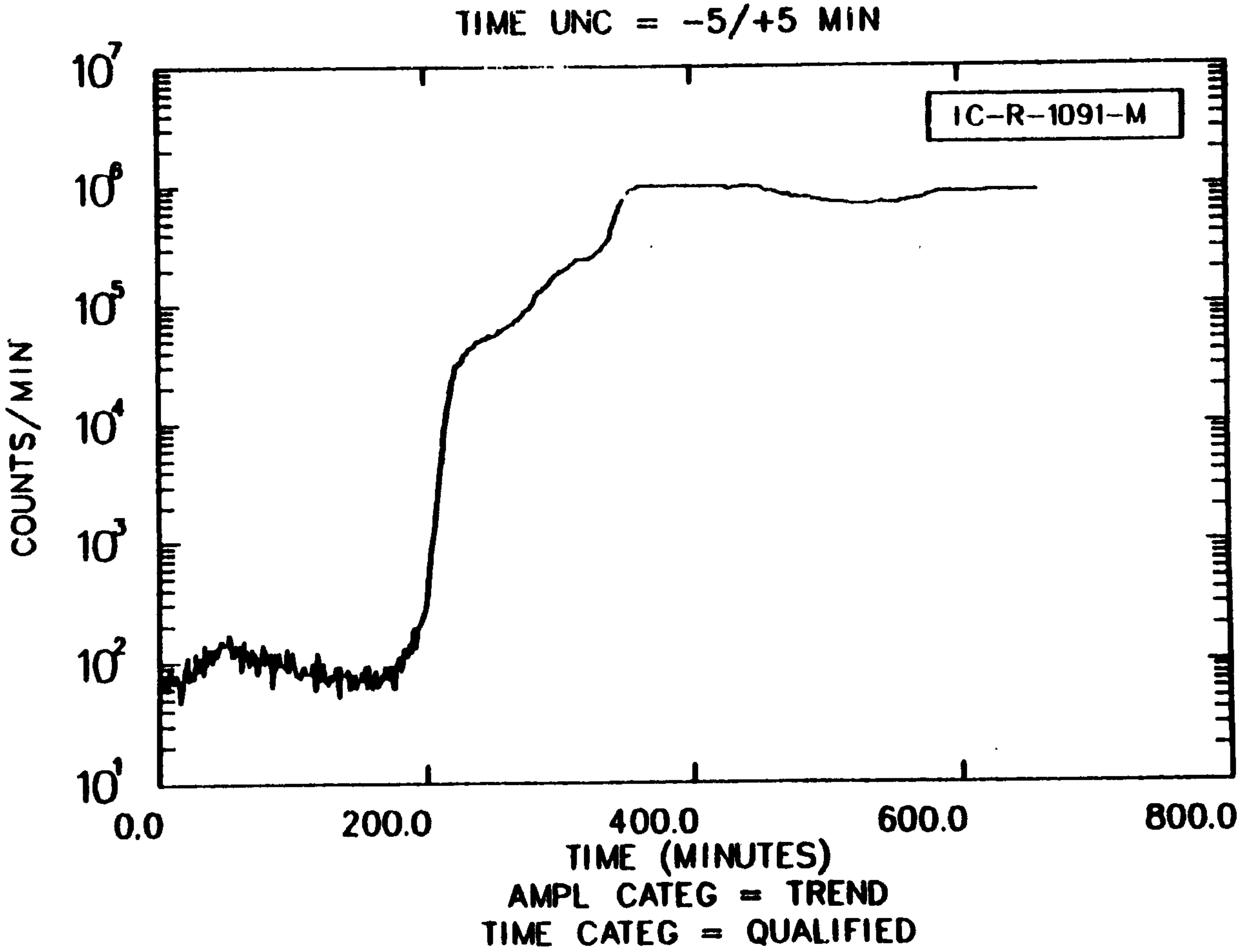

TIME UNC = -2/+2 MIN
IIP R-228 P-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

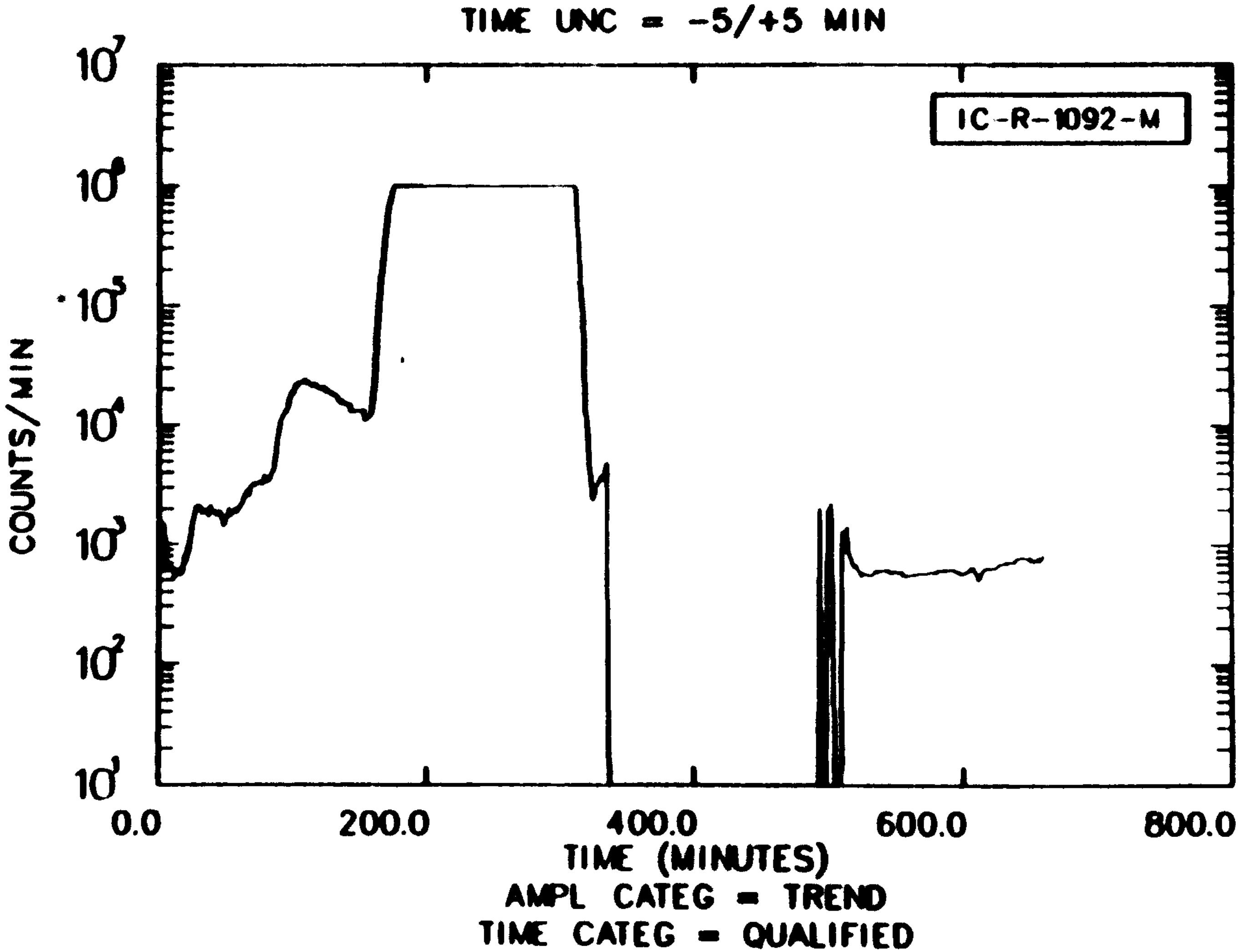

TIME UNC = -2/+2 MIN
HP-R-229-G-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = -15/+15 MIN
HP-R-3236-M
MR/HR
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0.0
5.0
10.0
15.0
20.0
25.0
$*10^{3}$
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

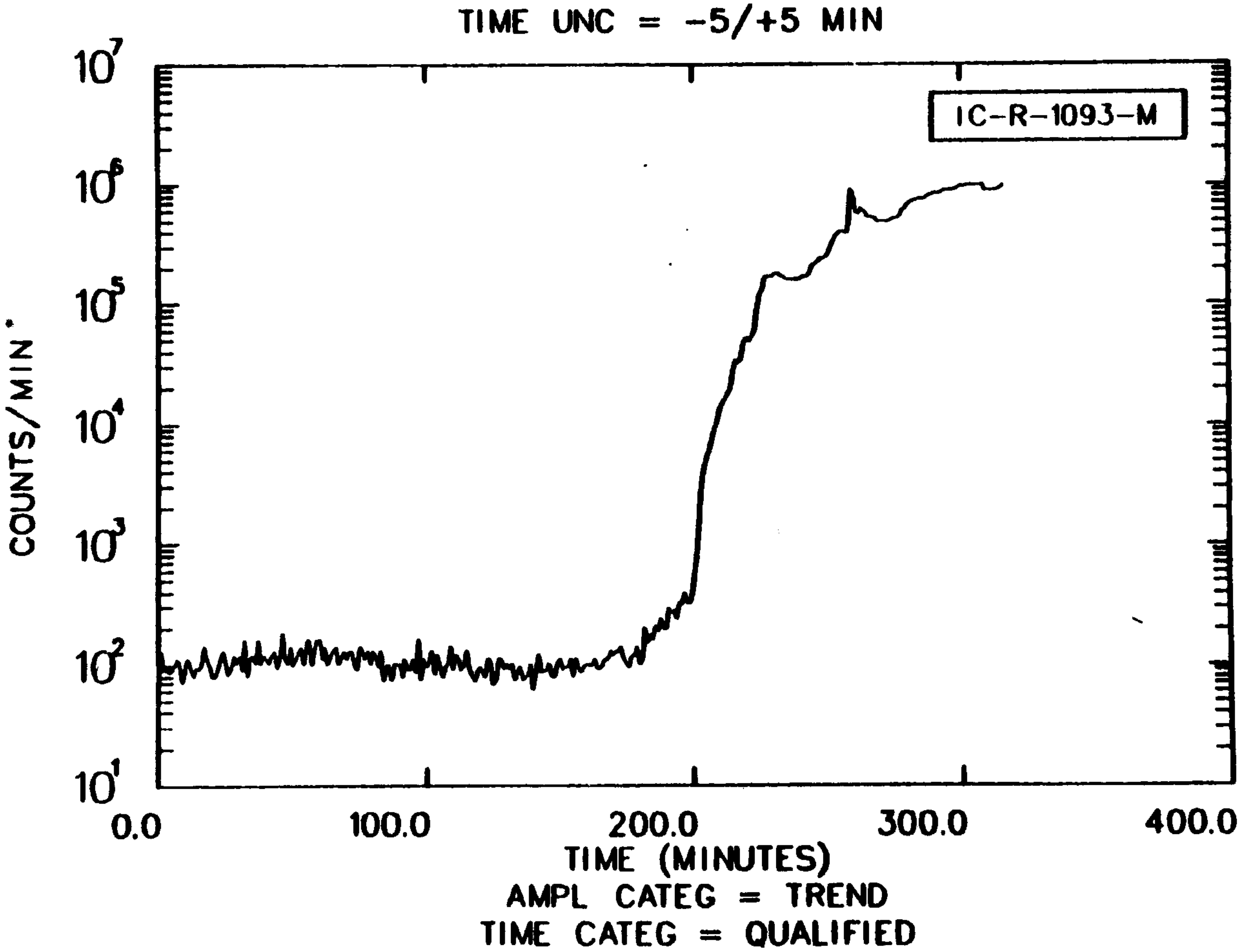

TIME UNC = −15/+15 MIN
HP-R-3238-M
MR/HR
10^1
10^0
10^{-1}
0.0
2000.0
4000.0
6000.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = -15/+15 MIN
HP-R-3240-M
MR/HR
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
0.0
2000.0
4000.0
6000.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

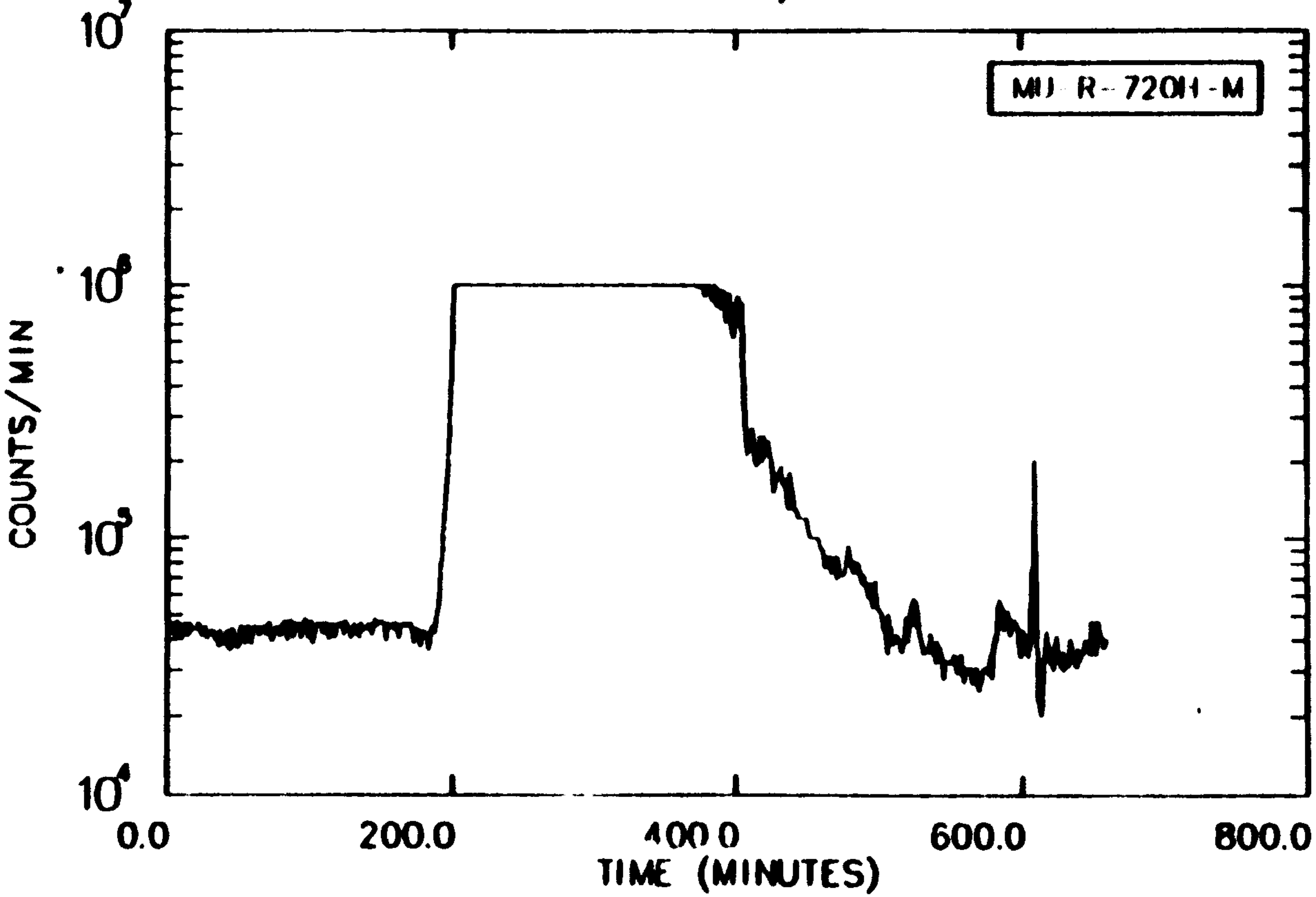

TIME UNC = -5/+5 MIN
IC-R-1091-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
200.0
400.0
600.0
800.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED



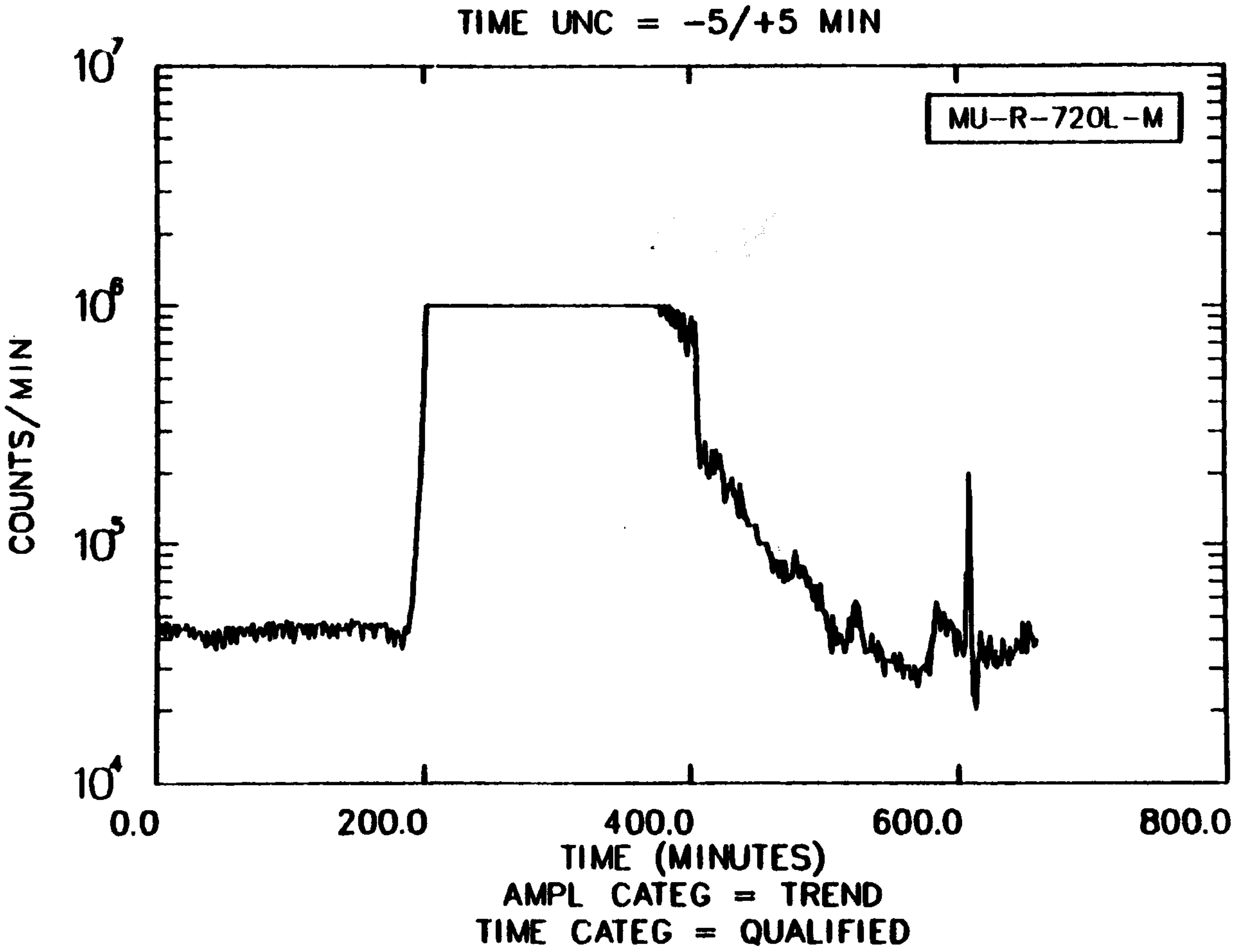
TIME UNC = -5/+5 MIN
IC-R-1092-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
200.0
400.0
600.0
800.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

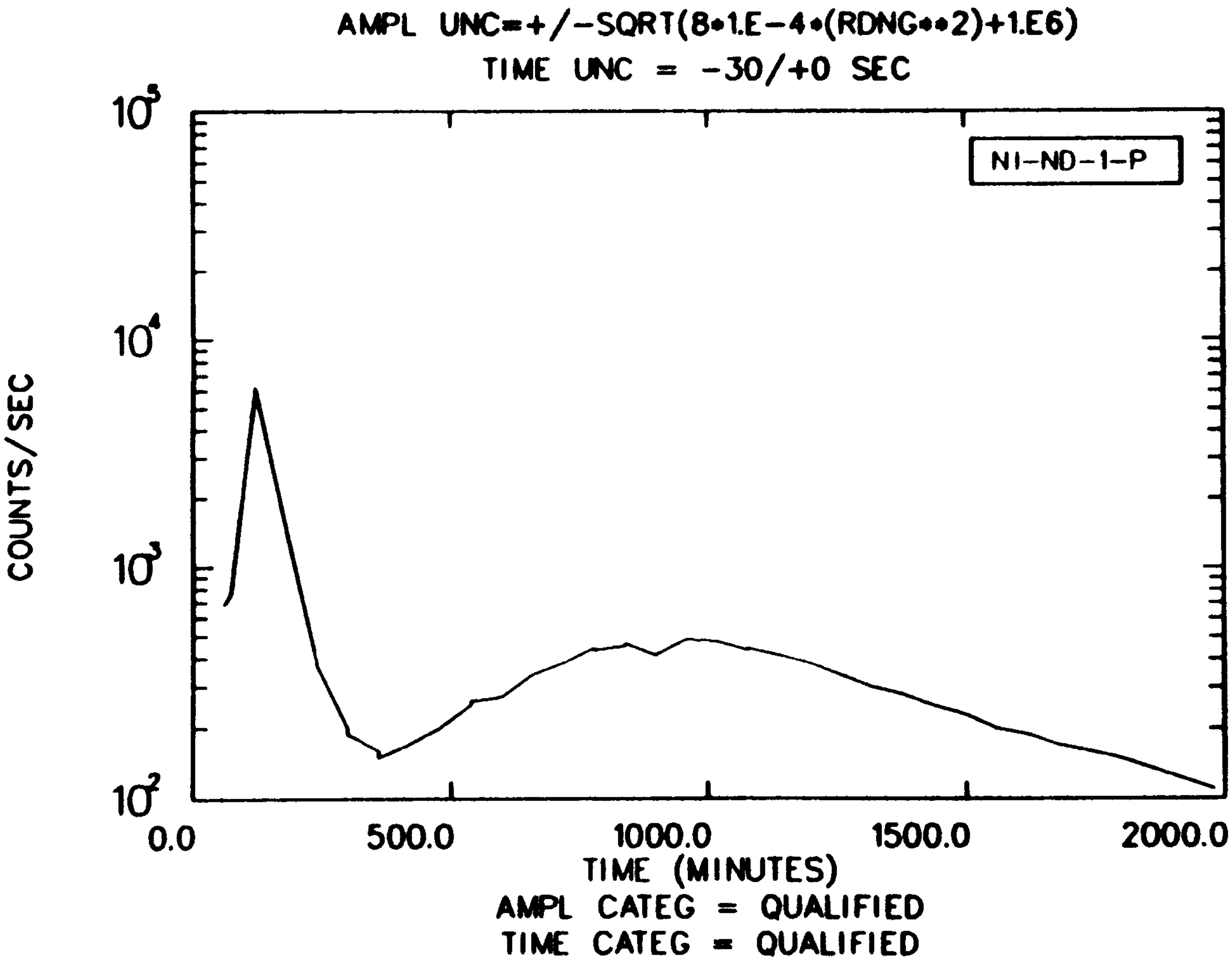

TIME UNC = -5/+5 MIN
IC-R-1093-M
COUNTS/MIN
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

TIME UNC = -5/+5 MIN

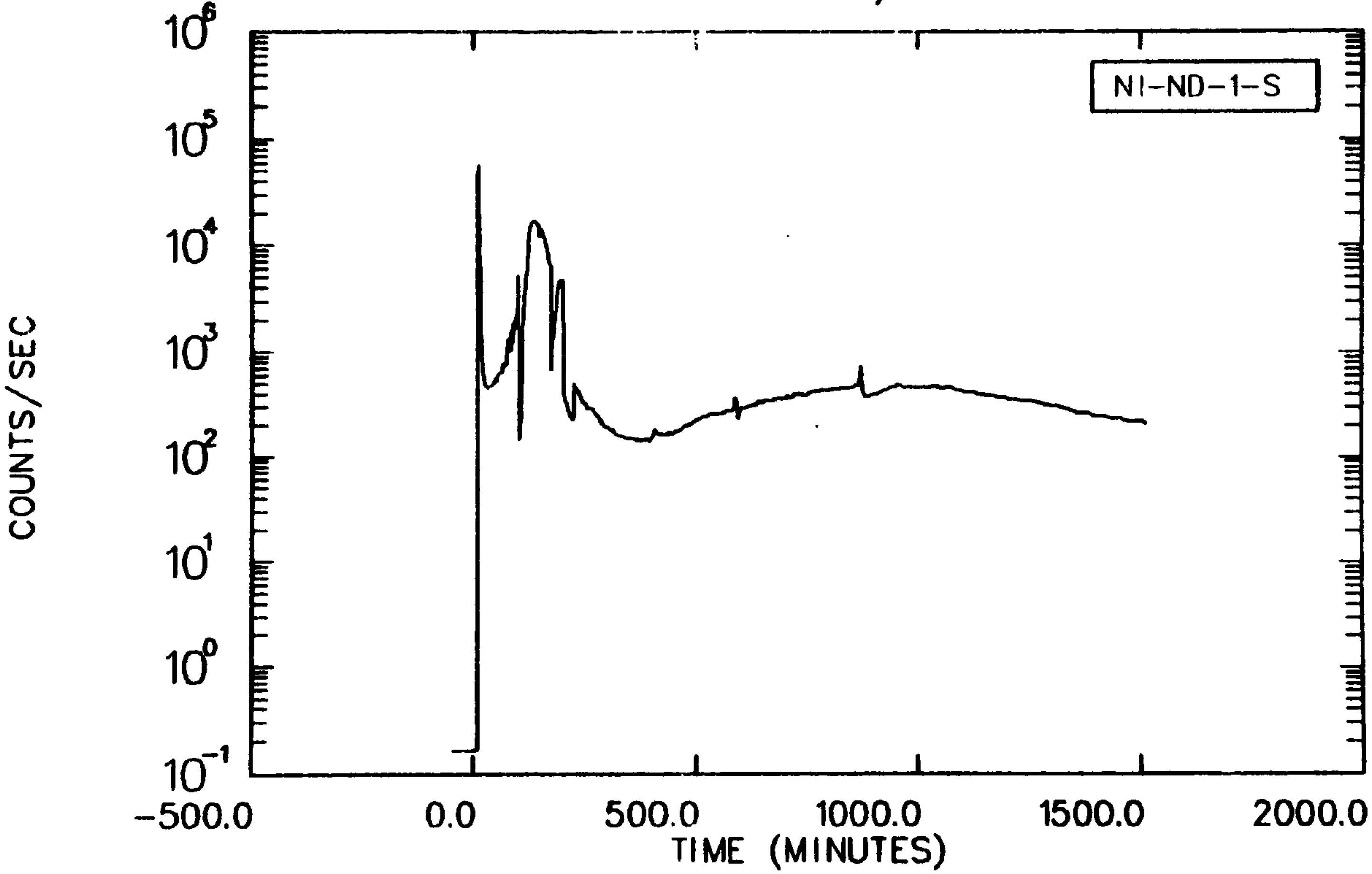


AMPL CATEG = TREND
TIME CATEG = QUALIFIED

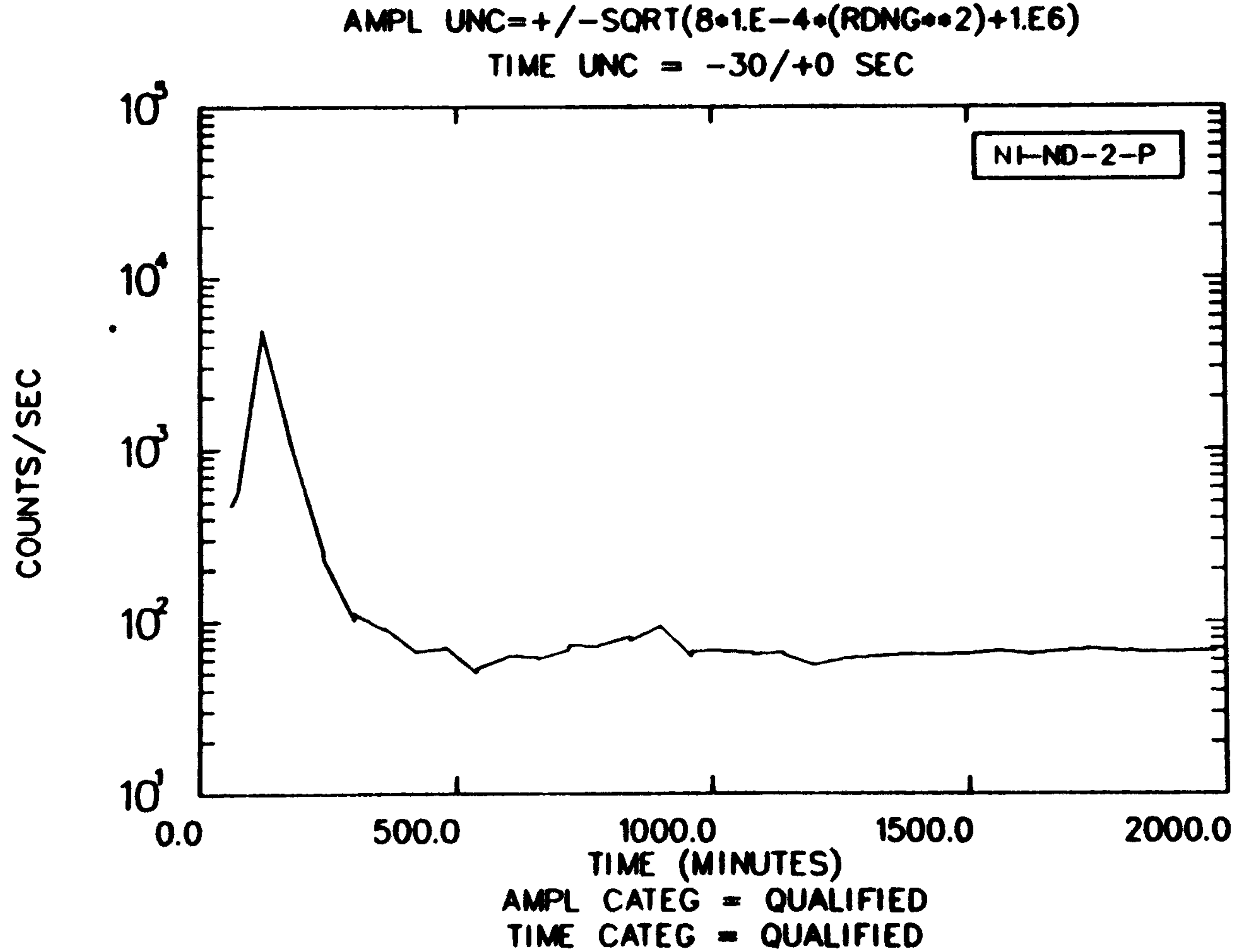

TIME UNC = -5/+5 MIN
MU-R-720L-M
COUNTS/MIN
10^7
10^6
10^5
10^4
0.0
200.0
400.0
600.0
800.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

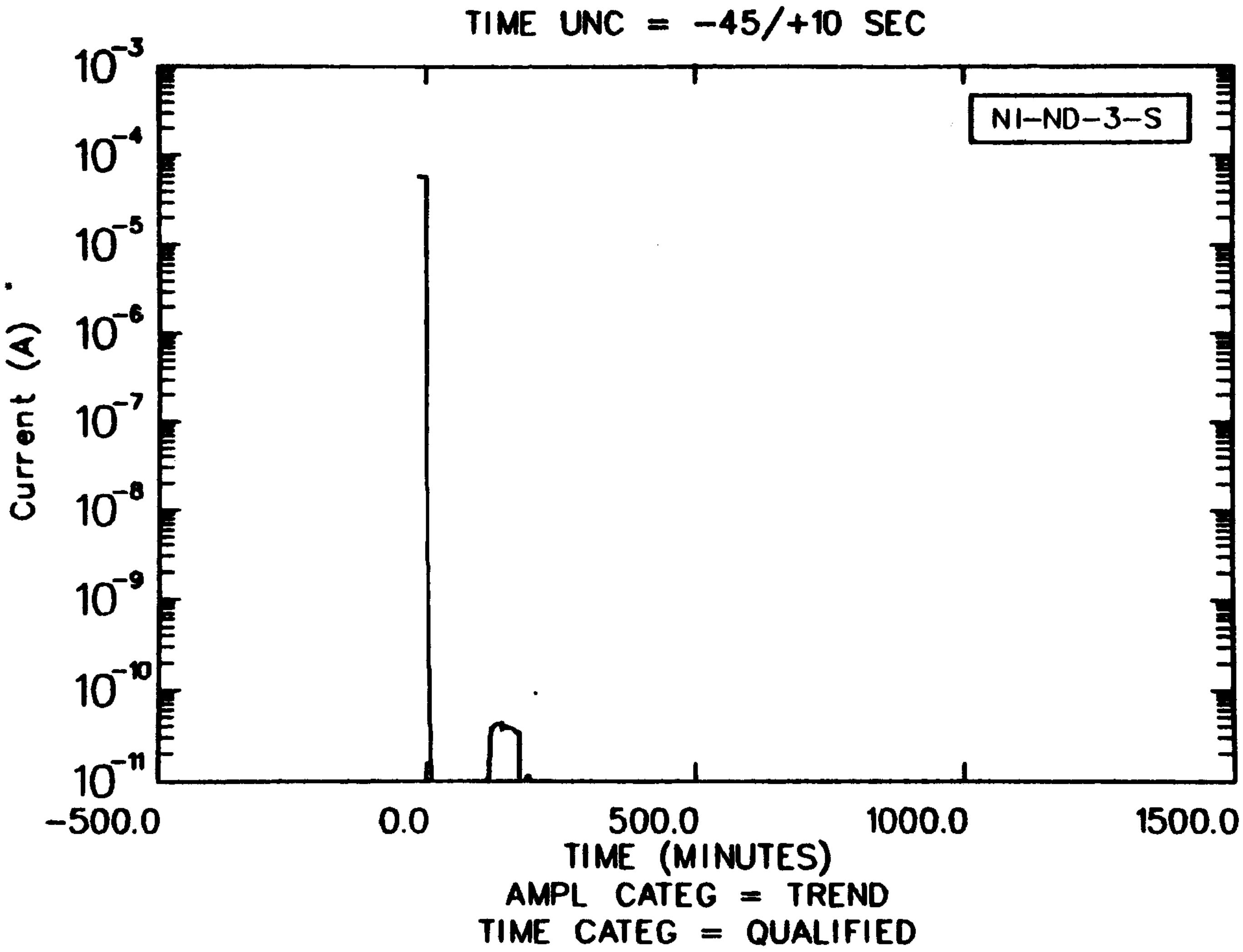

AMPL UNC=+/-SQRT(8*1.E-4*(RDNG**2)+1.E6)
TIME UNC = -30/+0 SEC
NI-ND-1-P
COUNTS/SEC
10^5
10^4
10^3
10^2
0.0
500.0
1000.0
1500.0
2000.0
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

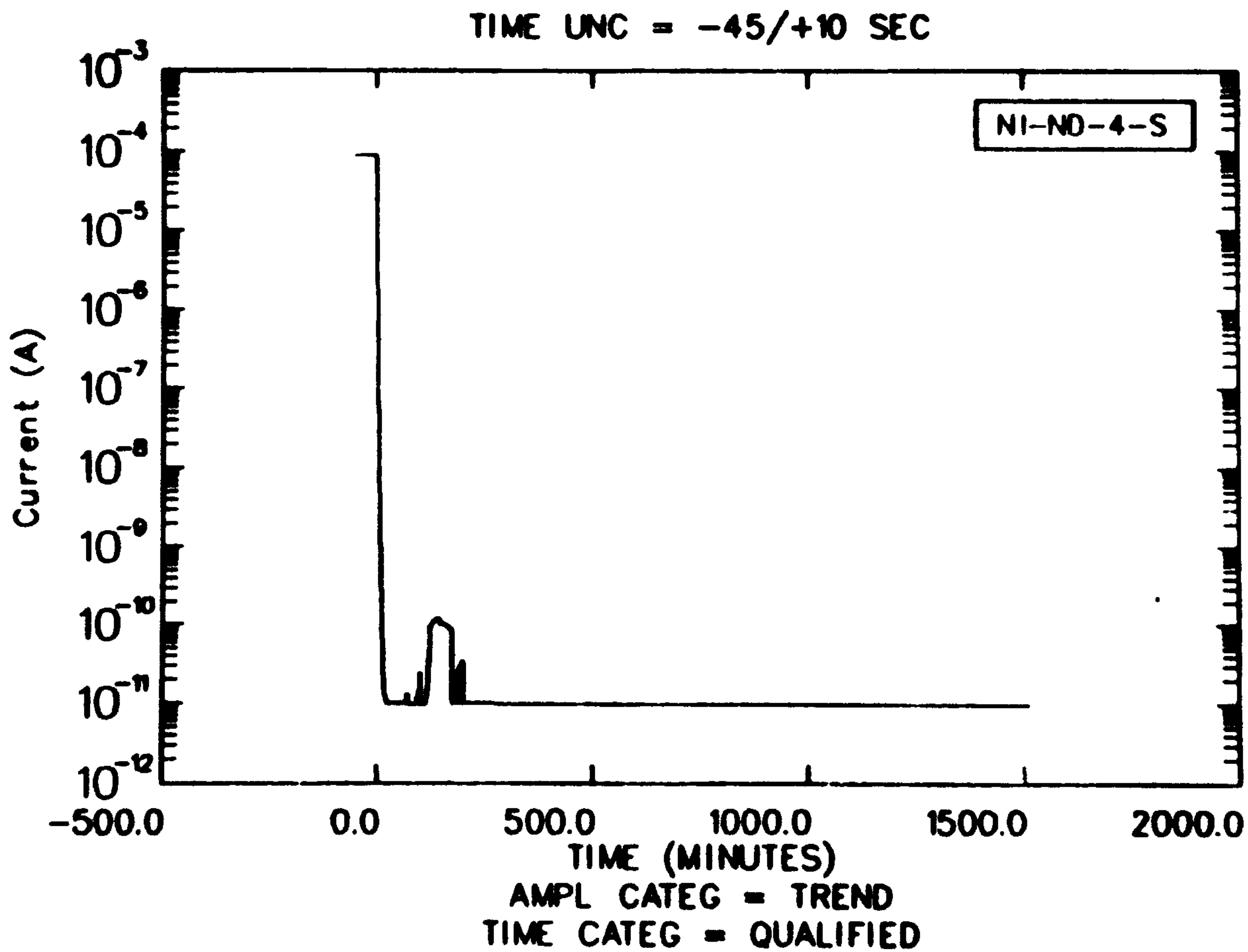
AMPL UNC=+/-SQRT(8*1.E-4*(RDNG**2)+1.E6)
TIME UNC = -45/+10 SEC



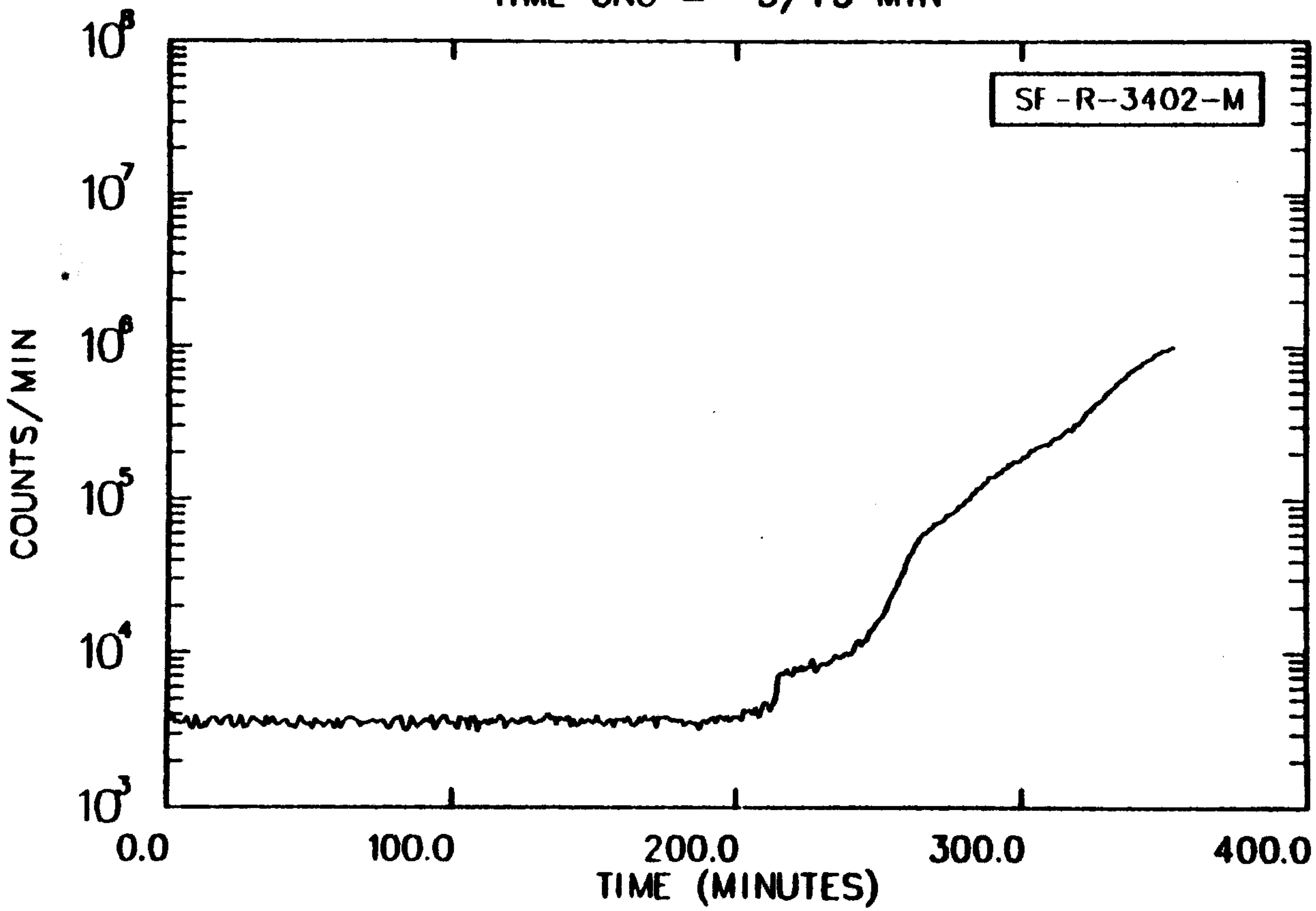
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC=+/-SQRT(8*1.E-4*(RDNG**2)+1.E6)
TIME UNC = -30/+0 SEC
NI-ND-2-P
COUNTS/SEC
10^5
10^4
10^3
10^2
10^1
0.0
500.0
1000.0
1500.0
2000.0
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

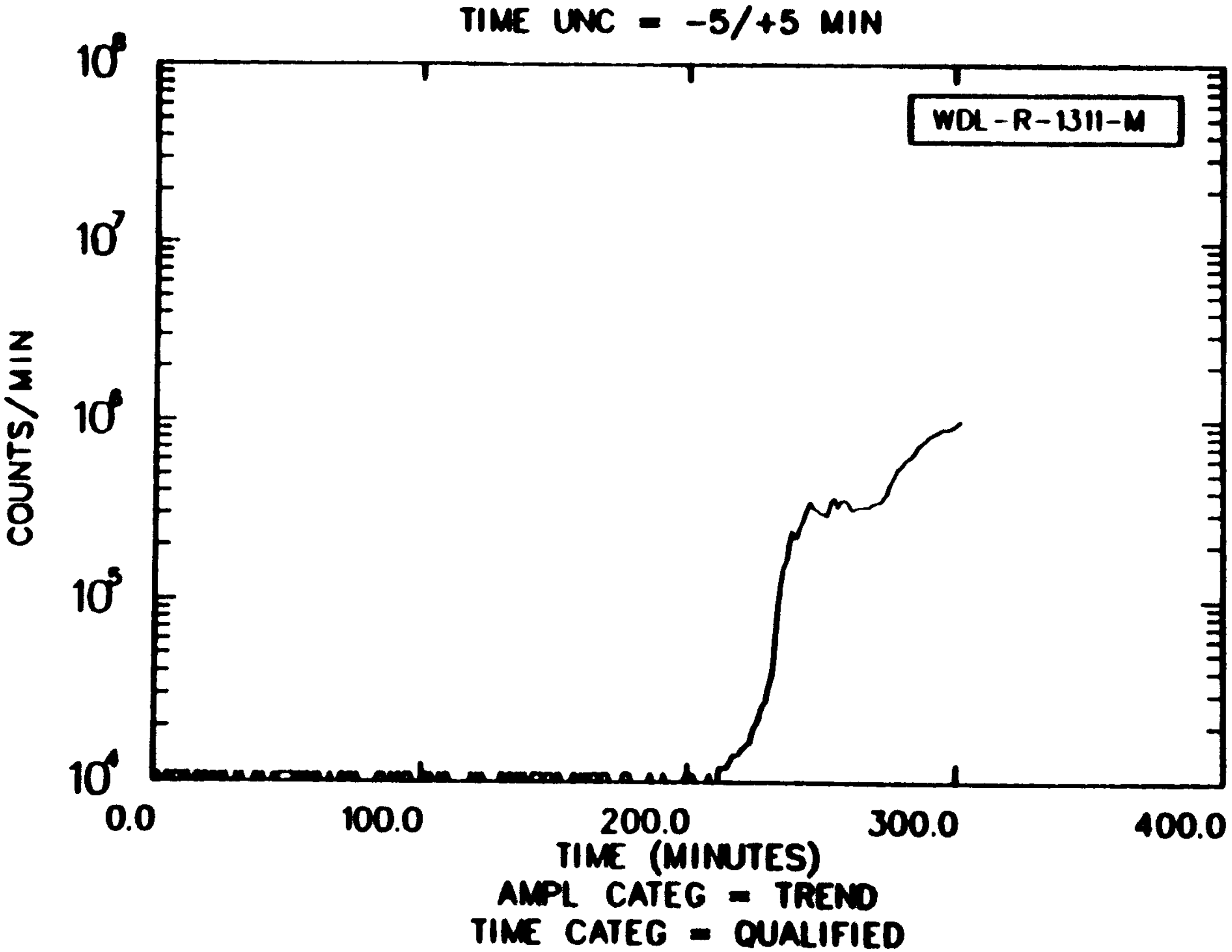

TIME UNC = −45/+10 SEC
NI−ND−3−S
Current (A)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
−500.0
0.0
500.0
1000.0
1500.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

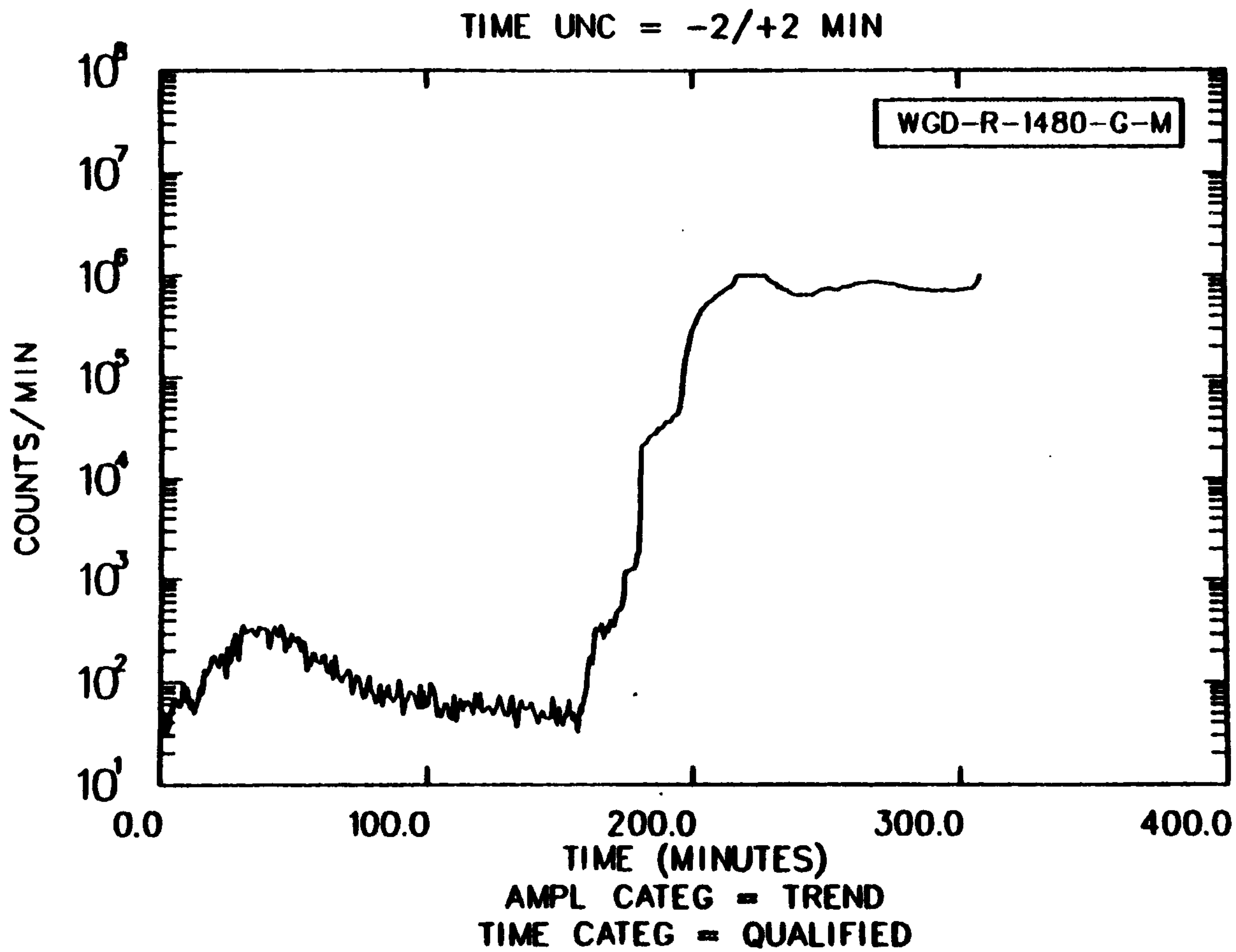

TIME UNC = -45/+10 SEC
NI-ND-4-S
Current (A)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
-500.0
0.0
500.0
1000.0
1500.0
2000.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

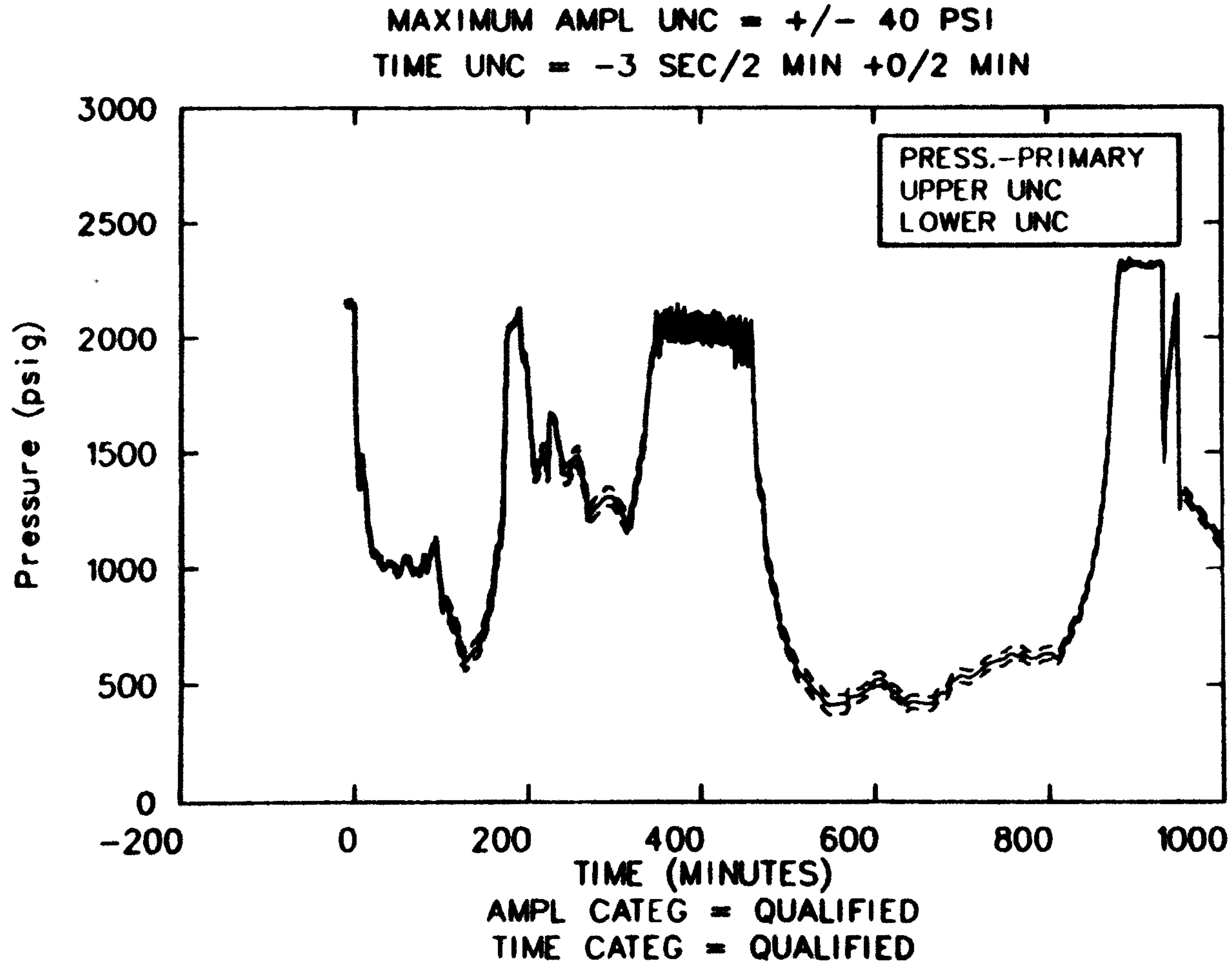
TIME UNC = -5/+5 MIN

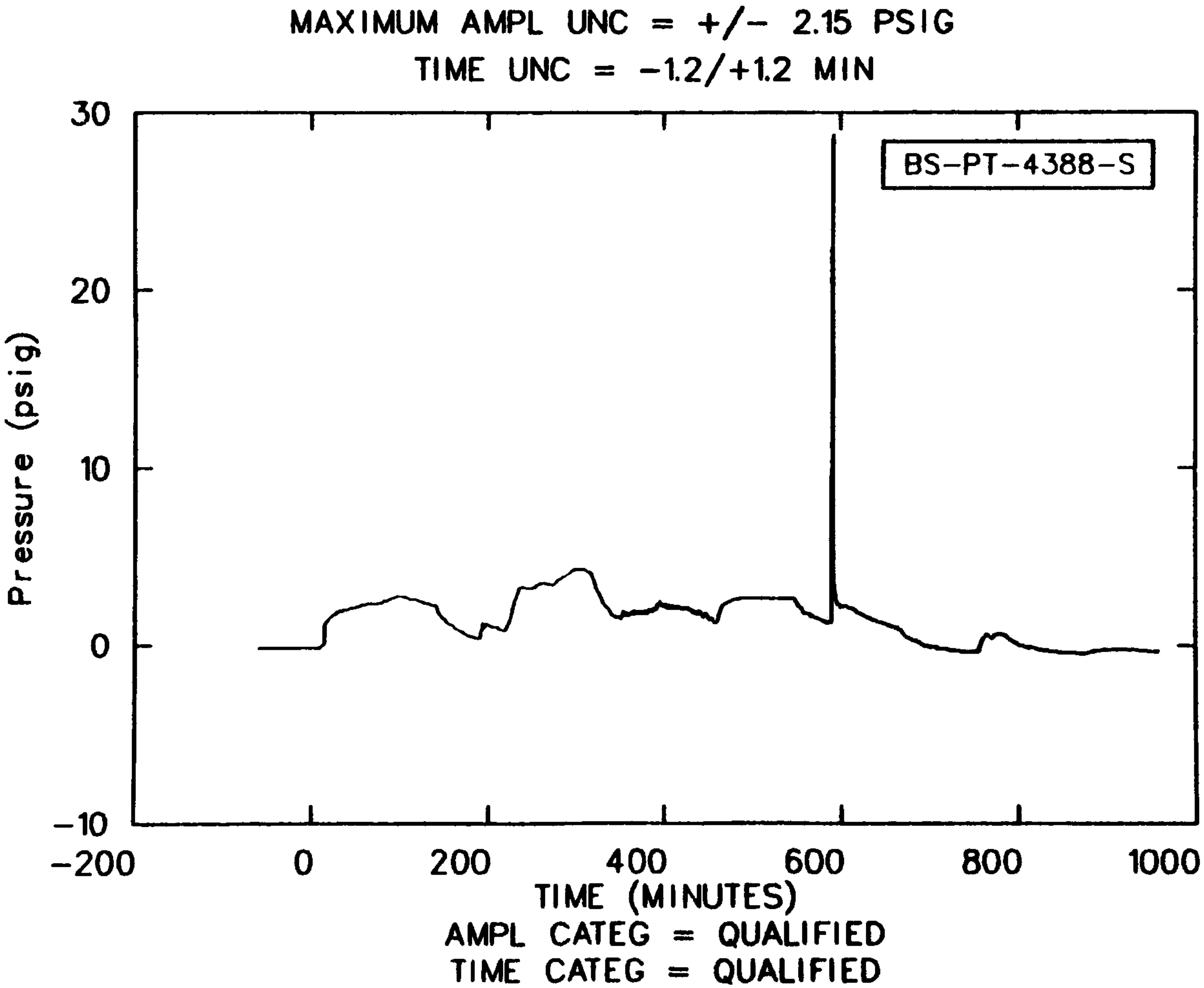


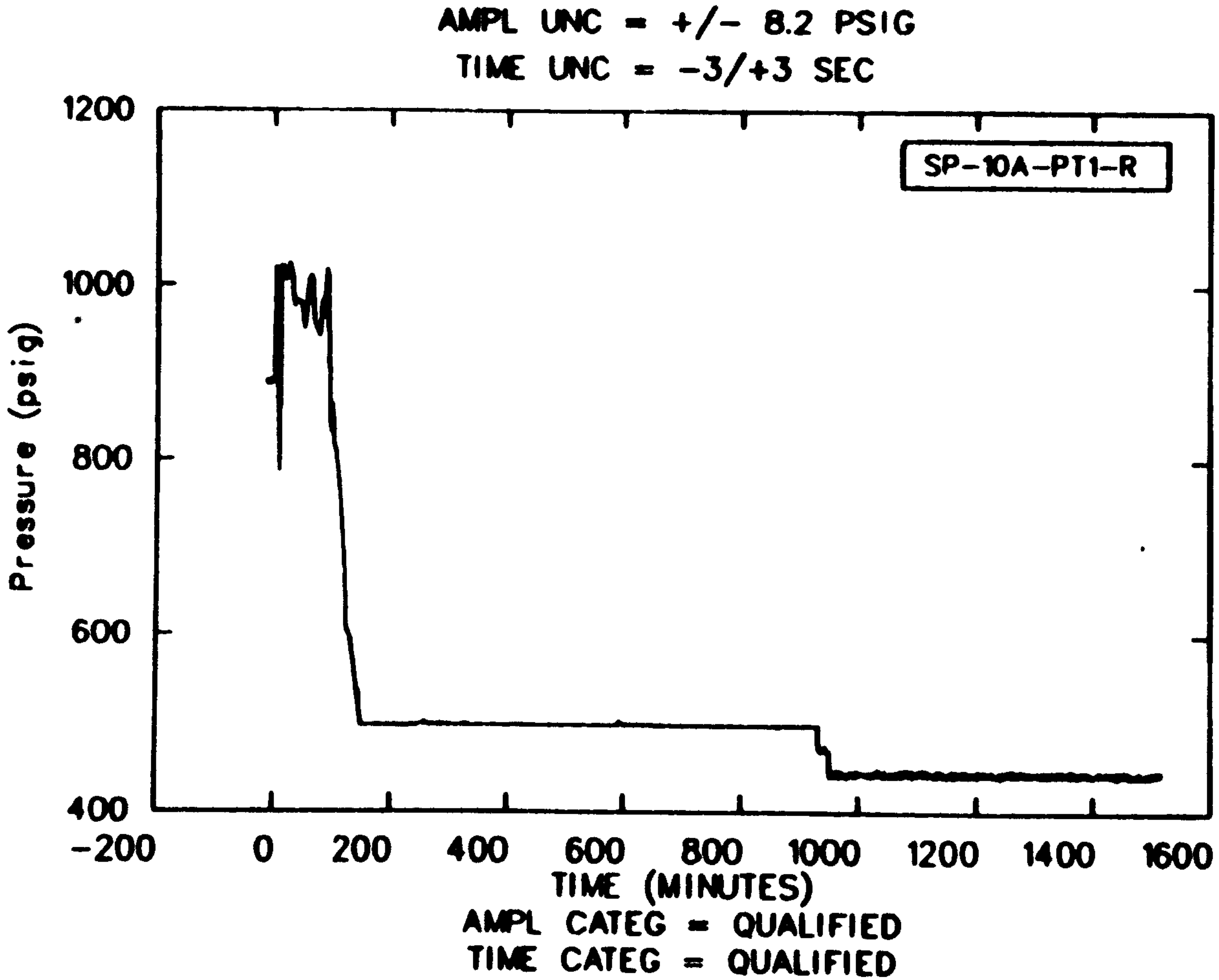
AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = -5/+5 MIN
WDL-R-1311-M
COUNTS/MIN
10^8
10^7
10^6
10^5
10^4
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

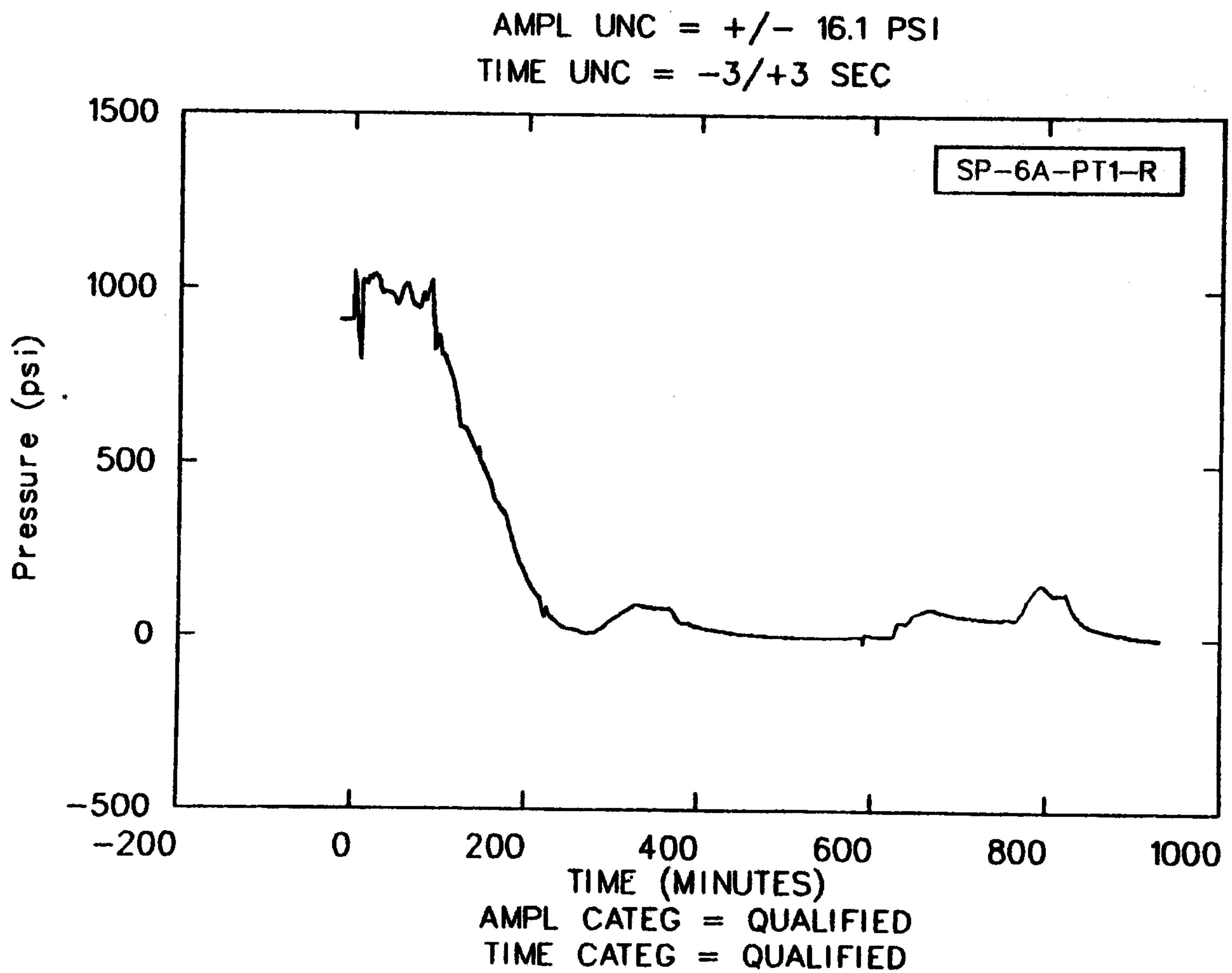

TIME UNC = -2/+2 MIN
WGD-R-1480-G-M
COUNTS/MIN
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0.0
100.0
200.0
300.0
400.0
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

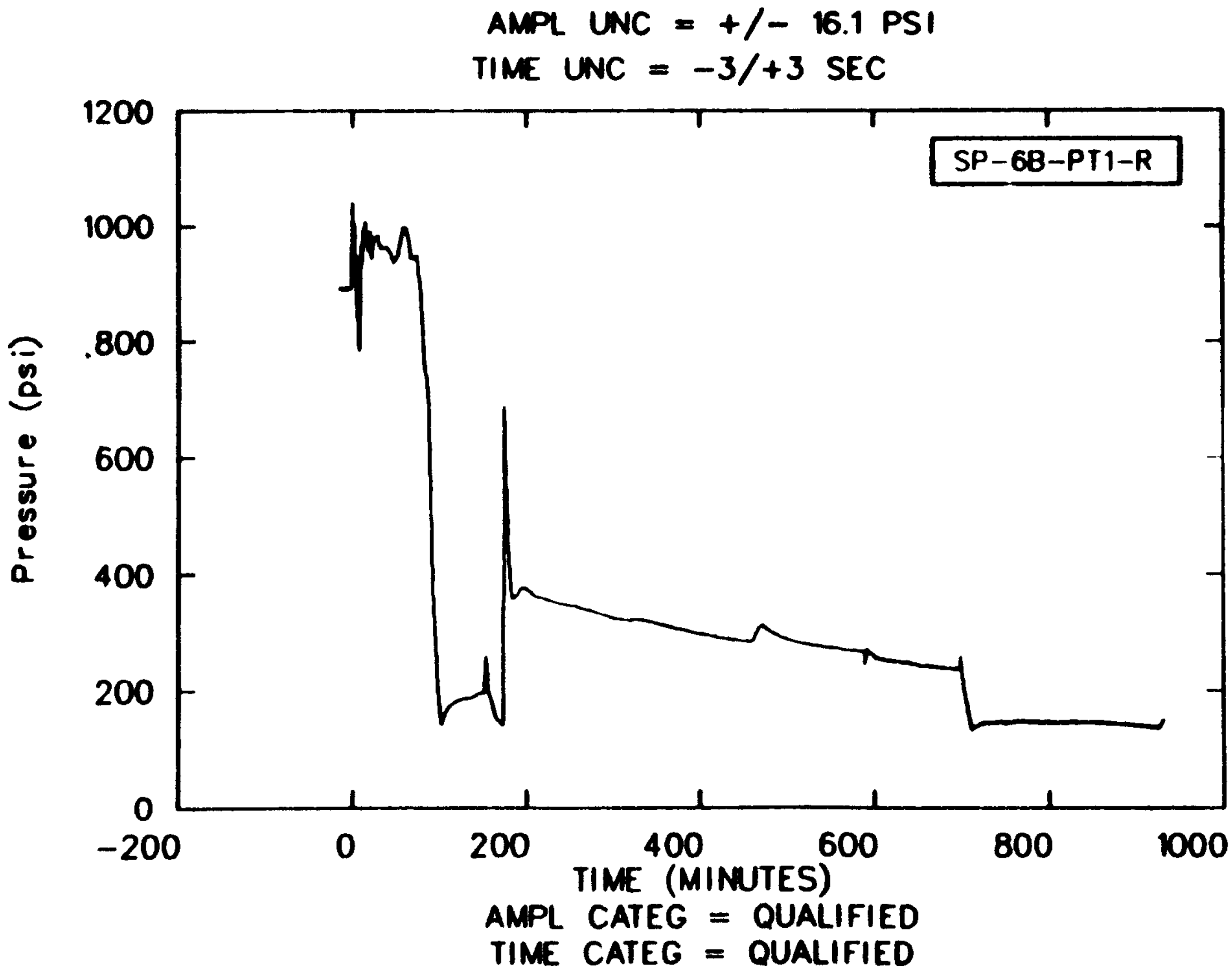

MAXIMUM AMPL UNC = +/- 40 PSI
TIME UNC = -3 SEC/2 MIN +0/2 MIN
PRESS.-PRIMARY
UPPER UNC
LOWER UNC
Pressure (psig)
3000
2500
2000
1500
1000
500
0
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

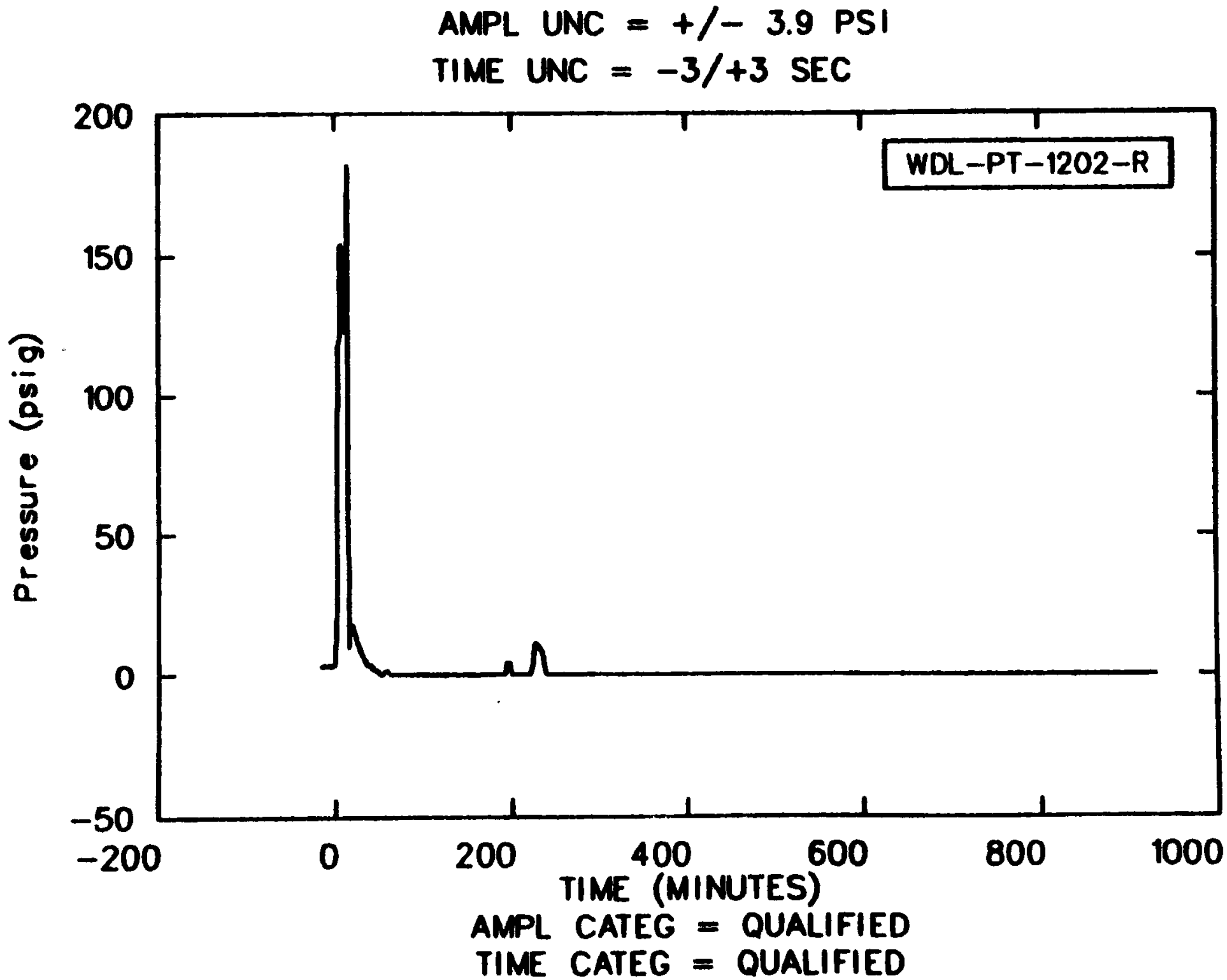

MAXIMUM AMPL UNC = +/- 2.15 PSIG
TIME UNC = -1.2/+1.2 MIN
BS-PT-4388-S
Pressure (psig)
30
20
10
0
-10
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

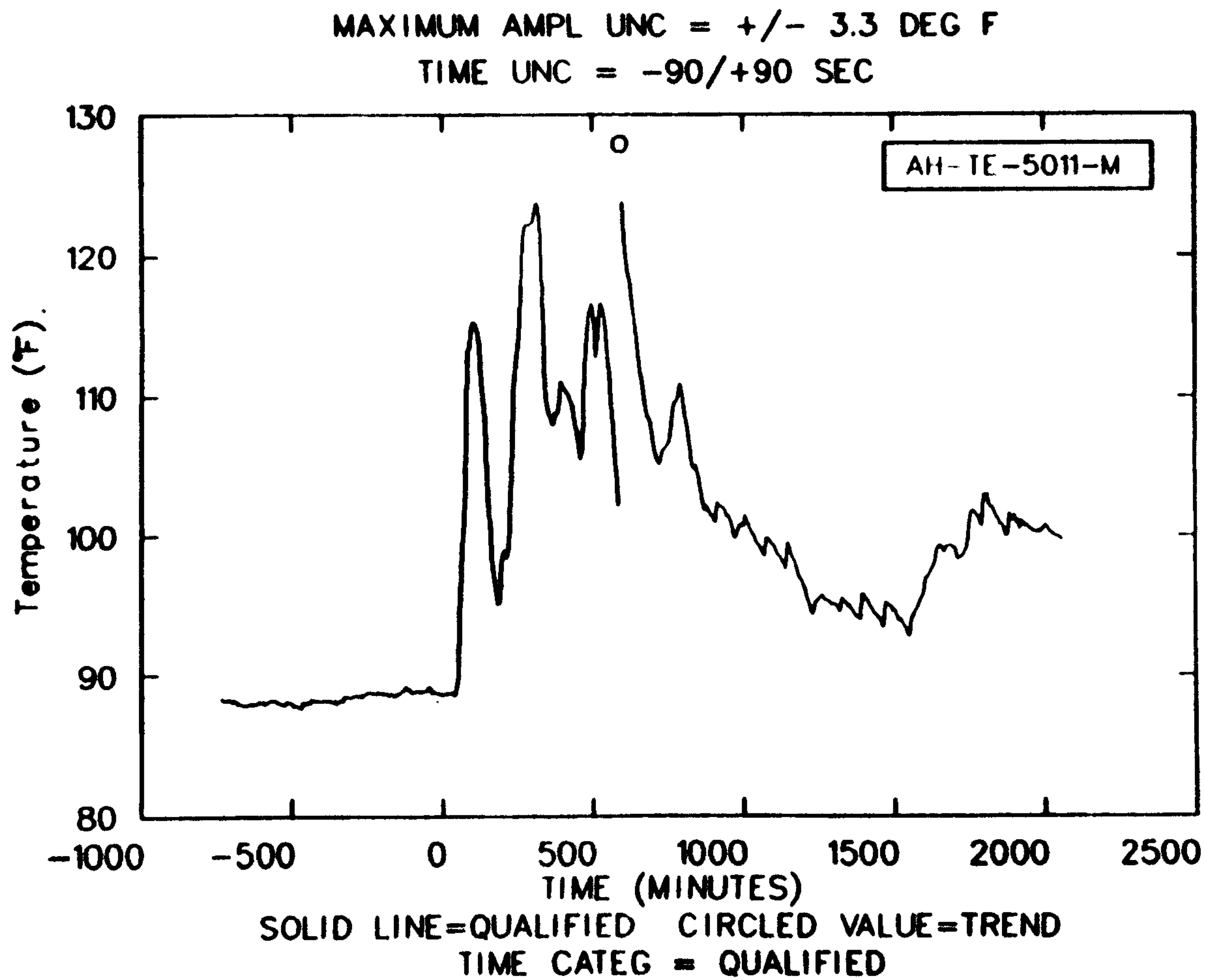


AMPL UNC = +/- 8.2 PSIG
TIME UNC = -3/+3 SEC
SP-10A-PT1-R
Pressure (psig)
1200
1000
800
600
400
-200
0
200
400
600
800
1000
1200
1400
1600
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

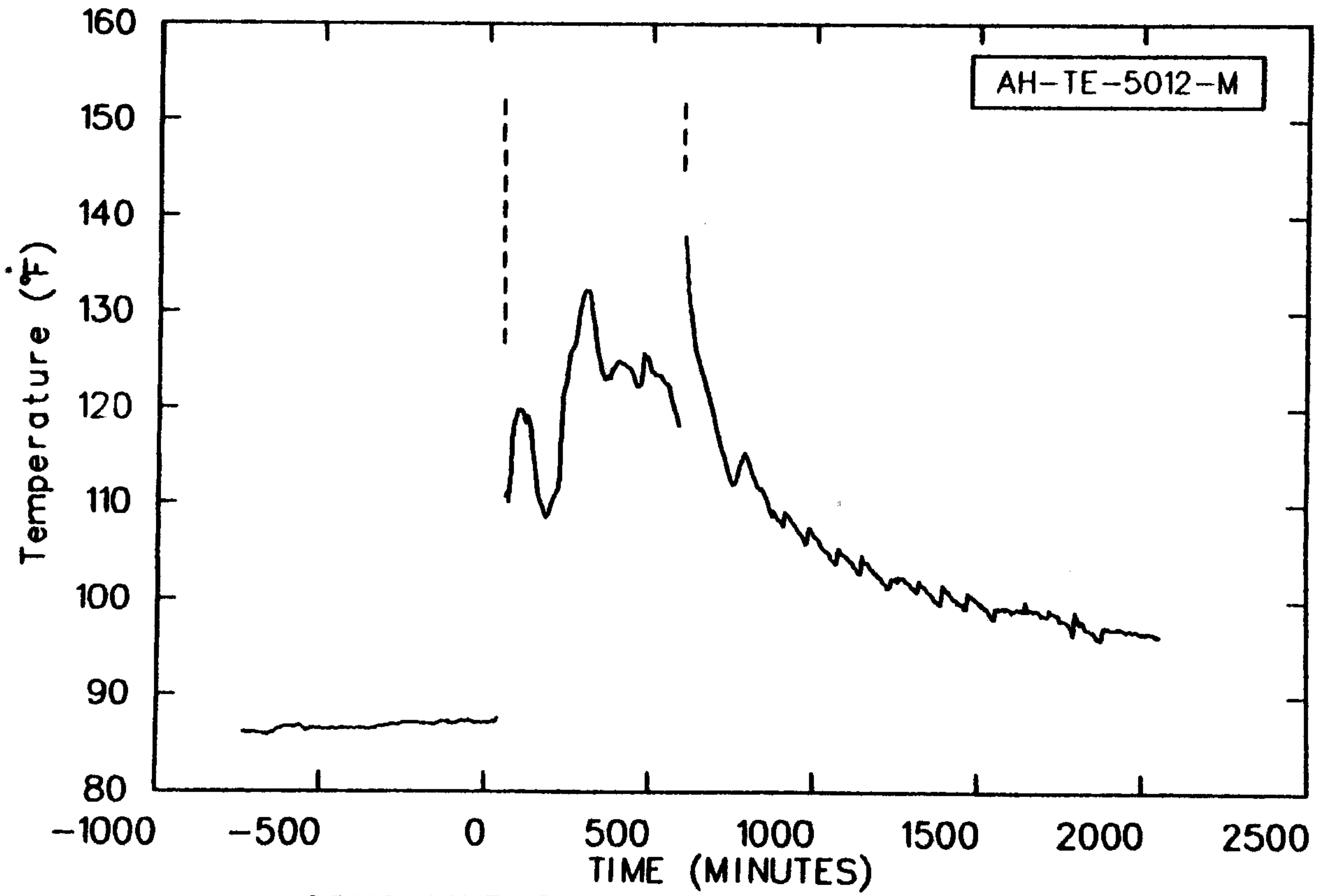

AMPL UNC = +/- 16.1 PSI
TIME UNC = -3/+3 SEC
SP-6A-PT1-R
1500
1000
500
0
-500
Pressure (psi)
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 16.1 PSI
TIME UNC = -3/+3 SEC
SP-6B-PT1-R
Pressure (psi)
1200
1000
800
600
400
200
0
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

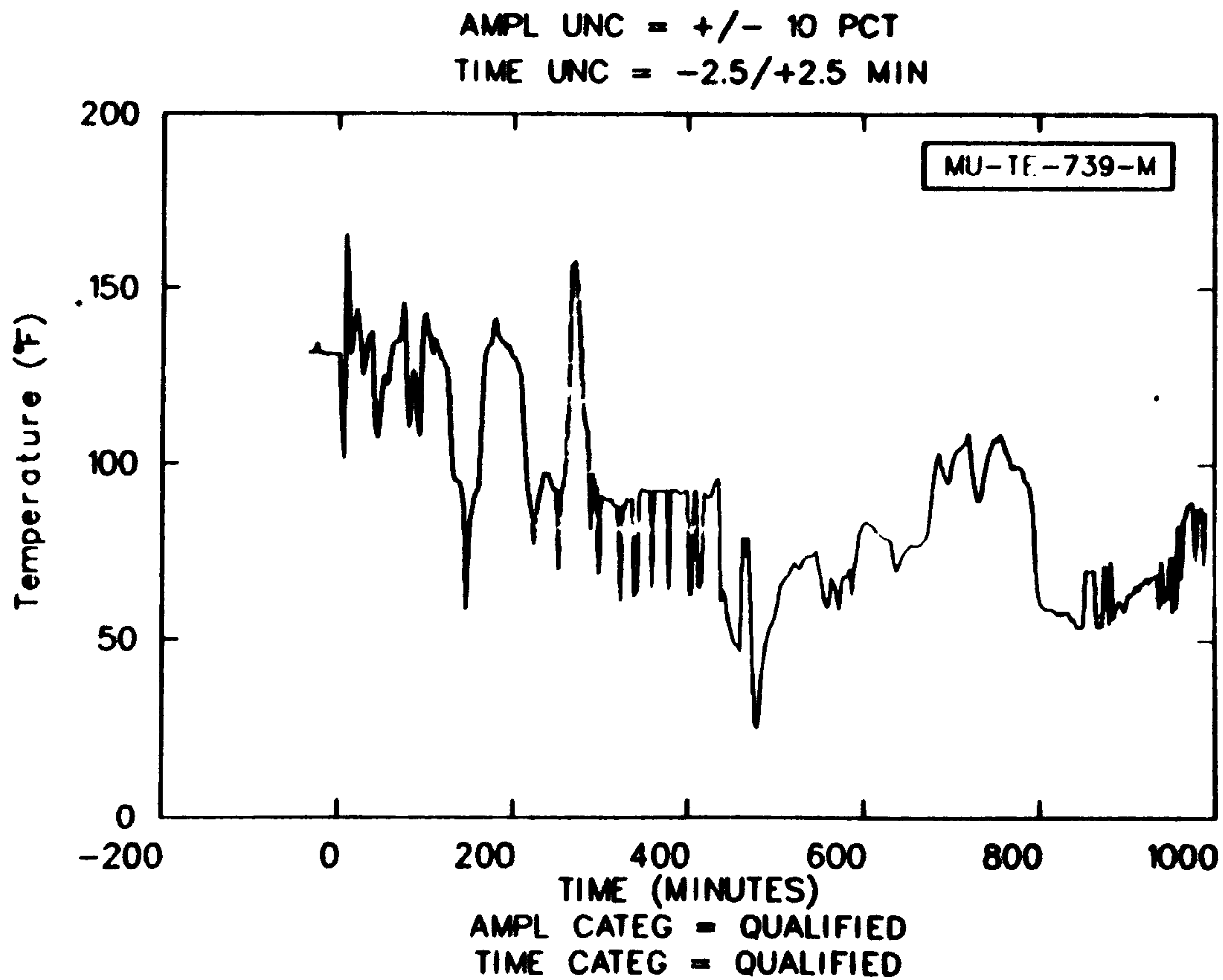

AMPL UNC = +/- 3.9 PSI
TIME UNC = -3/+3 SEC
WDL-PT-1202-R
Pressure (psig)
200
150
100
50
0
-50
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


MAXIMUM AMPL UNC = +/- 3.3 DEG F
TIME UNC = -90/+90 SEC
AH-TE-5011-M
Temperature (°F)
130
120
110
100
90
80
-1000
-500
0
500
1000
1500
2000
2500
TIME (MINUTES)
SOLID LINE=QUALIFIED CIRCLED VALUE=TREND
TIME CATEG = QUALIFIED

MAXIMUM AMPL UNC = +/- 3.3 DEG F
TIME UNC = -90/+90 SEC

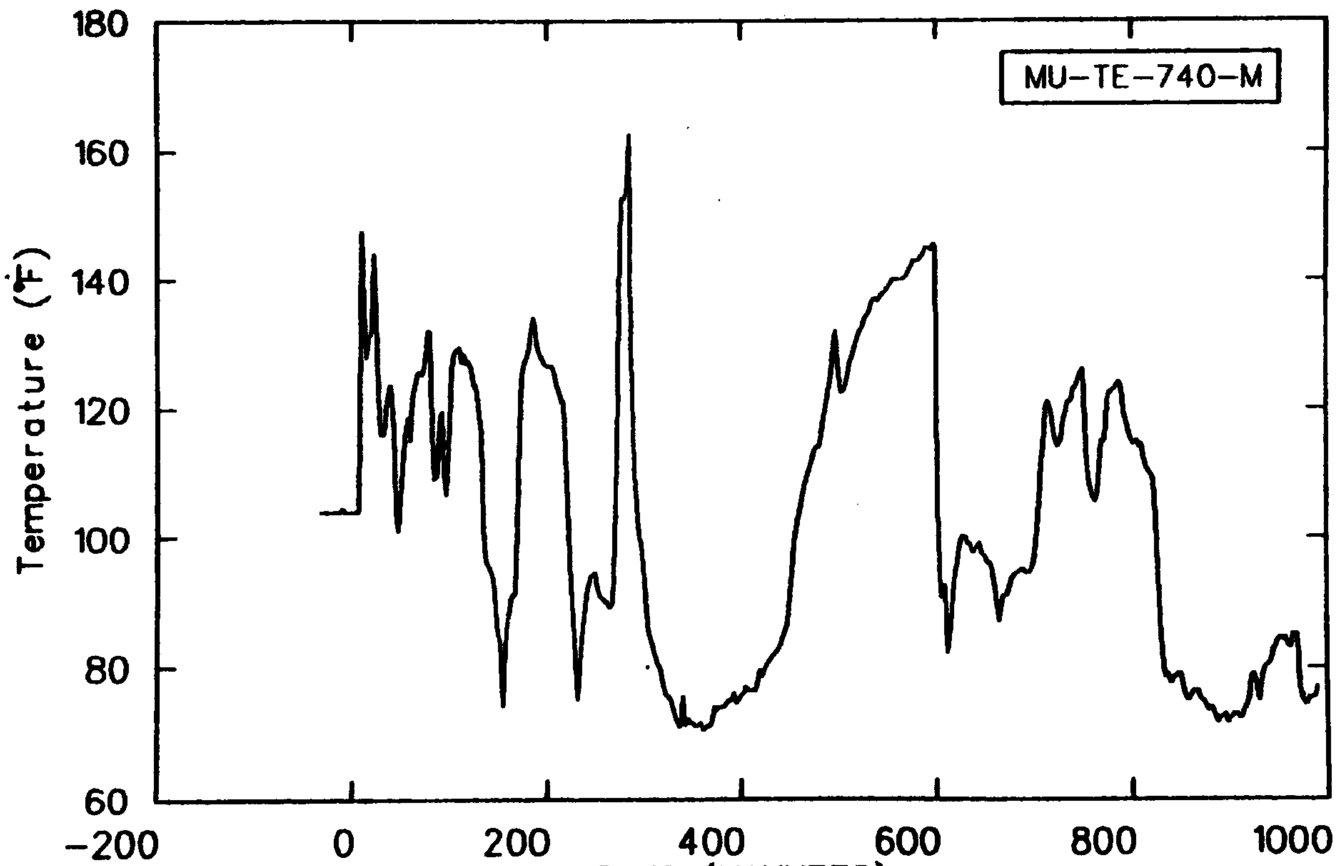


SOLID LINE=QUALIFIED DASHED LINE=TREND
TIME CATEG = QUALIFIED

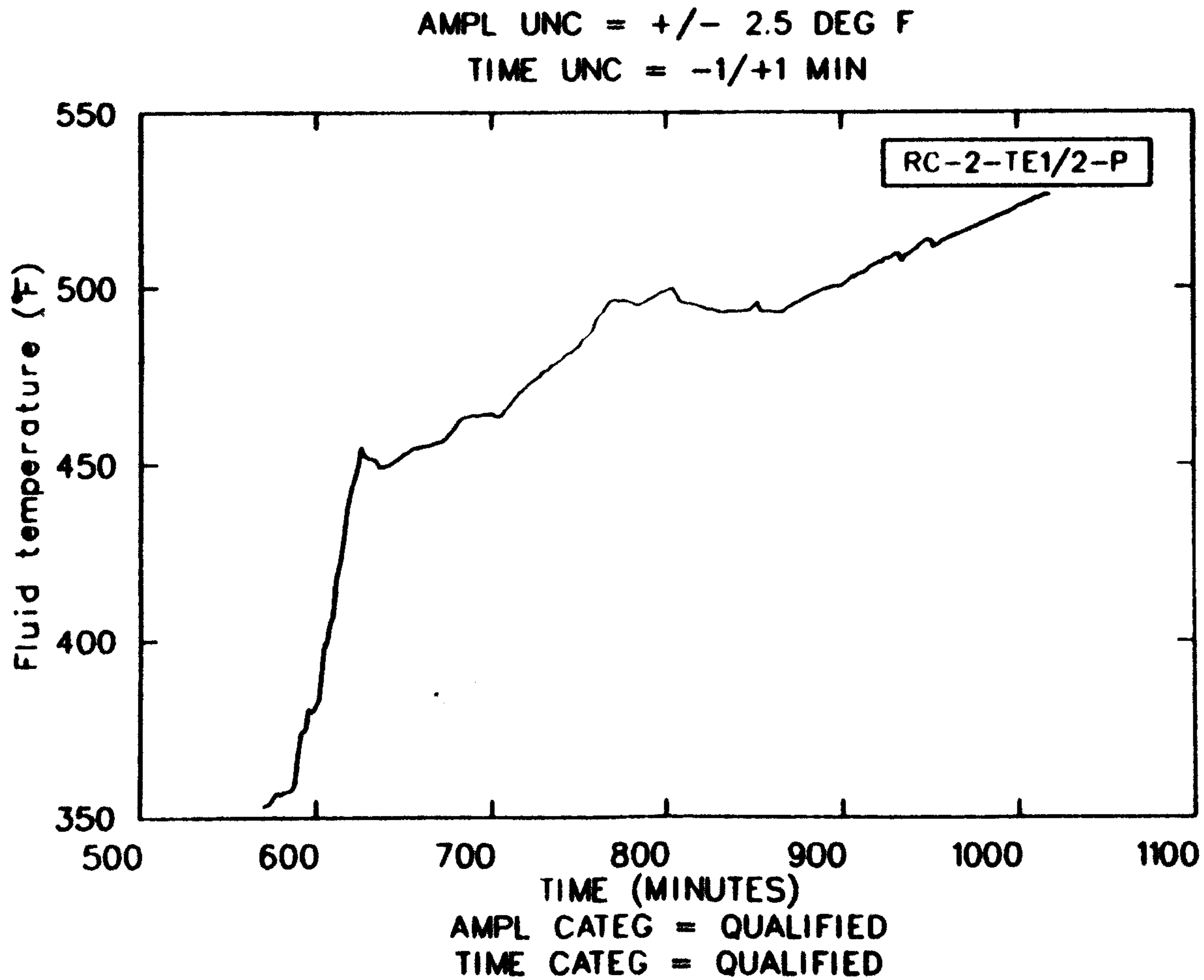


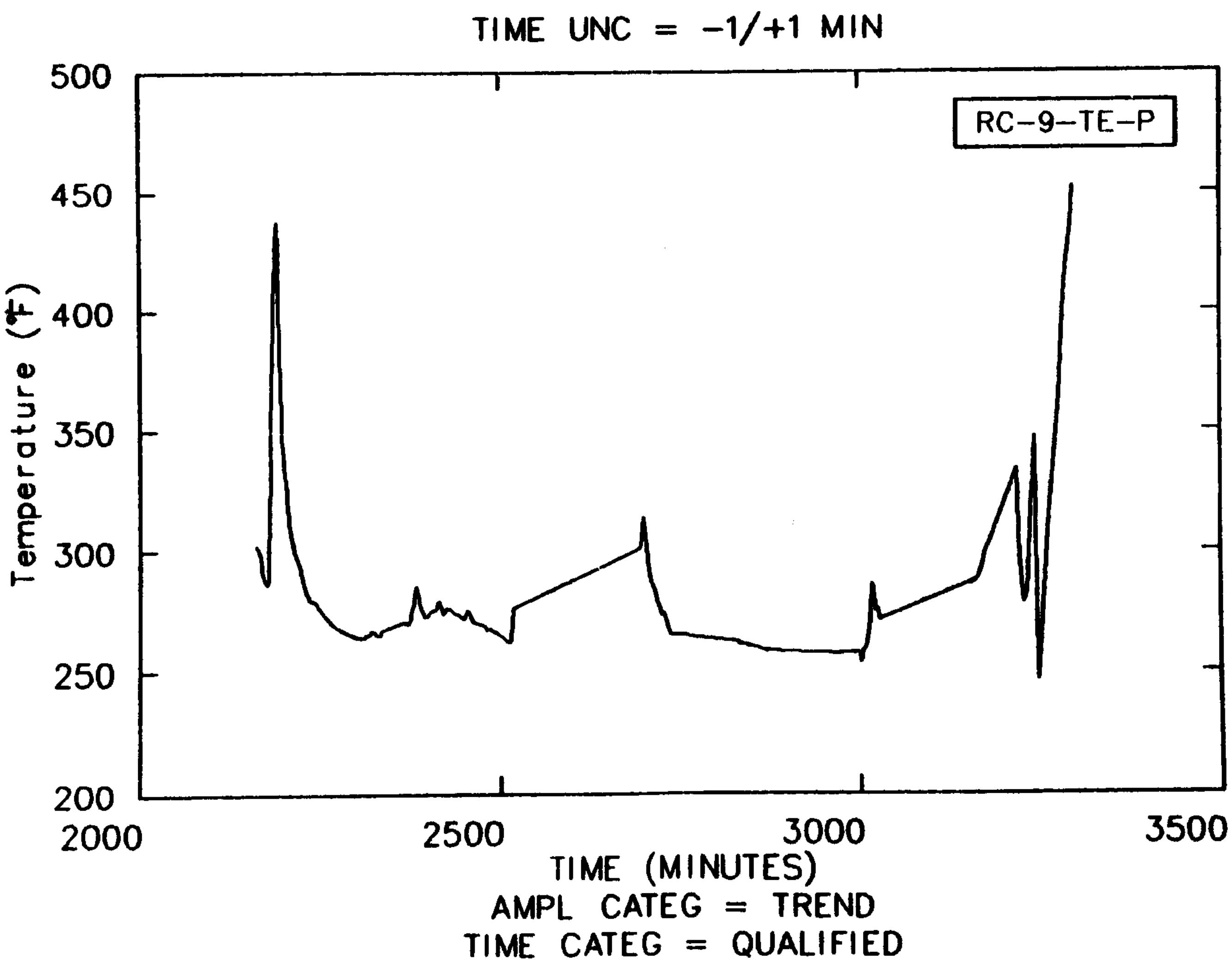
AMPL UNC = +/- 10 PCT
TIME UNC = -2.5/+2.5 MIN
MU-TE-739-M
Temperature (°F)
0
50
100
150
200
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

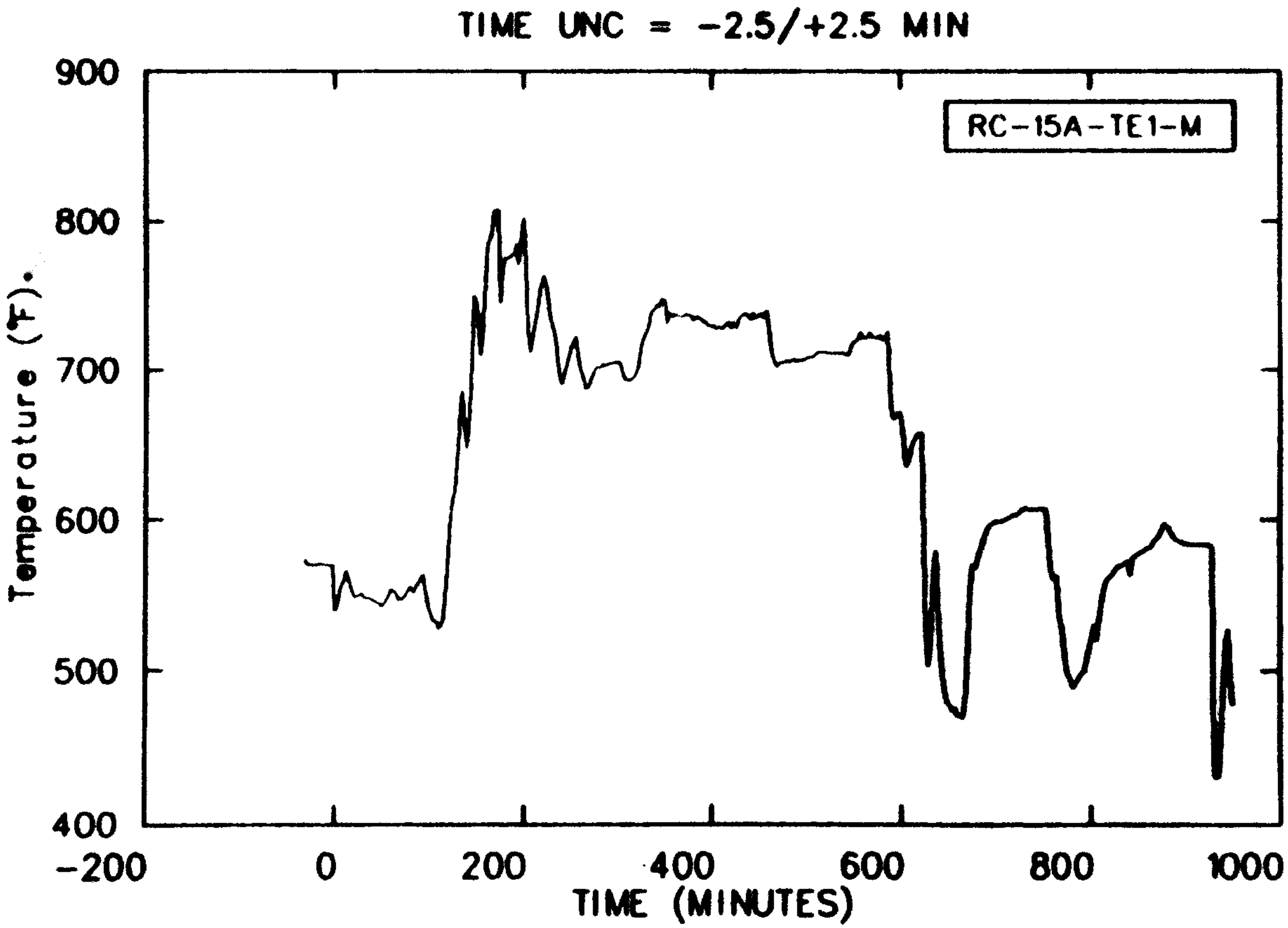
AMPL UNC = +/- 10 PCT
TIME UNC = -2.5/+2.5 MIN



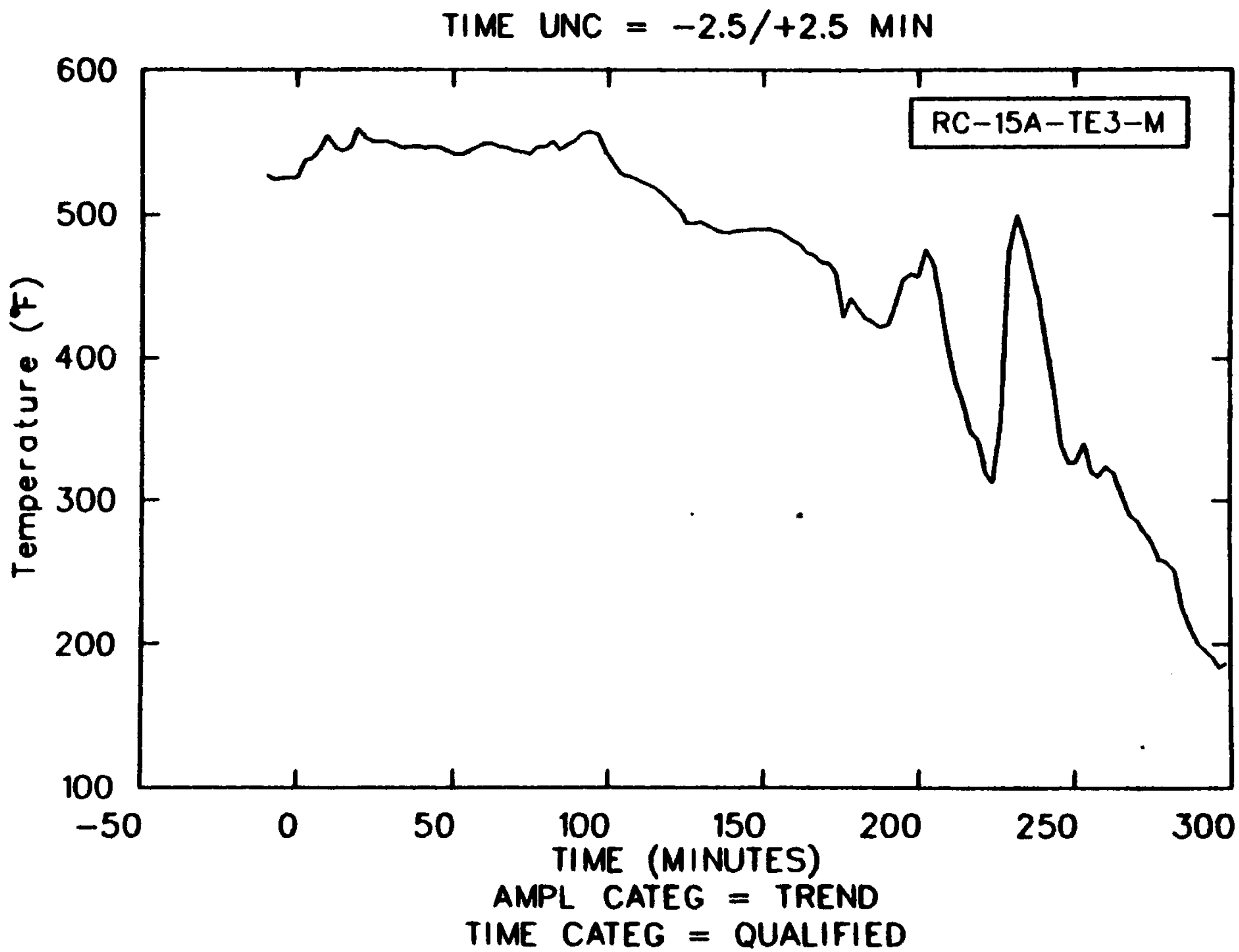
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 2.5 DEG F
TIME UNC = -1/+1 MIN
RC-2-TE1/2-P
Fluid temperature (°F)
550
500
450
400
350
500
600
700
800
900
1000
1100
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

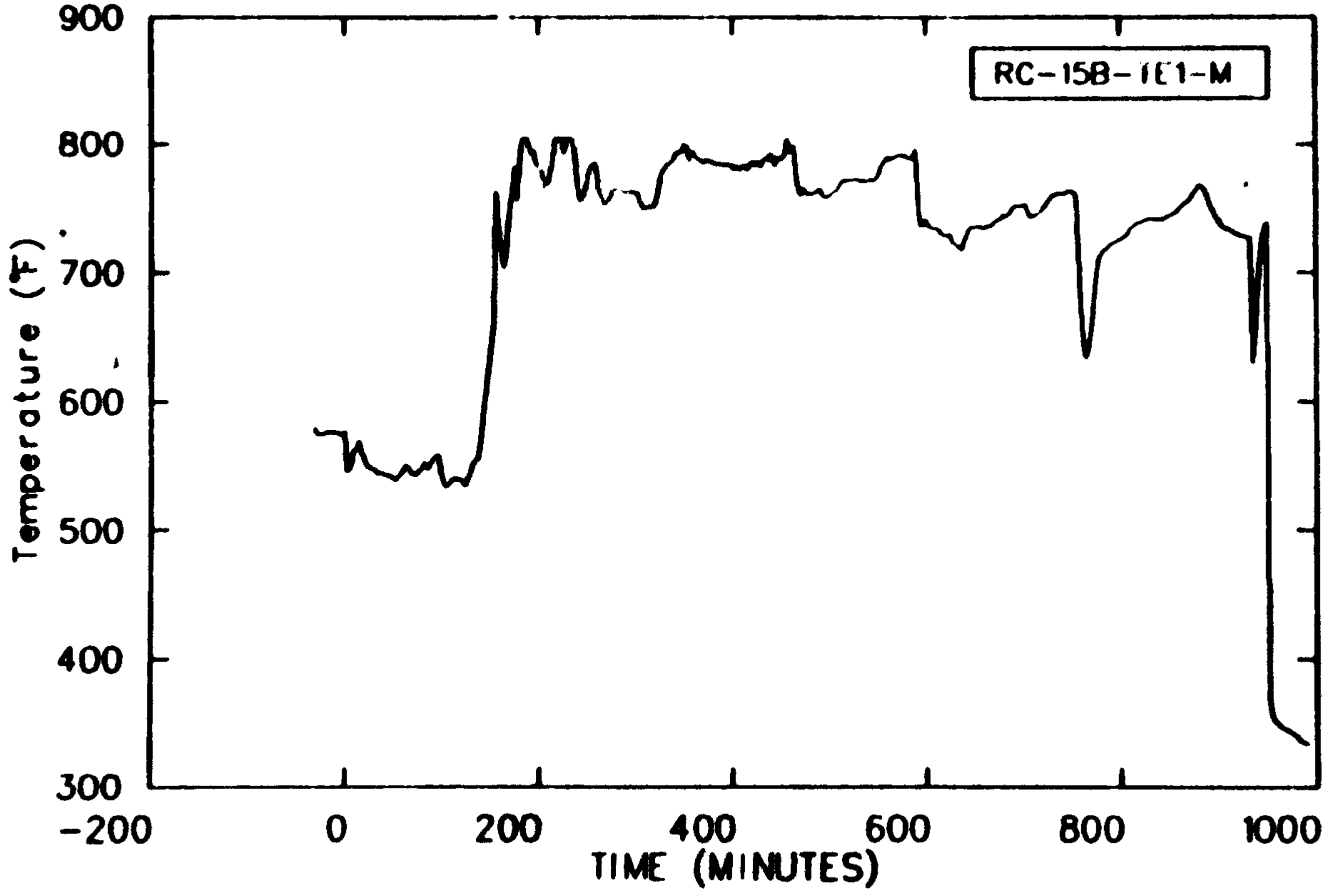

TIME UNC = -1/+1 MIN
RC-9-TE-P
Temperature (°F)
500
450
400
350
300
250
200
2000
2500
3000
3500
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED



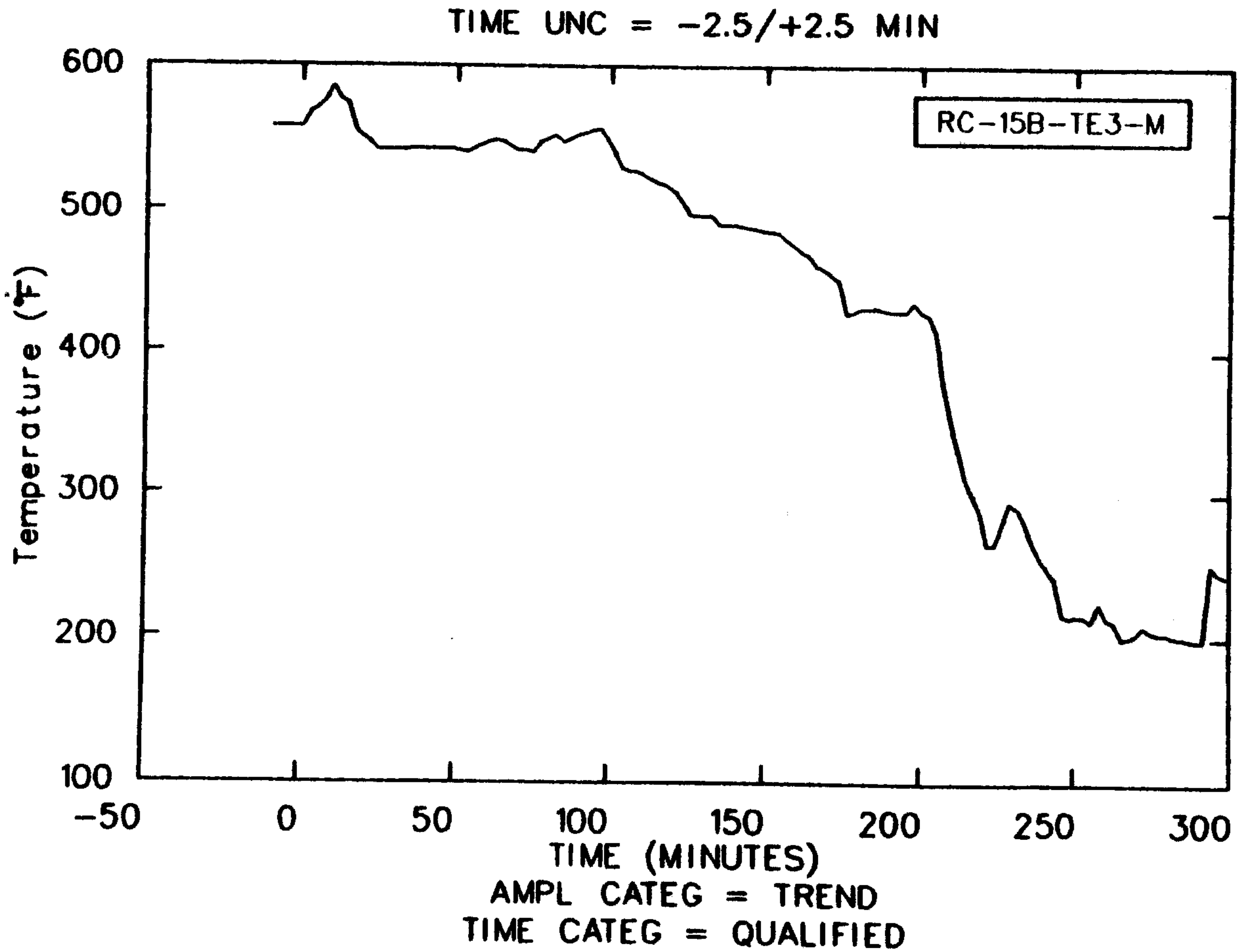
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

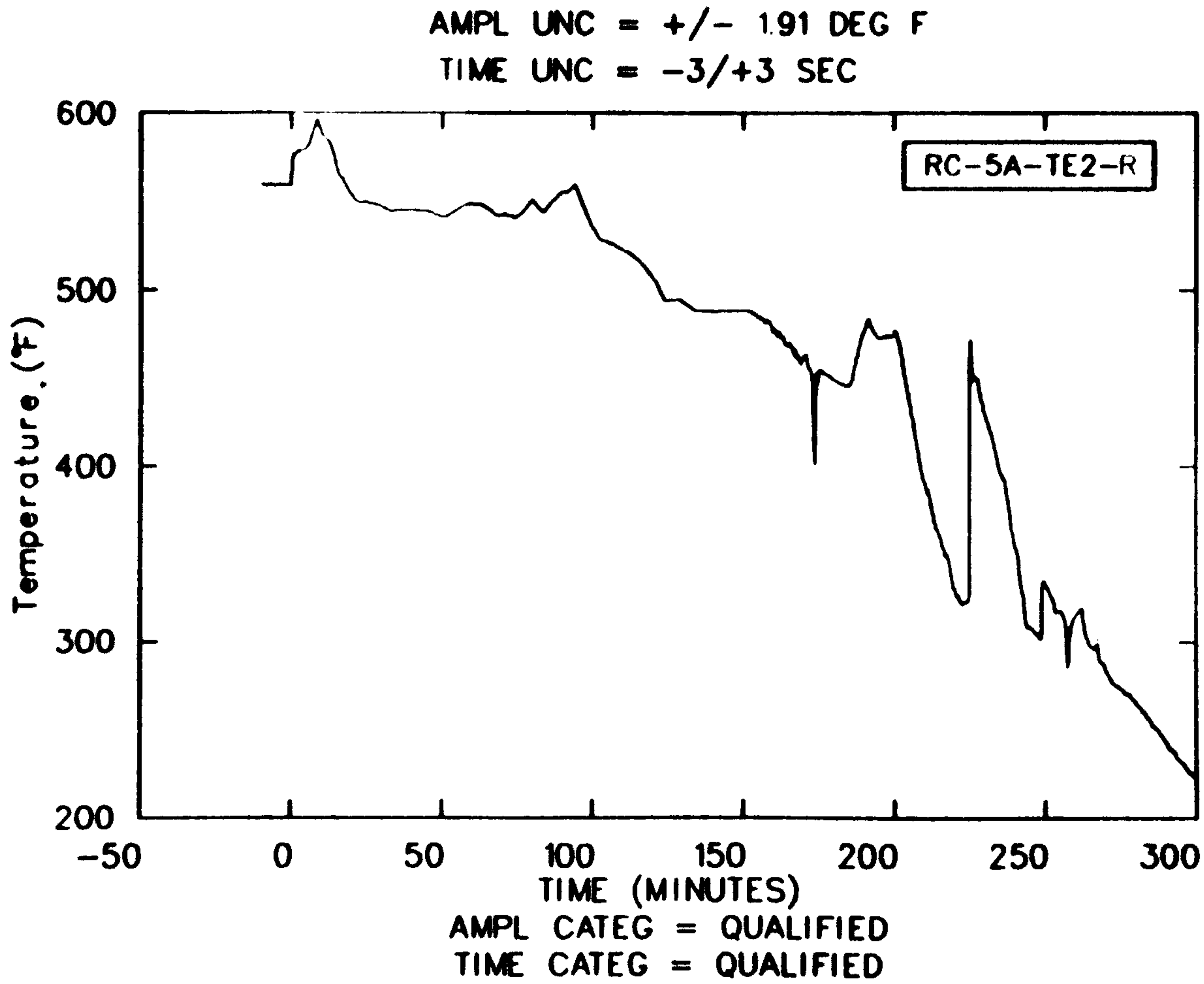

TIME UNC = -2.5/+2.5 MIN
RC-15A-TE3-M
Temperature (°F)
600
500
400
300
200
100
-50
0
50
100
150
200
250
300
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

TIME UNC = -2.5/+2.5 MIN

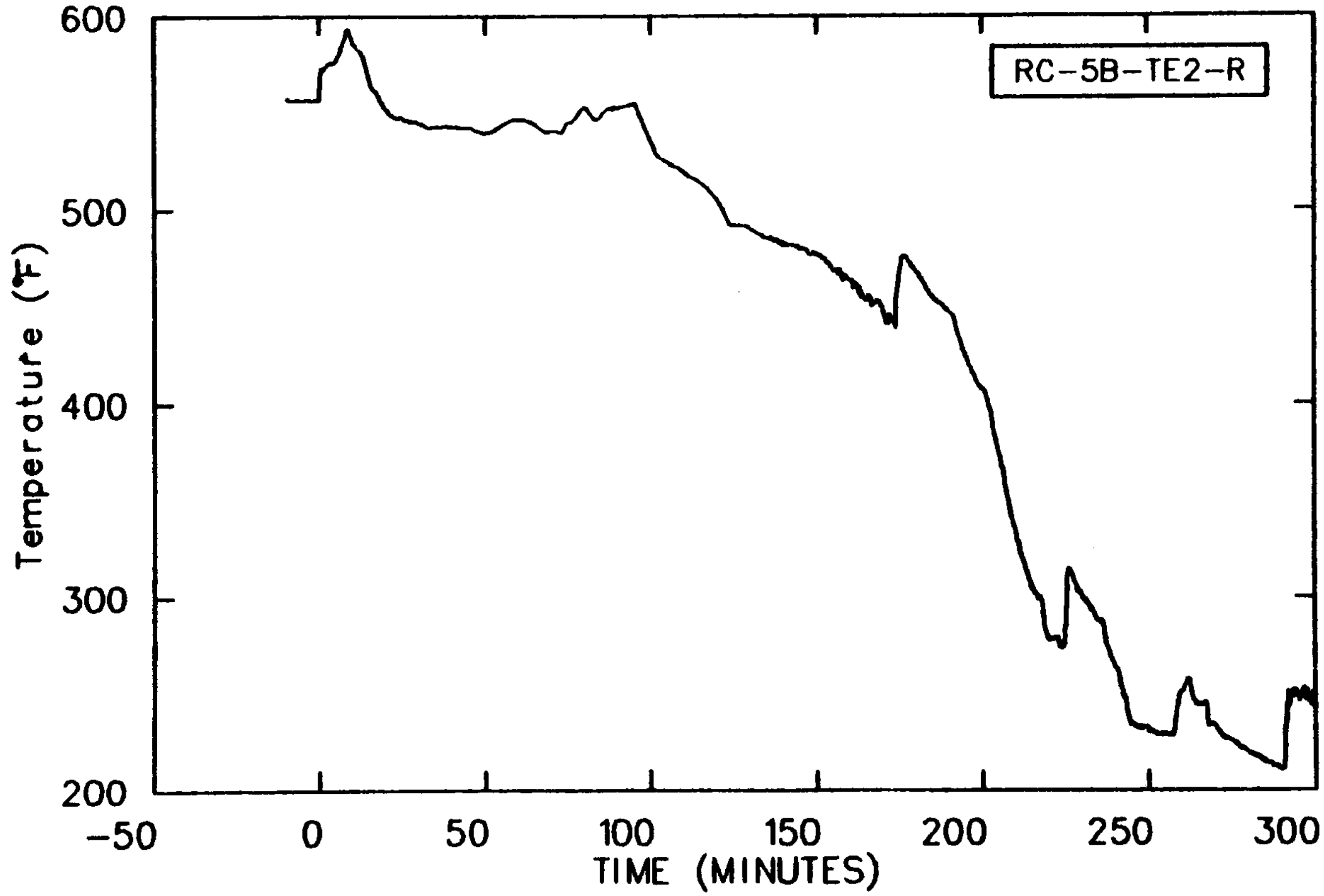


AMPL CATEG = TREND
TIME CATEG = QUALIFIED


TIME UNC = −2.5/+2.5 MIN
RC−15B−TE3−M
Temperature (°F)
600
500
400
300
200
100
−50
0
50
100
150
200
250
300
TIME (MINUTES)
AMPL CATEG = TREND
TIME CATEG = QUALIFIED

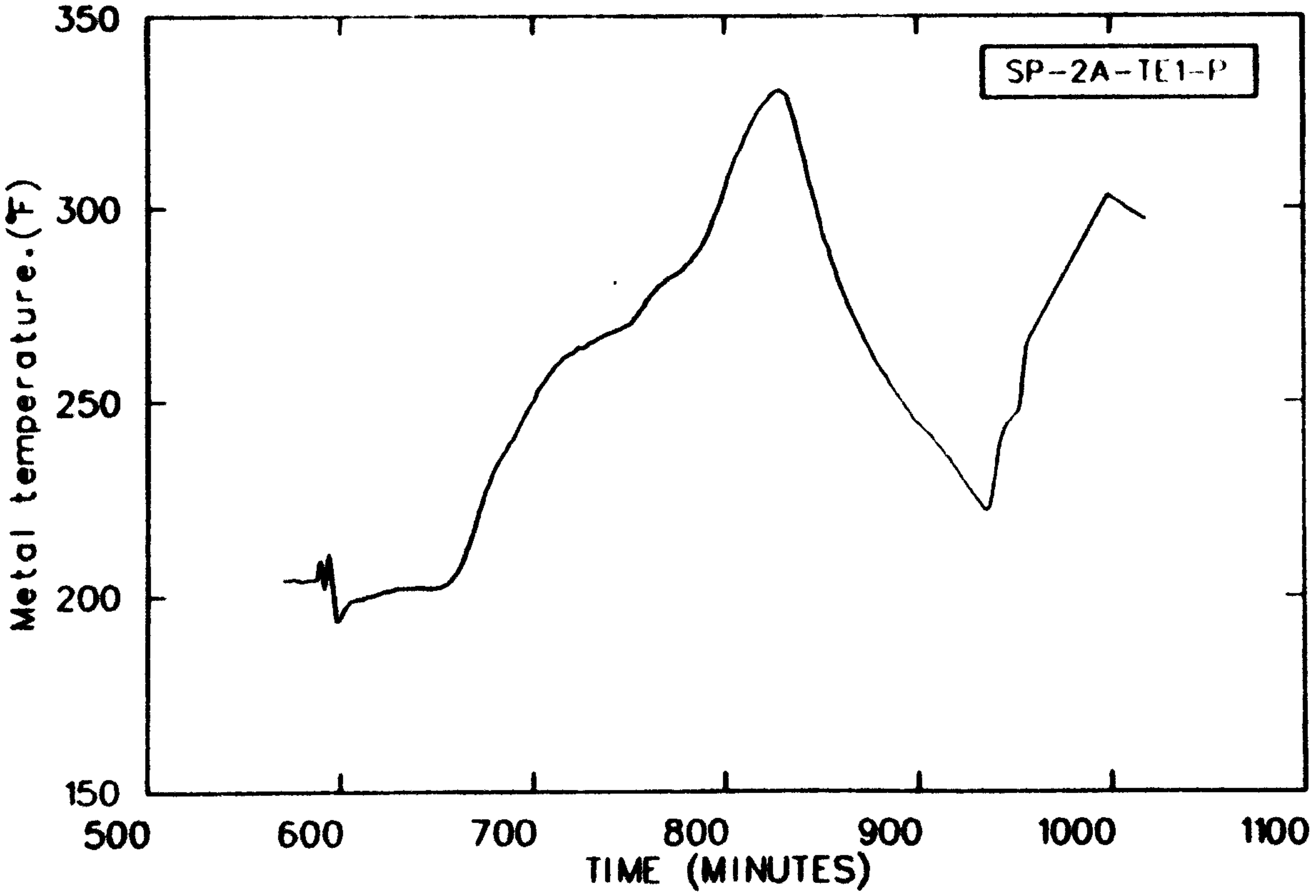

AMPL UNC = +/- 1.91 DEG F
TIME UNC = -3/+3 SEC
RC-5A-TE2-R
Temperature (°F)
600
500
400
300
200
-50
0
50
100
150
200
250
300
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

AMPL UNC = +/- 1.91 DEG F
TIME UNC = -3/+3 SEC

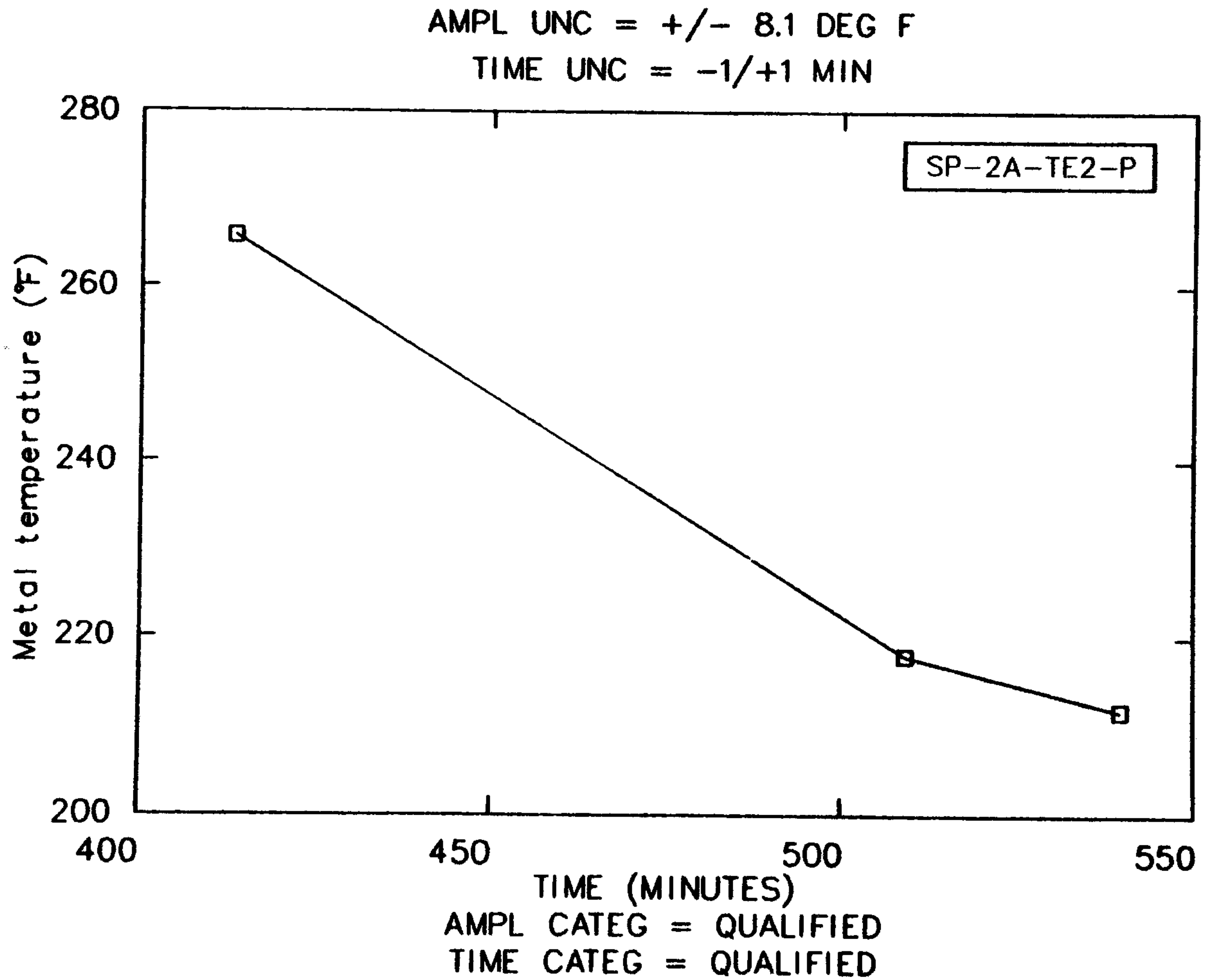


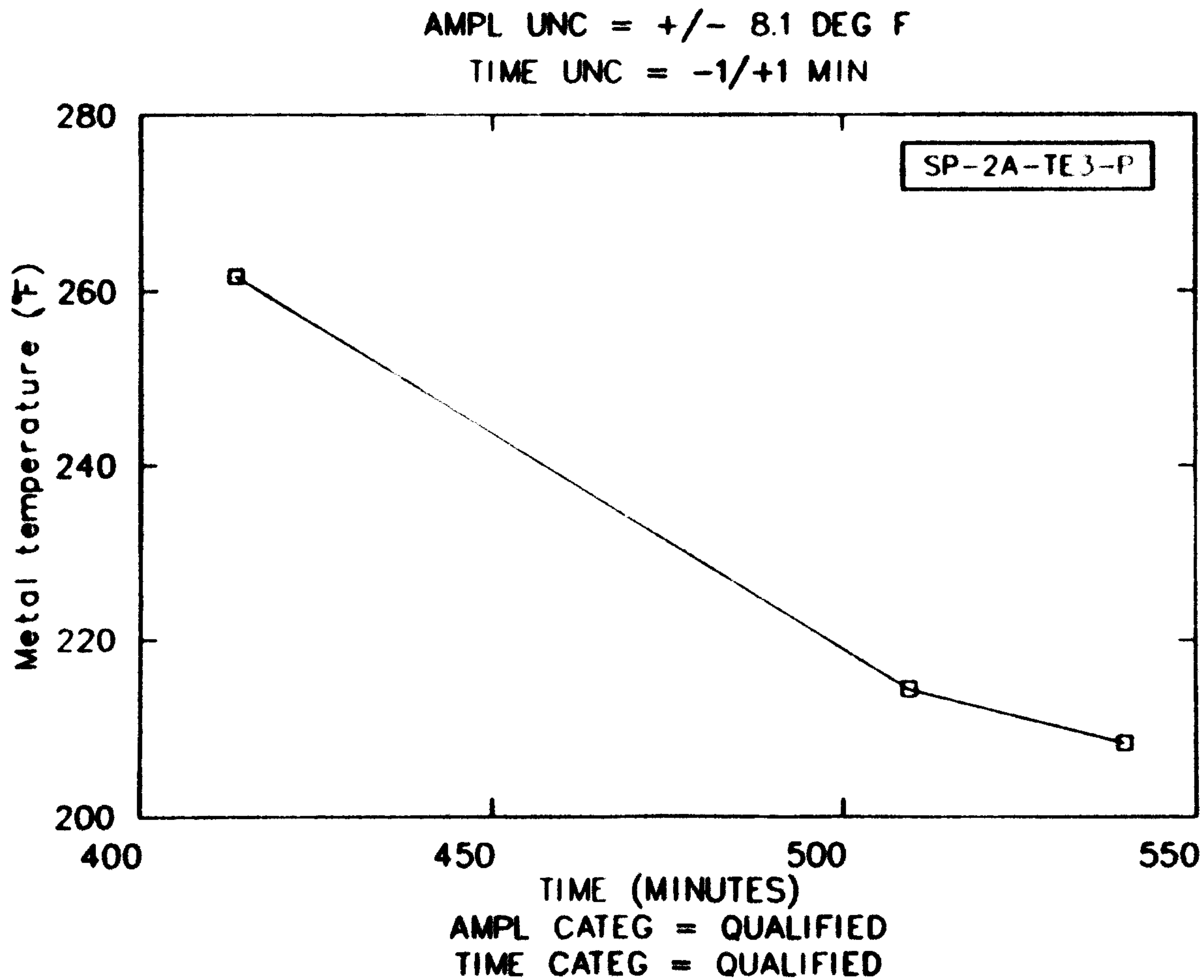
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

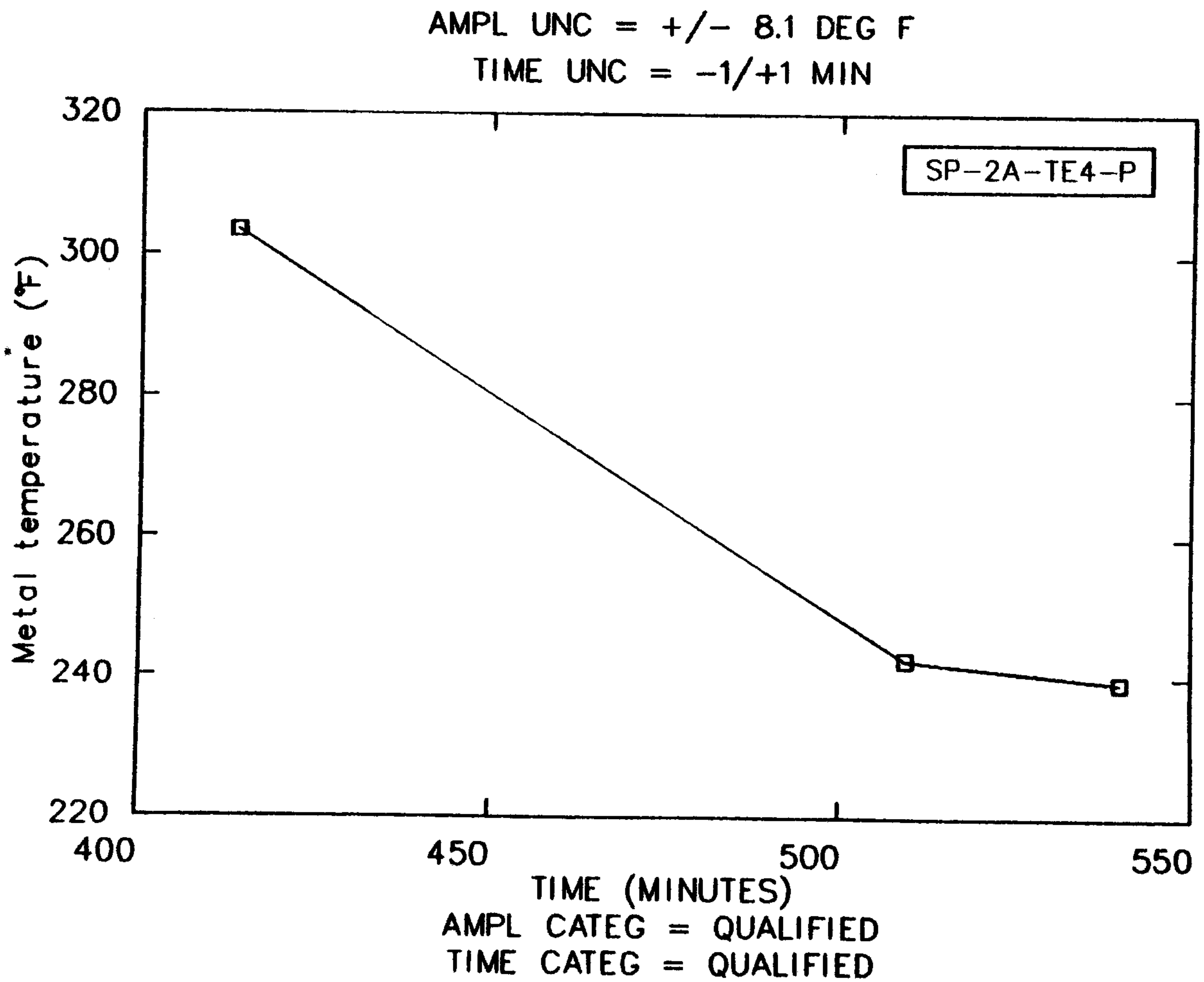
AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN



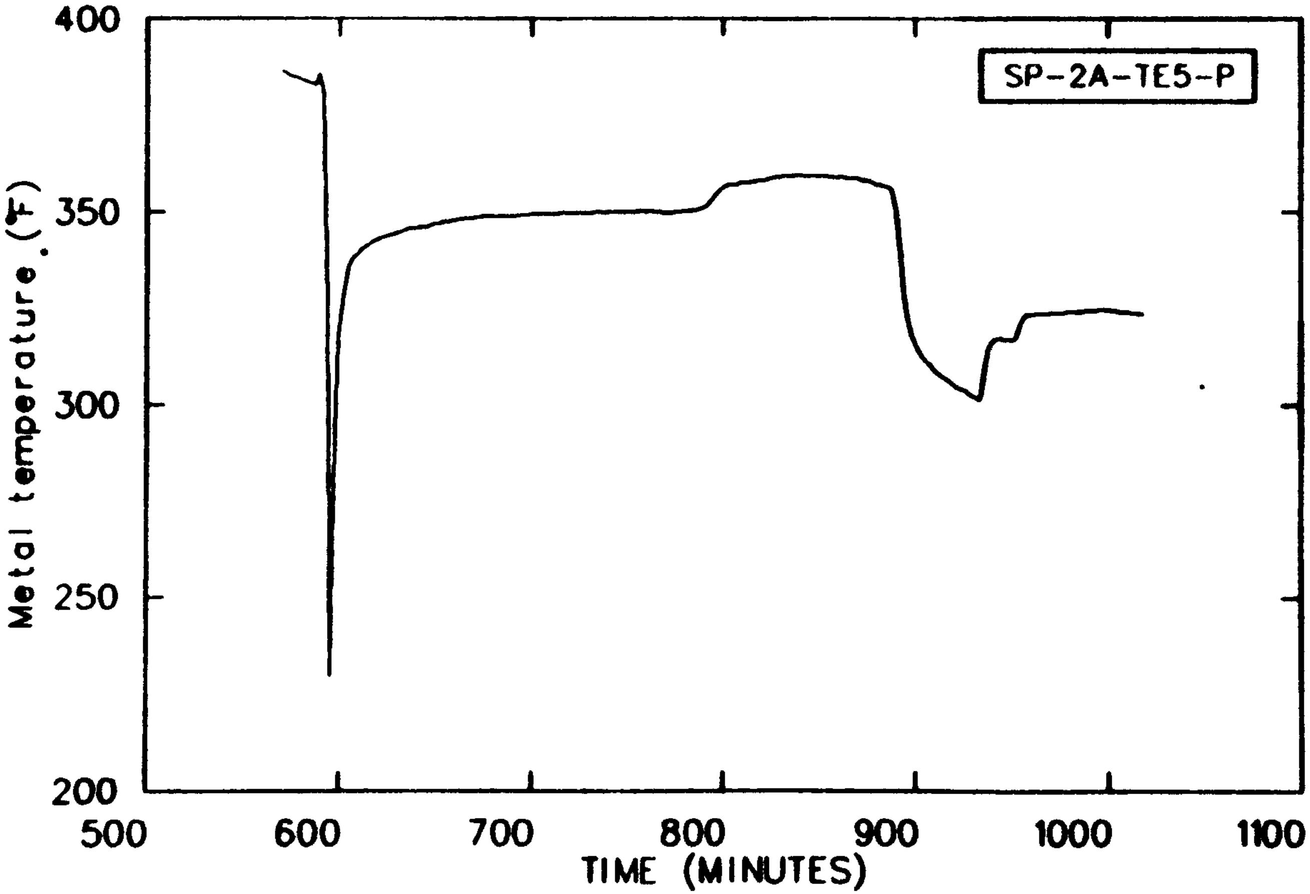
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2A-TE2-P
Metal temperature (°F)
280
260
240
220
200
400
450
500
550
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2A-TE3-P
Metal temperature (°F)
280
260
240
220
200
400
450
500
550
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

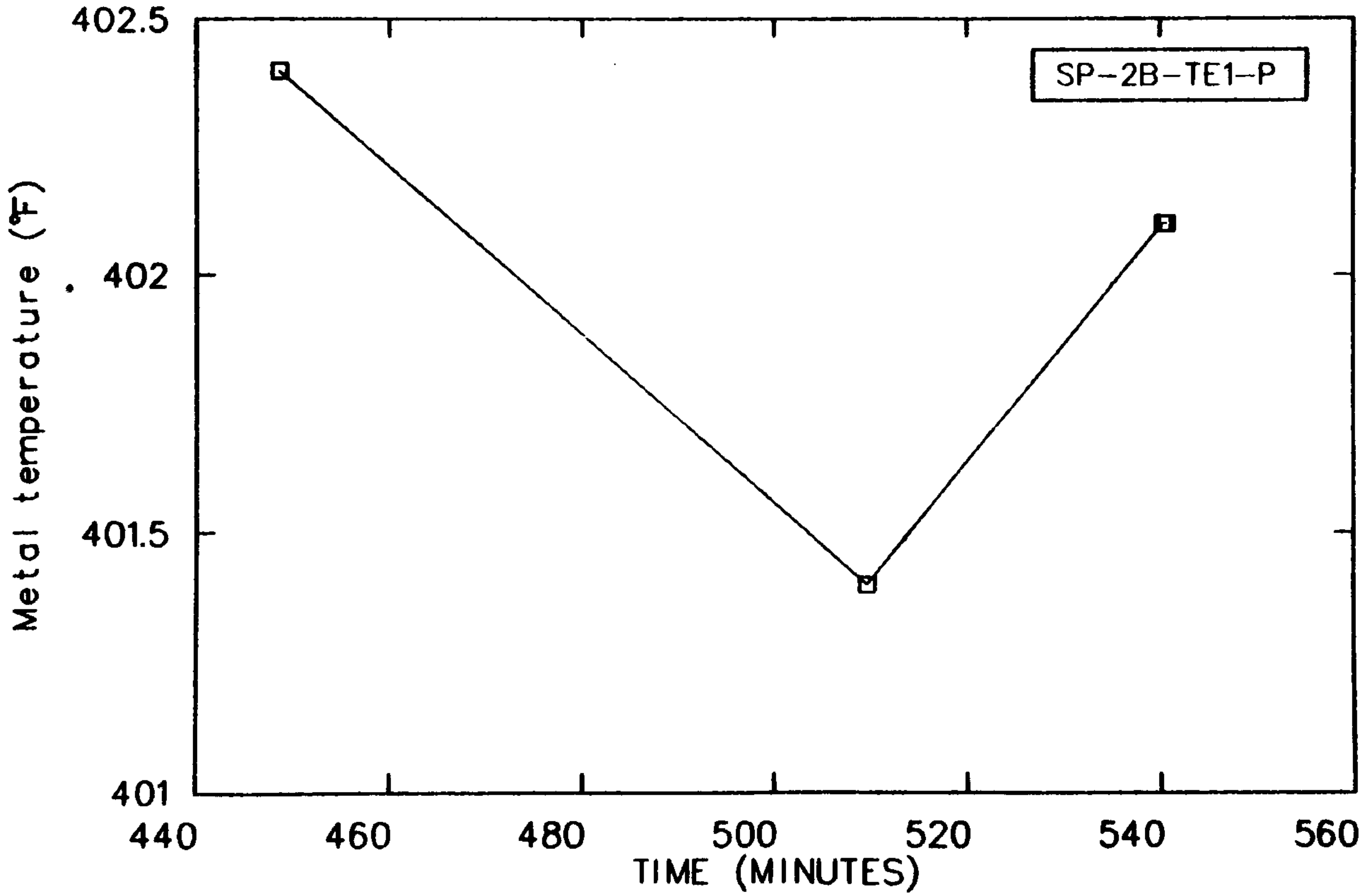

AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2A-TE4-P
Metal temperature (°F)
320
300
280
260
240
220
400
450
500
550
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN

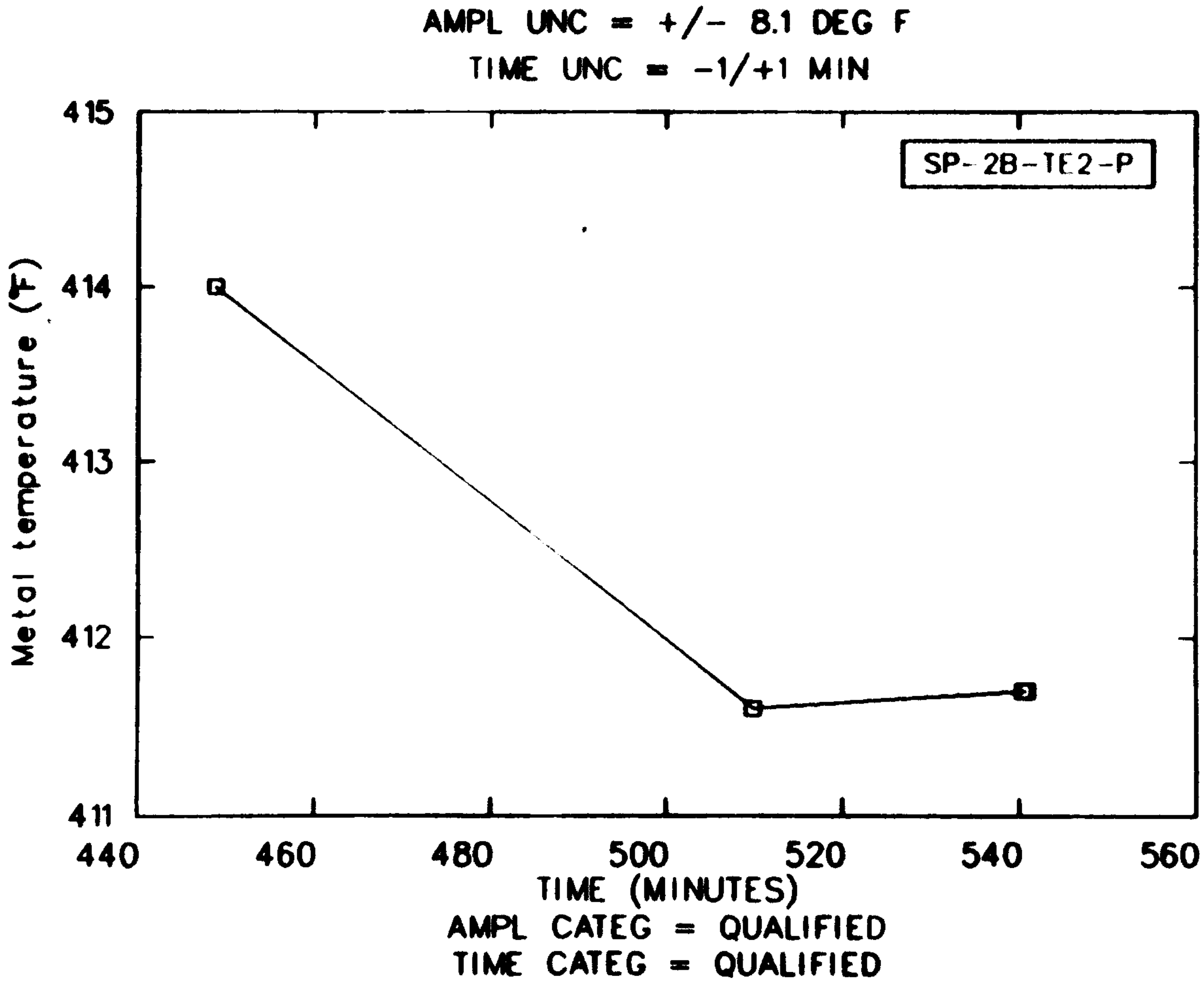


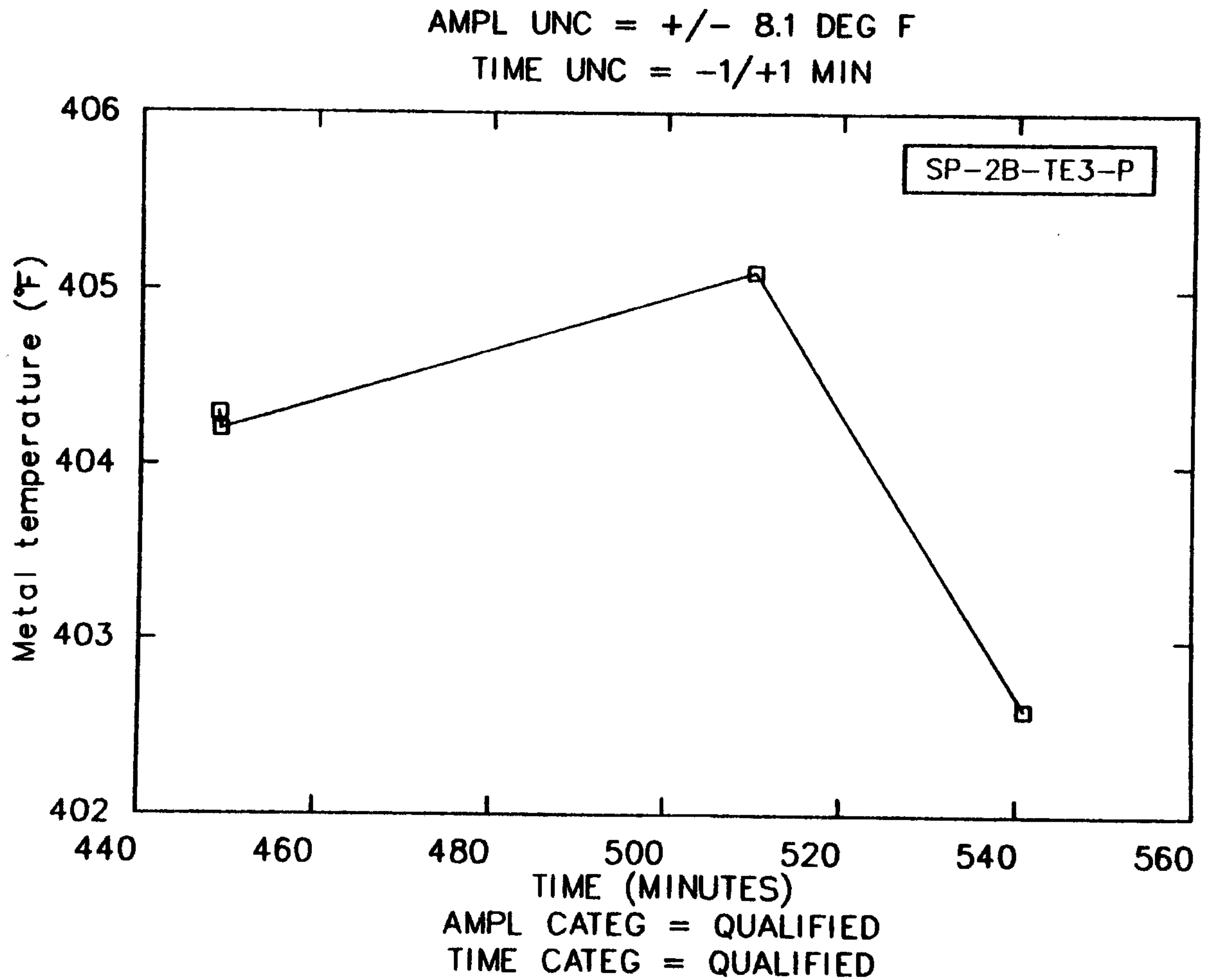
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

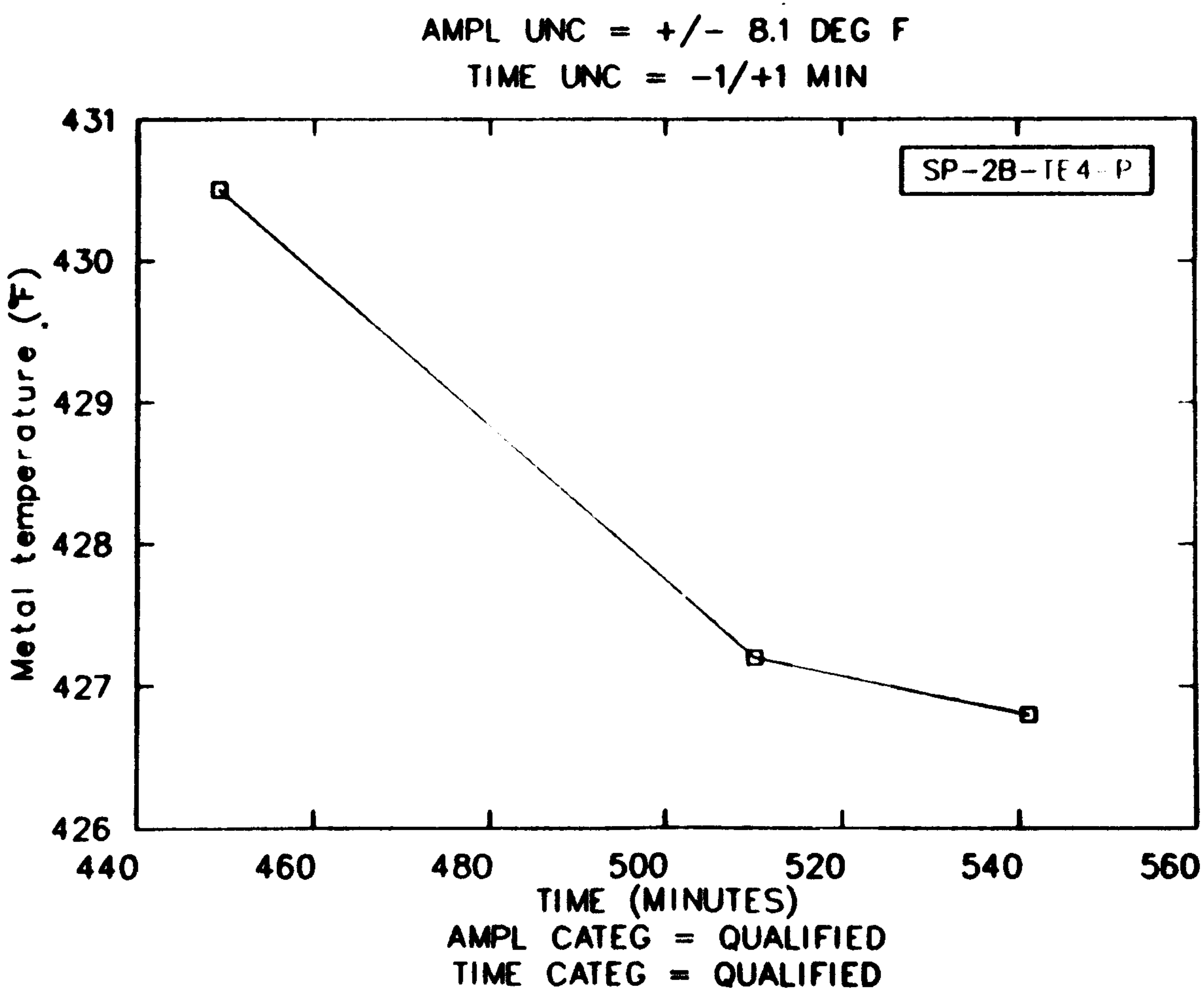
AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN

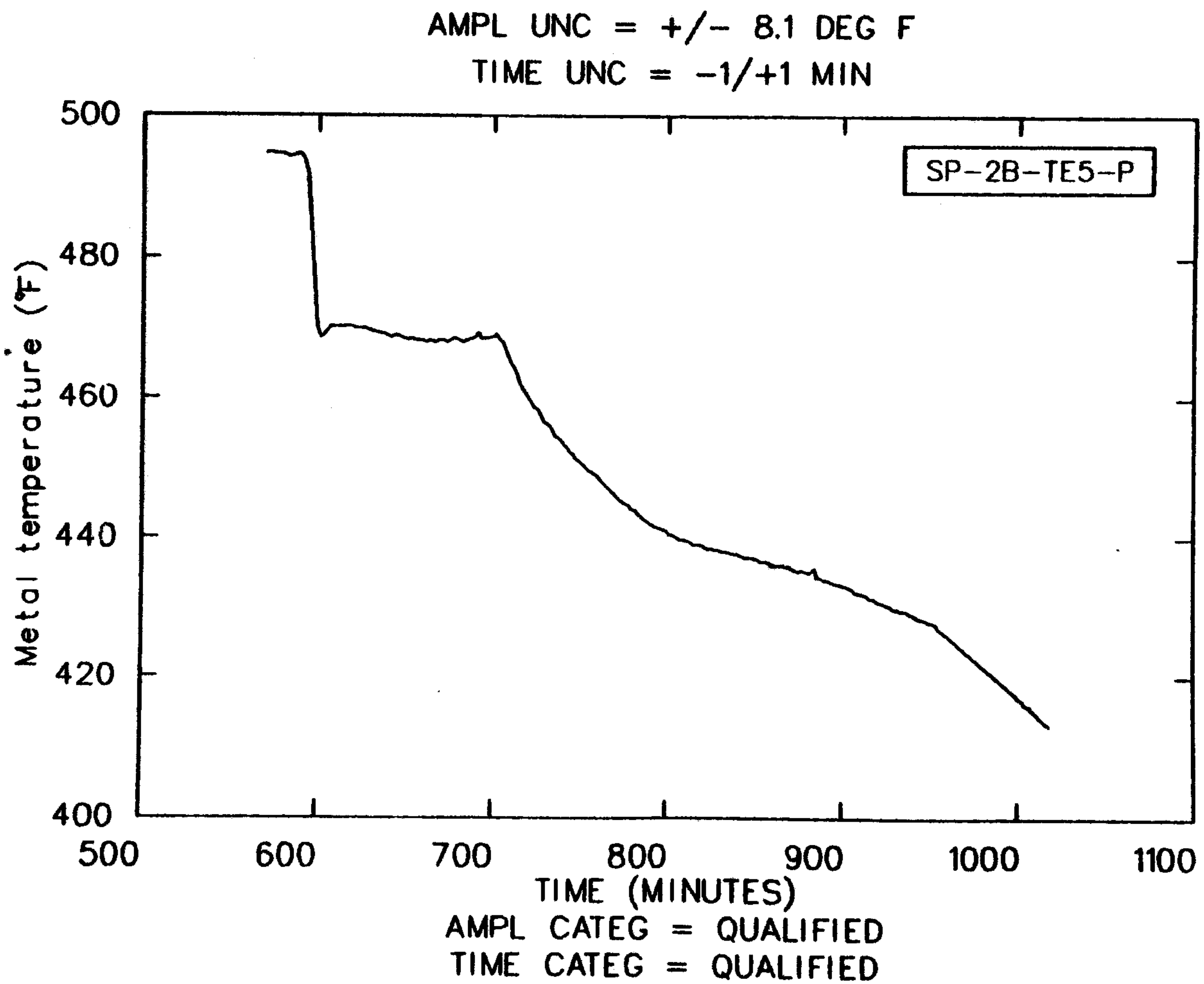


AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

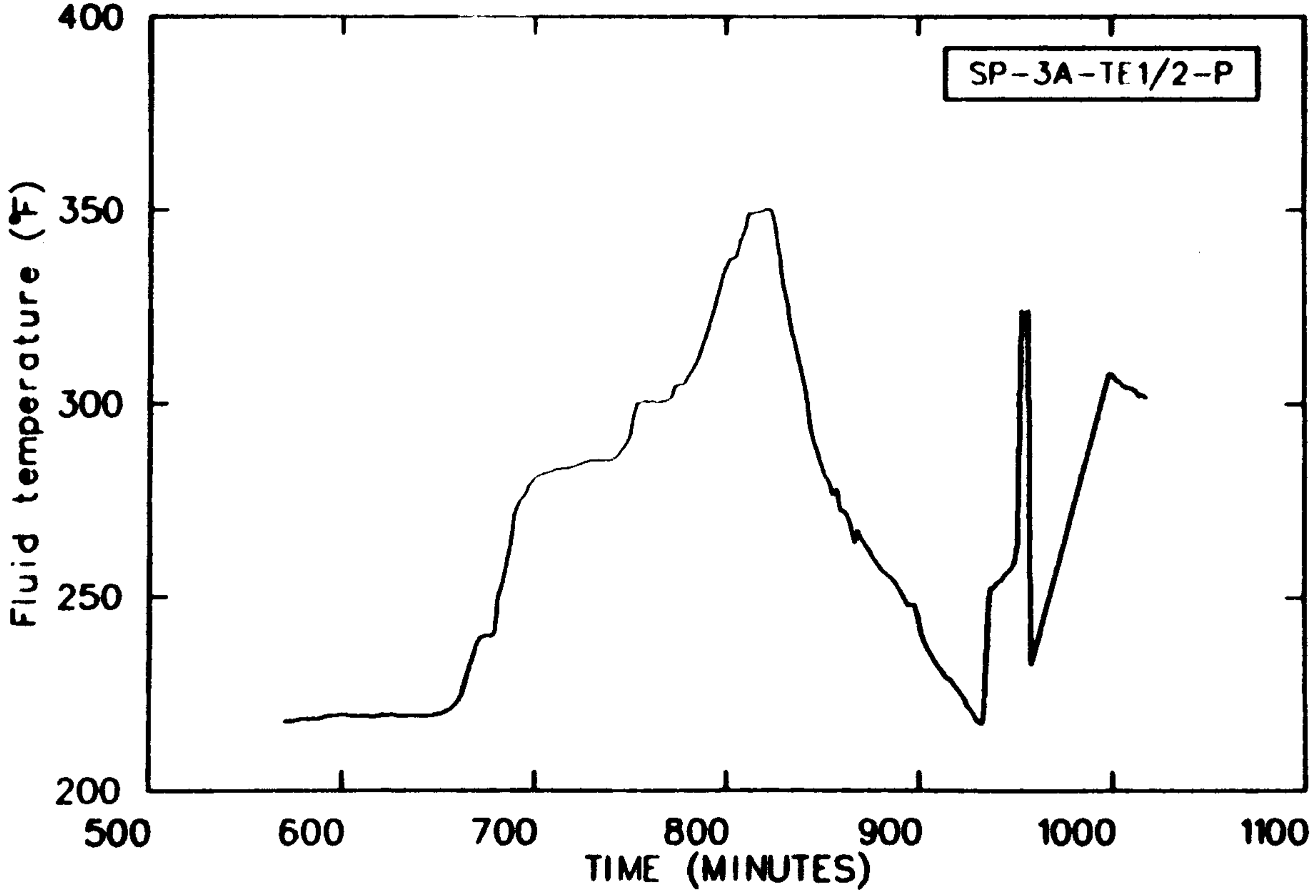

AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2B-TE2-P
Metal temperature (°F)
415
414
413
412
411
440
460
480
500
520
540
560
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2B-TE3-P
Metal temperature (°F)
406
405
404
403
402
440
460
480
500
520
540
560
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

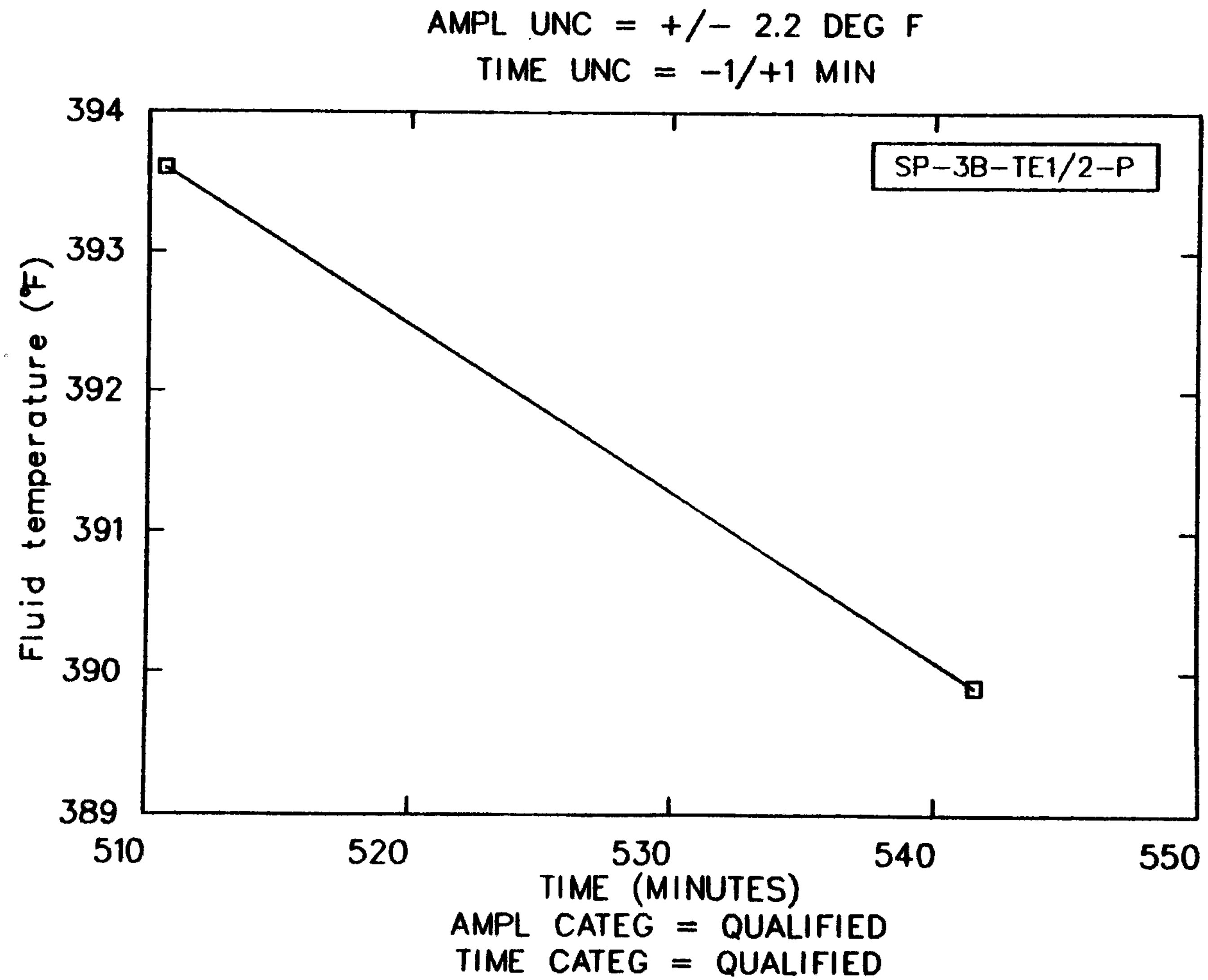

AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2B-TE4-P
Metal temperature (°F)
431
430
429
428
427
426
440
460
480
500
520
540
560
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

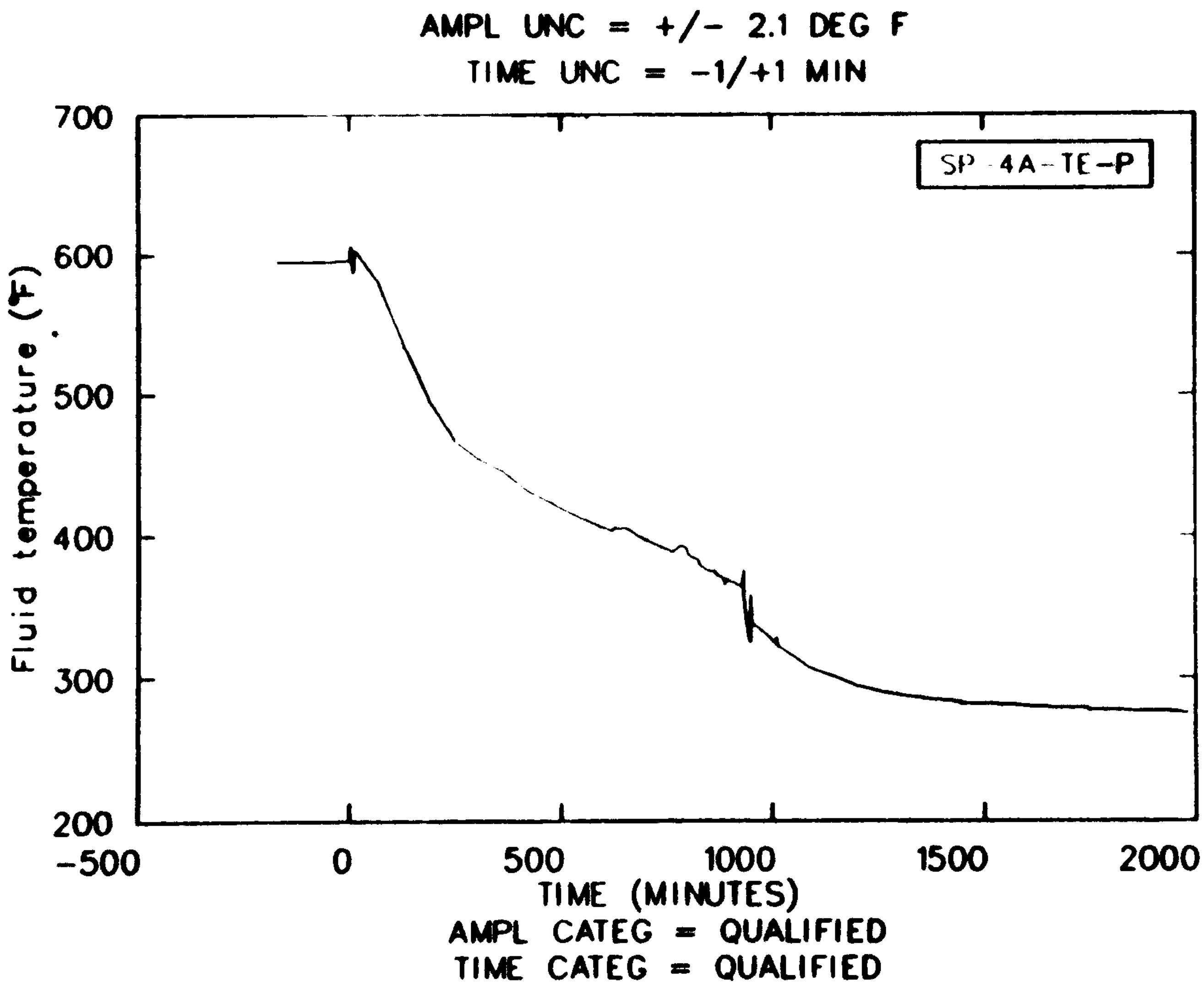

AMPL UNC = +/- 8.1 DEG F
TIME UNC = -1/+1 MIN
SP-2B-TE5-P
Metal temperature (°F)
500
480
460
440
420
400
500
600
700
800
900
1000
1100
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN

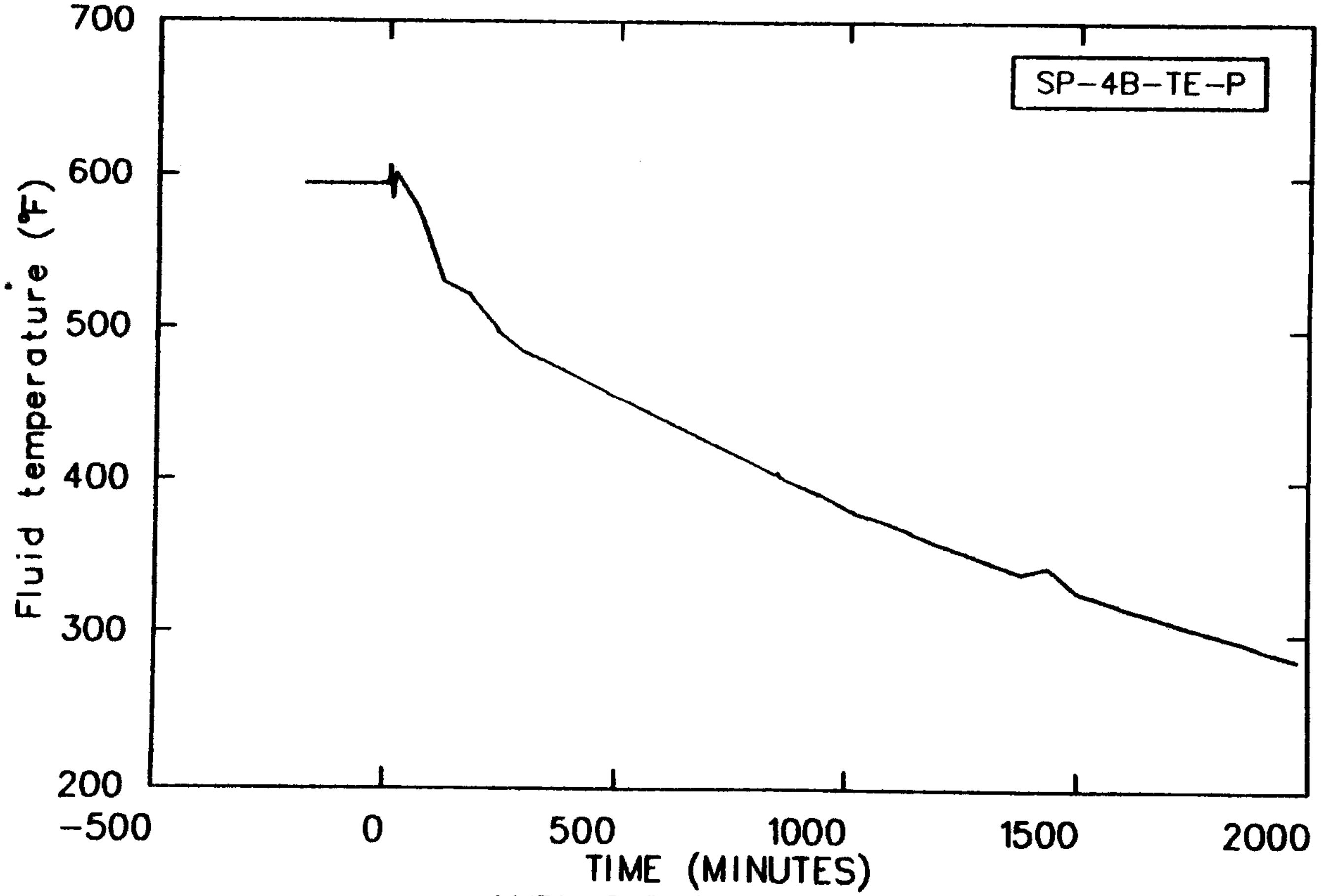


AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

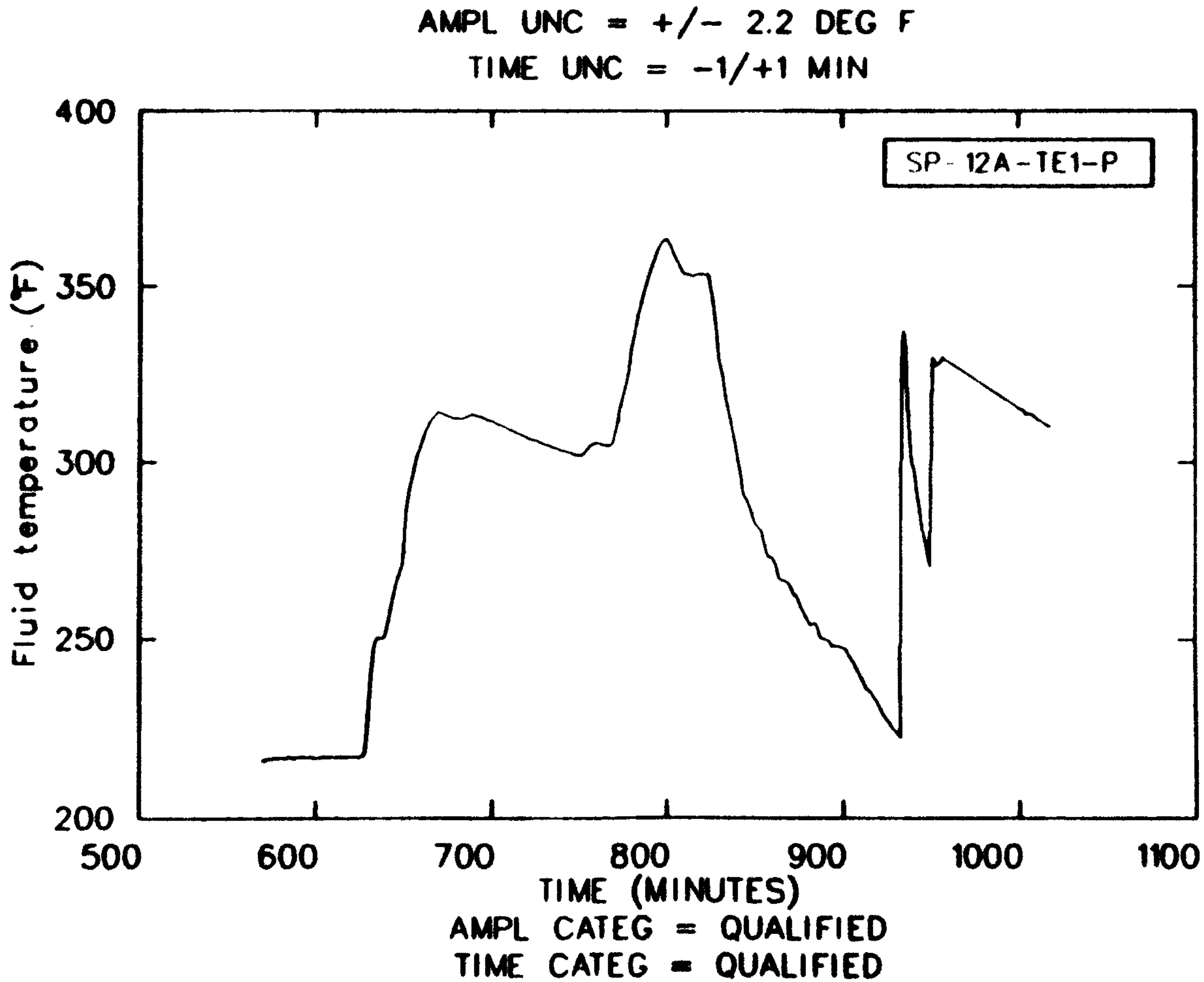

AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN
SP-3B-TE1/2-P
Fluid temperature (°F)
394
393
392
391
390
389
510
520
530
540
550
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

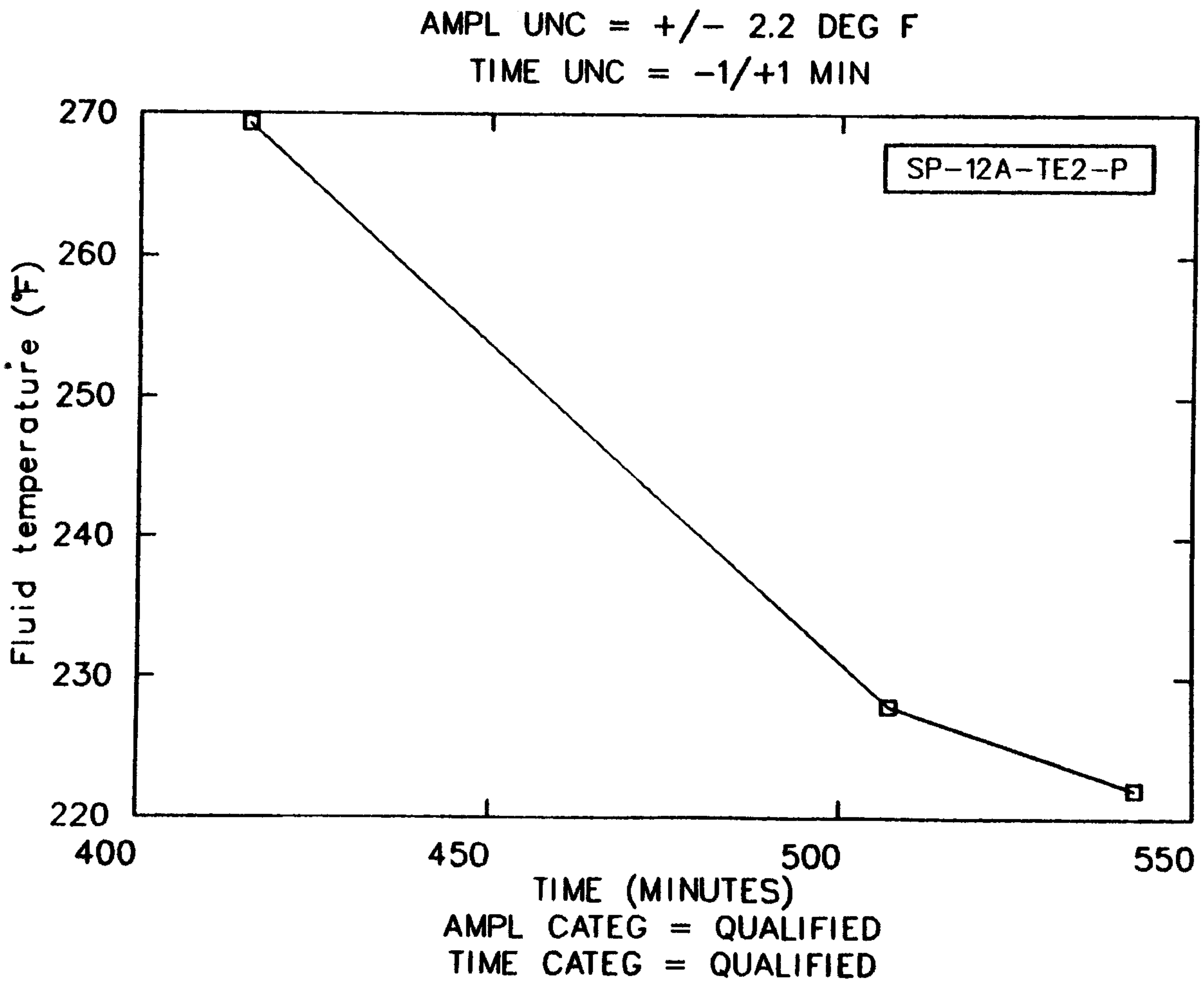

AMPL UNC = +/- 2.1 DEG F
TIME UNC = -1/+1 MIN
SP-4A-TE-P
Fluid temperature (°F)
700
600
500
400
300
200
-500
0
500
1000
1500
2000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

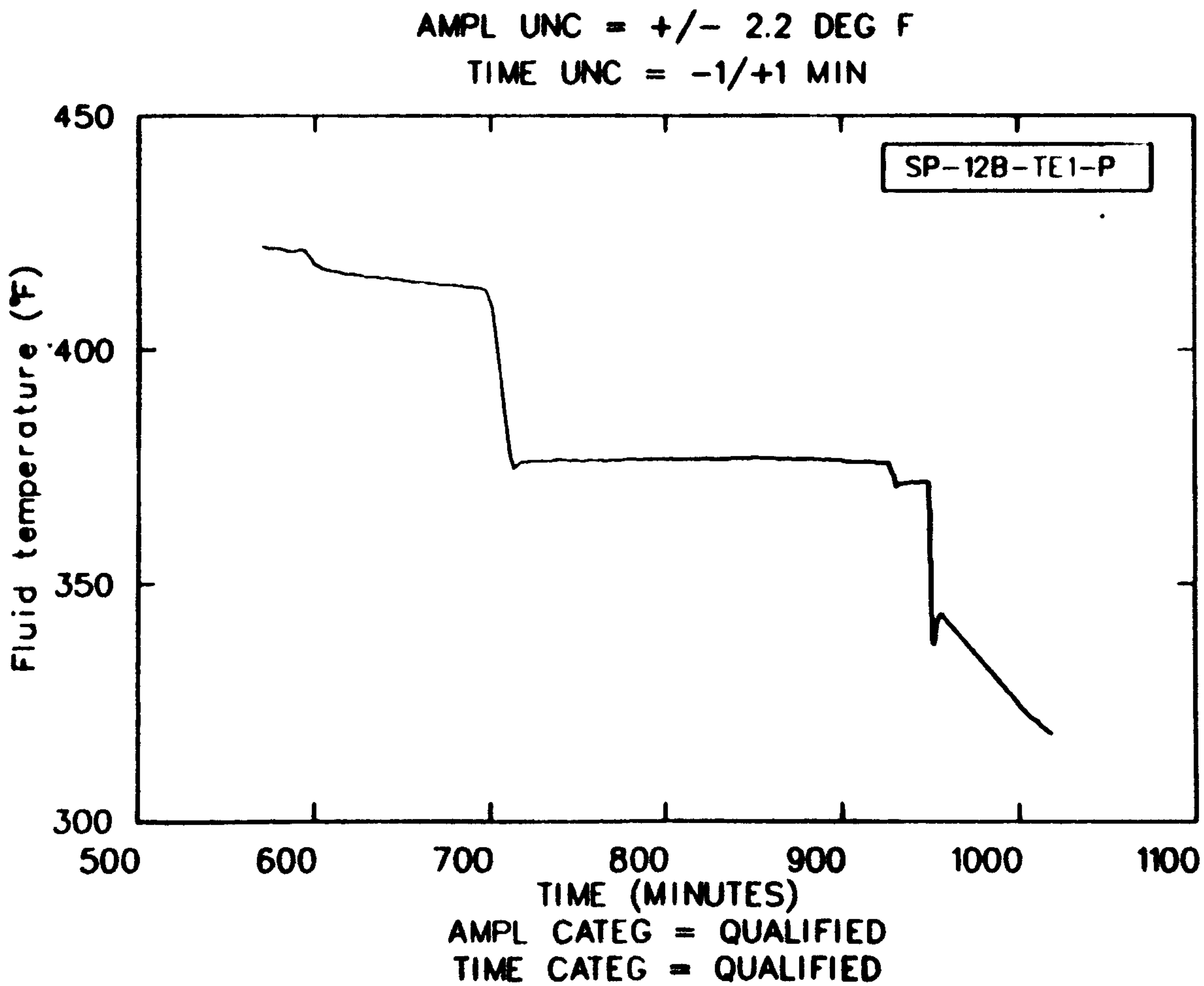
AMPL UNC = +/- 2.1 DEG F
TIME UNC = -1/+1 MIN

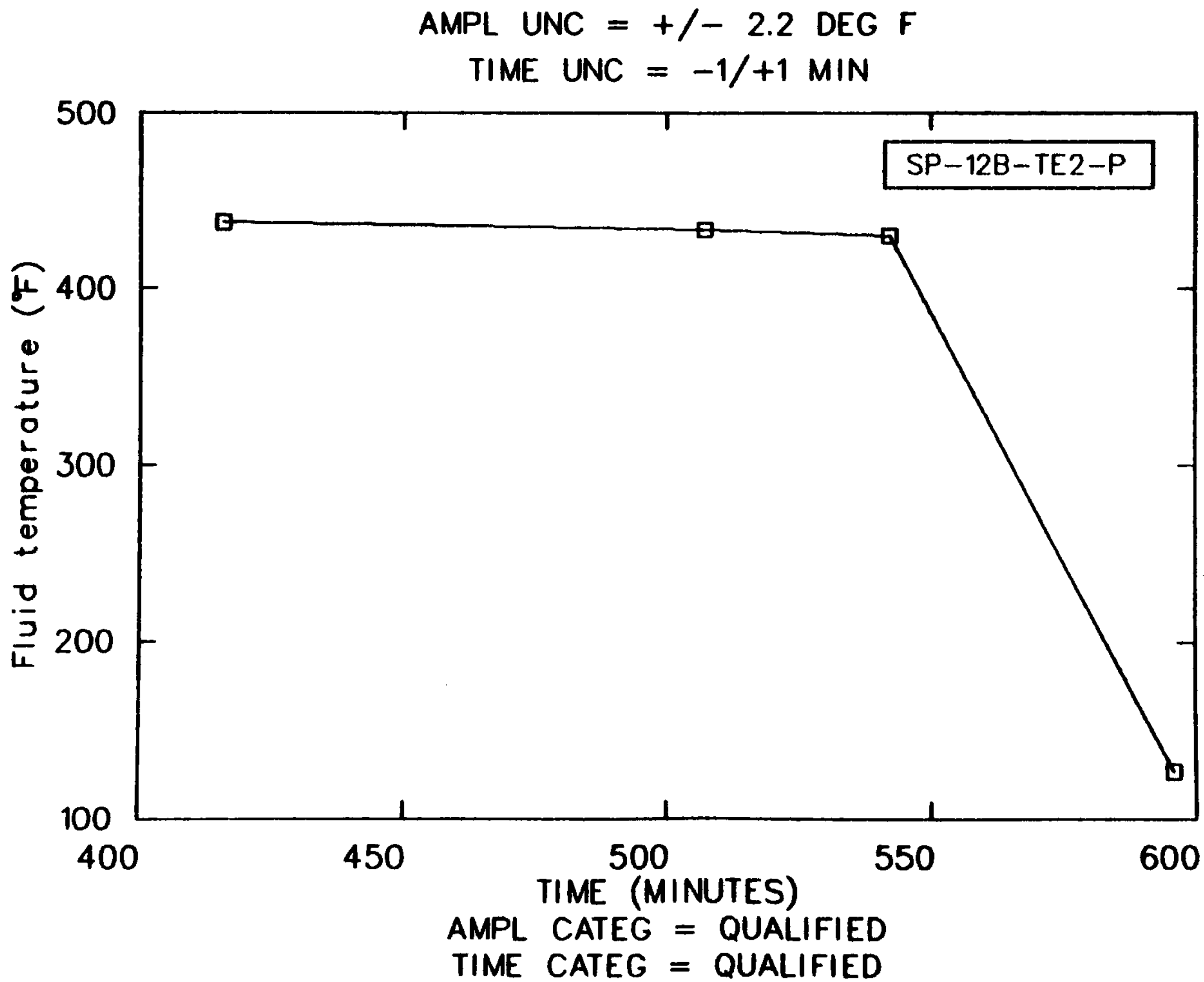


AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

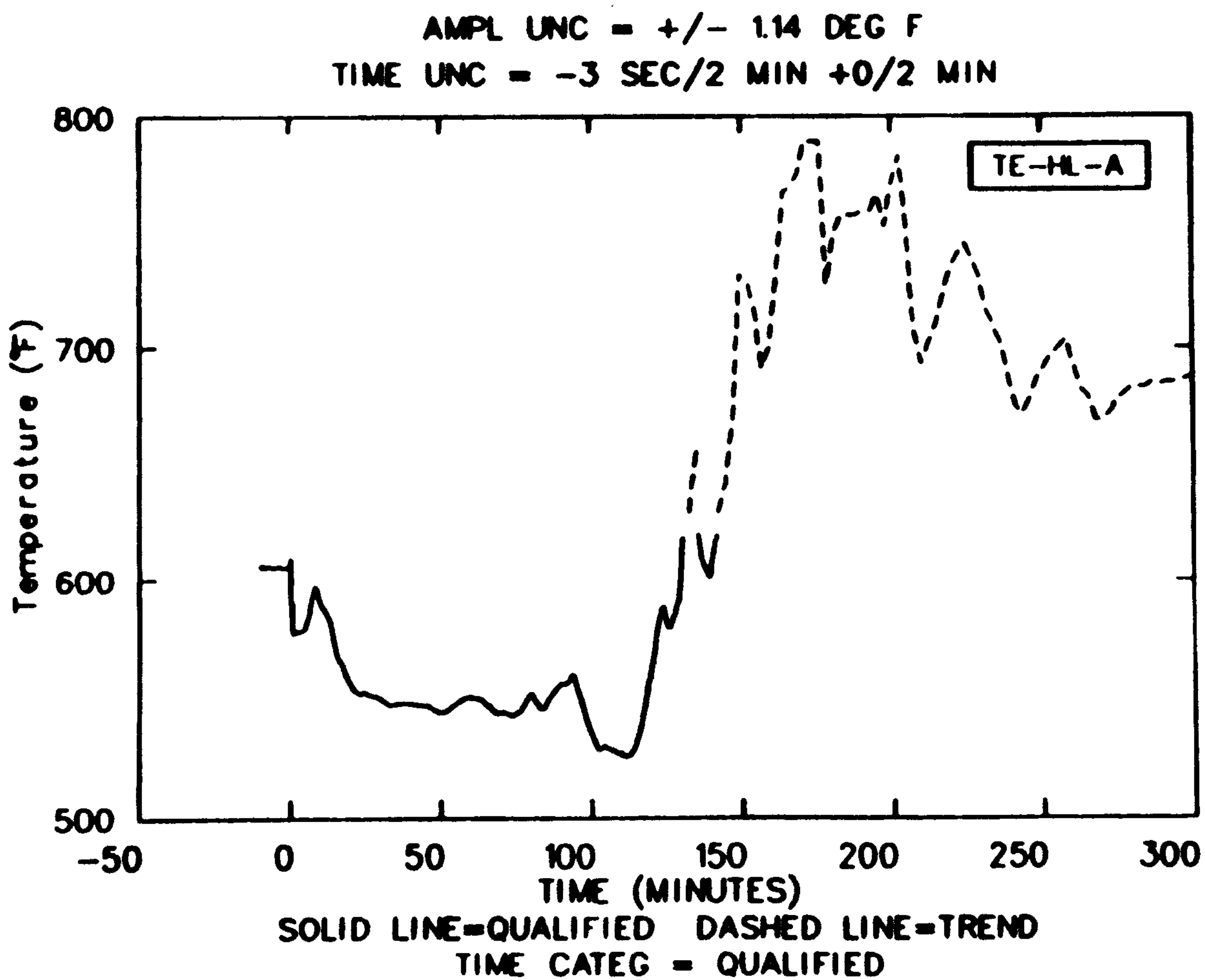

AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN
SP-12A-TE1-P
Fluid temperature (F)
400
350
300
250
200
500
600
700
800
900
1000
1100
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN
SP-12A-TE2-P
Fluid temperature (°F)
270
260
250
240
230
220
400
450
500
550
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

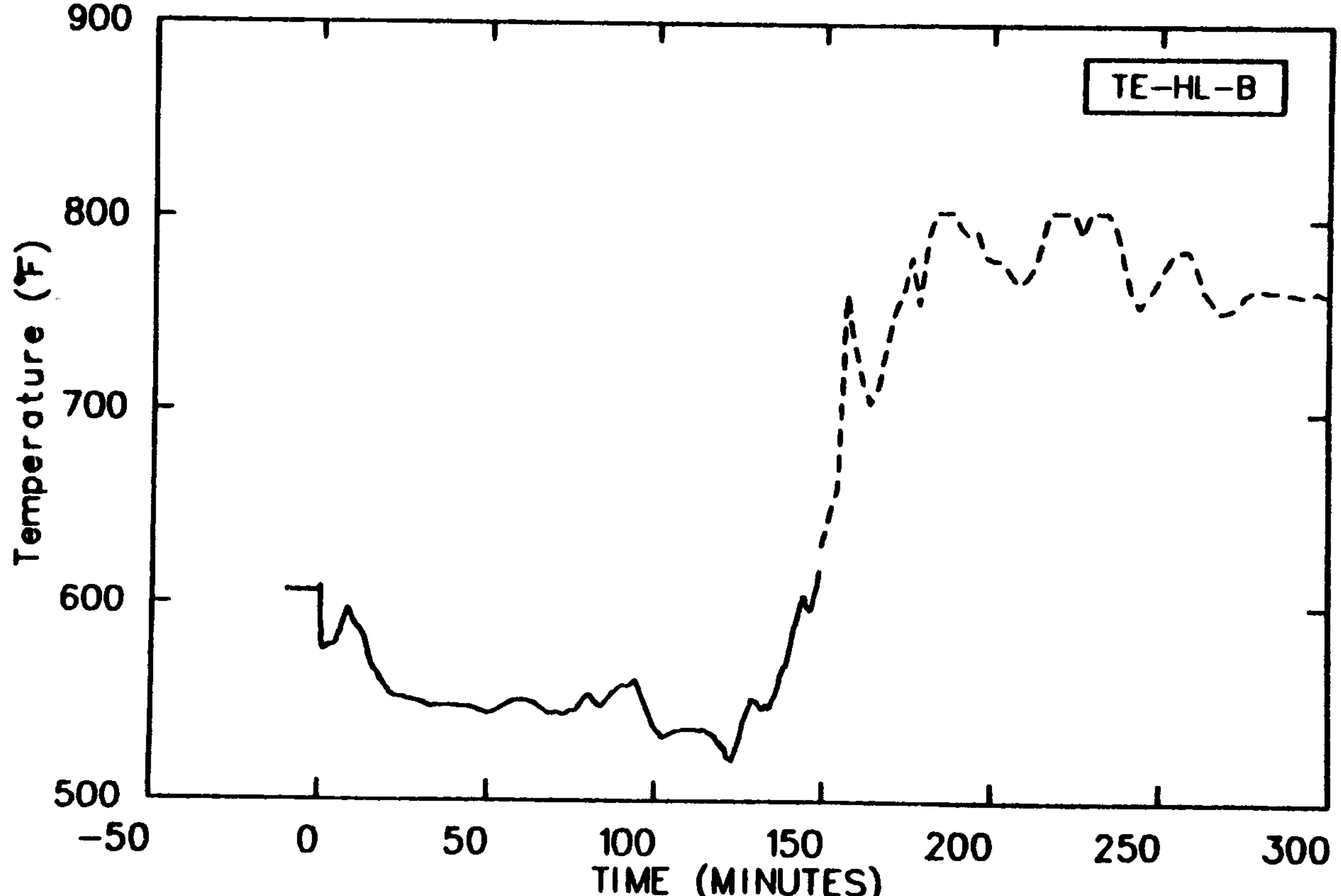

AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN
SP-12B-TE1-P
Fluid temperature (°F)
450
400
350
300
500
600
700
800
900
1000
1100
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED



AMPL UNC = +/- 2.2 DEG F
TIME UNC = -1/+1 MIN
SP-12B-TE2-P
Fluid temperature (°F)
500
400
300
200
100
400
450
500
550
600
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

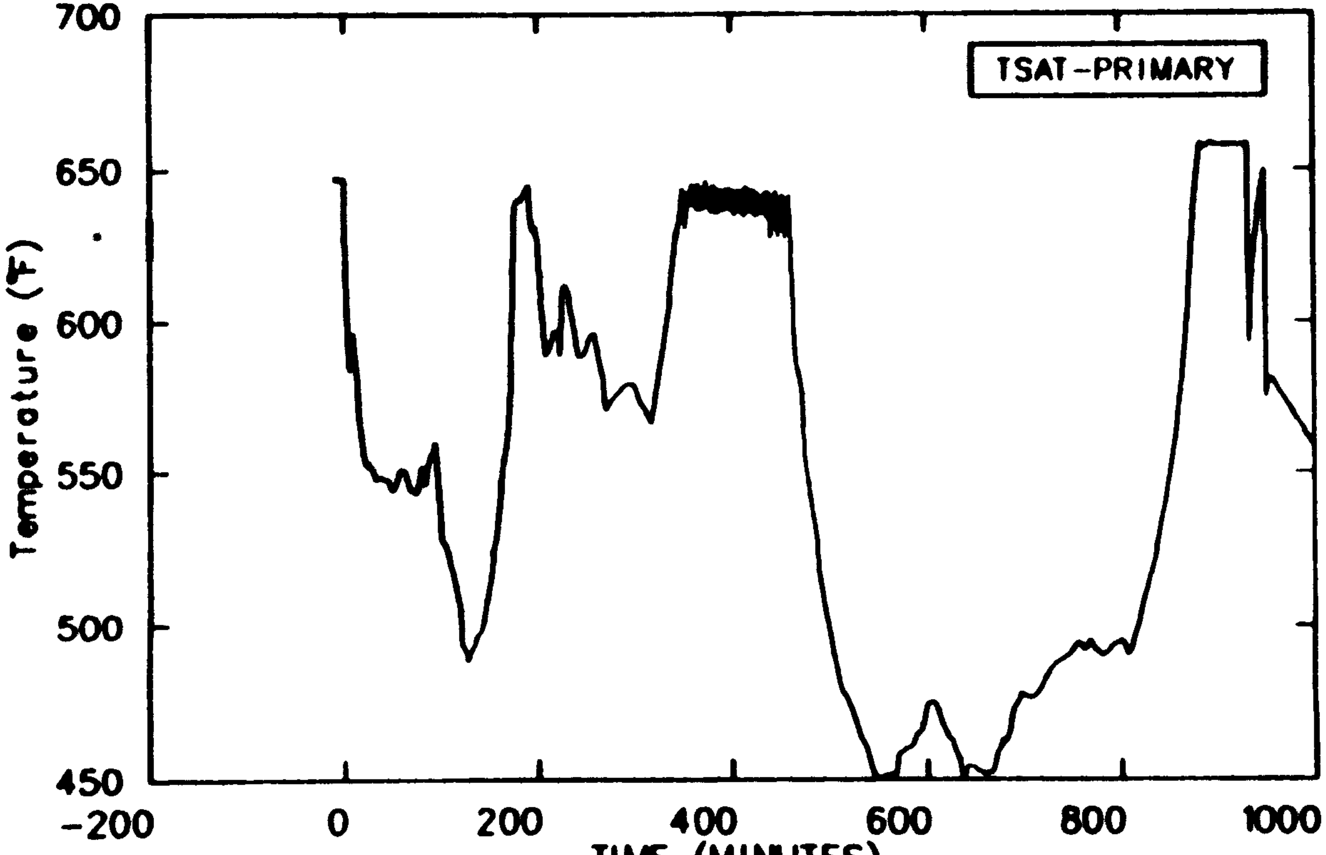

AMPL UNC = +/- 1.14 DEG F
TIME UNC = -3 SEC/2 MIN +0/2 MIN
TE-HL-A
Temperature (°F)
800
700
600
500
-50
0
50
100
150
200
250
300
TIME (MINUTES)
SOLID LINE=QUALIFIED DASHED LINE=TREND
TIME CATEG = QUALIFIED

AMPL UNC = +/- 1.14 DEG F
TIME UNC = -3 SEC/2 MIN +0/2 MIN

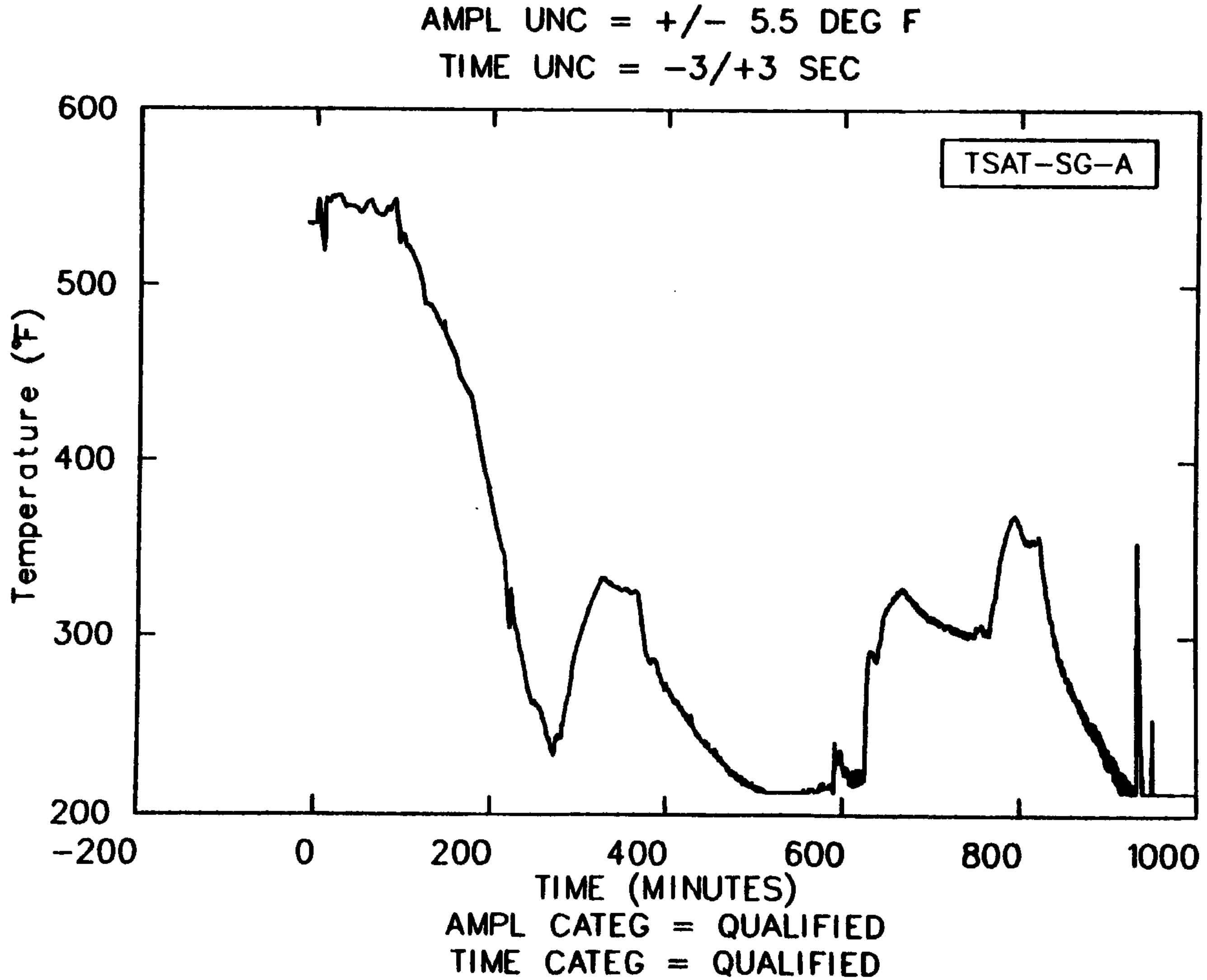


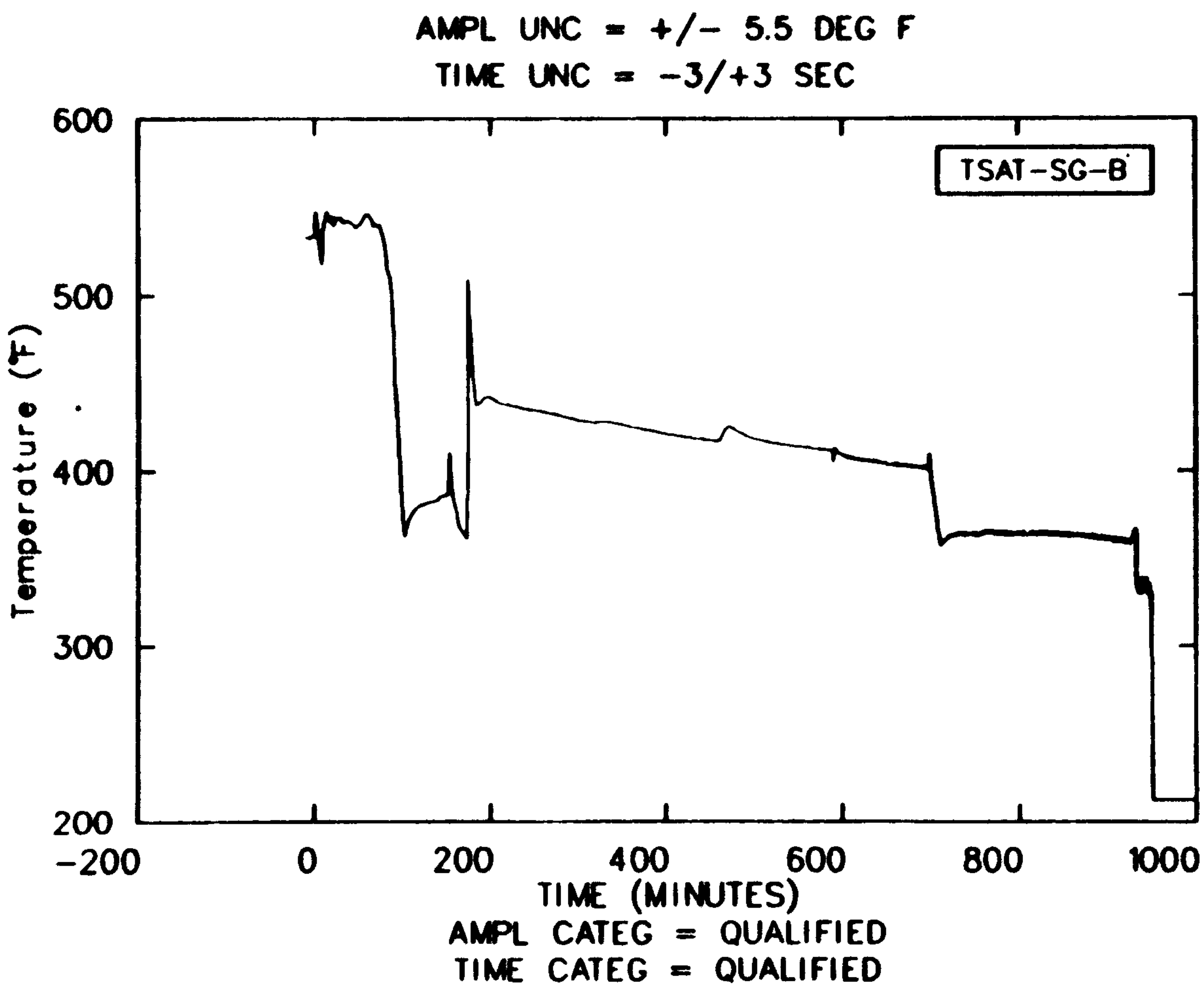
SOLID LINE=QUALIFIED DASHED LINE=TREND
TIME CATEG = QUALIFIED

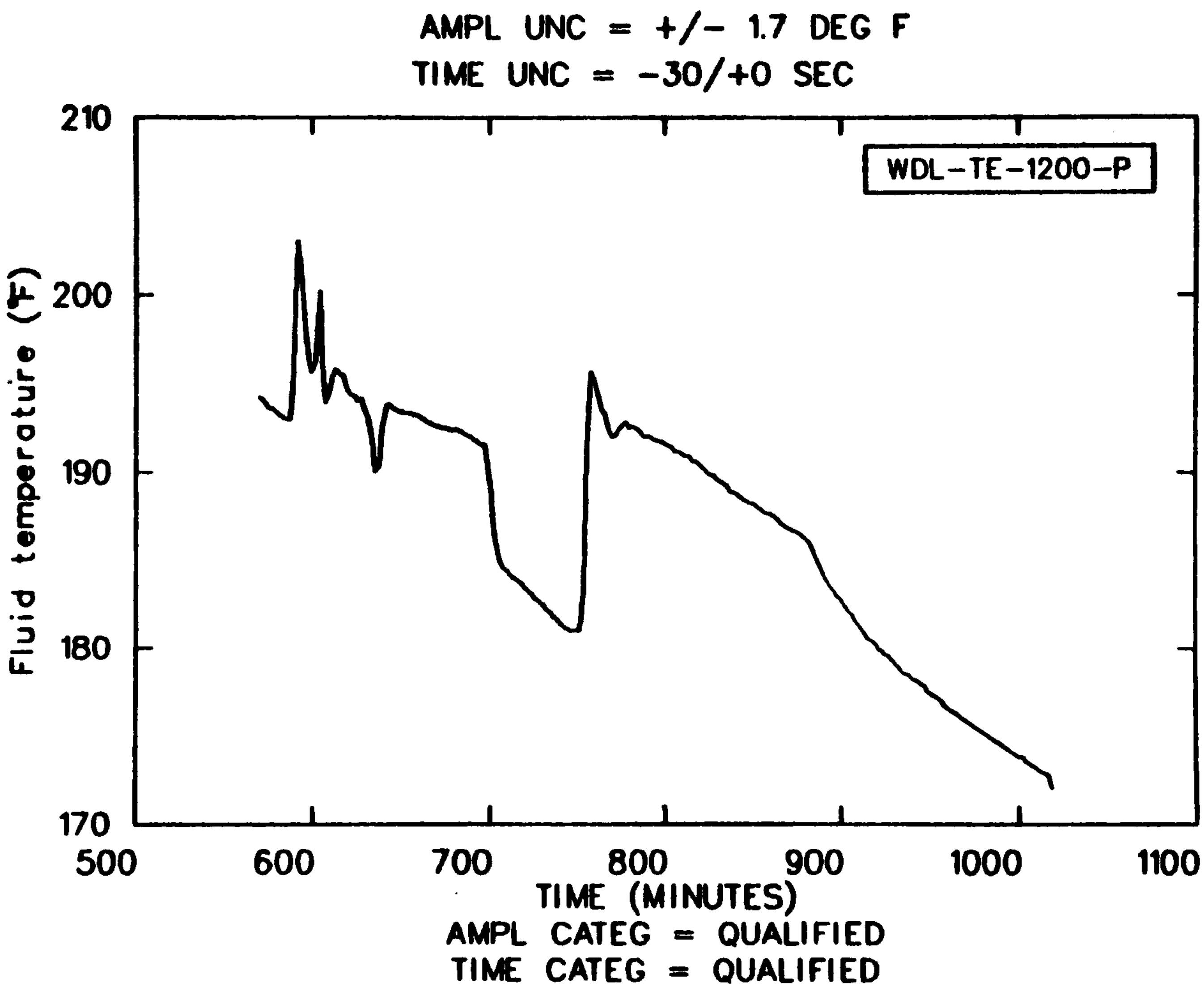
CONSTANT AMPL UNC = +/- 4.8 DEG F

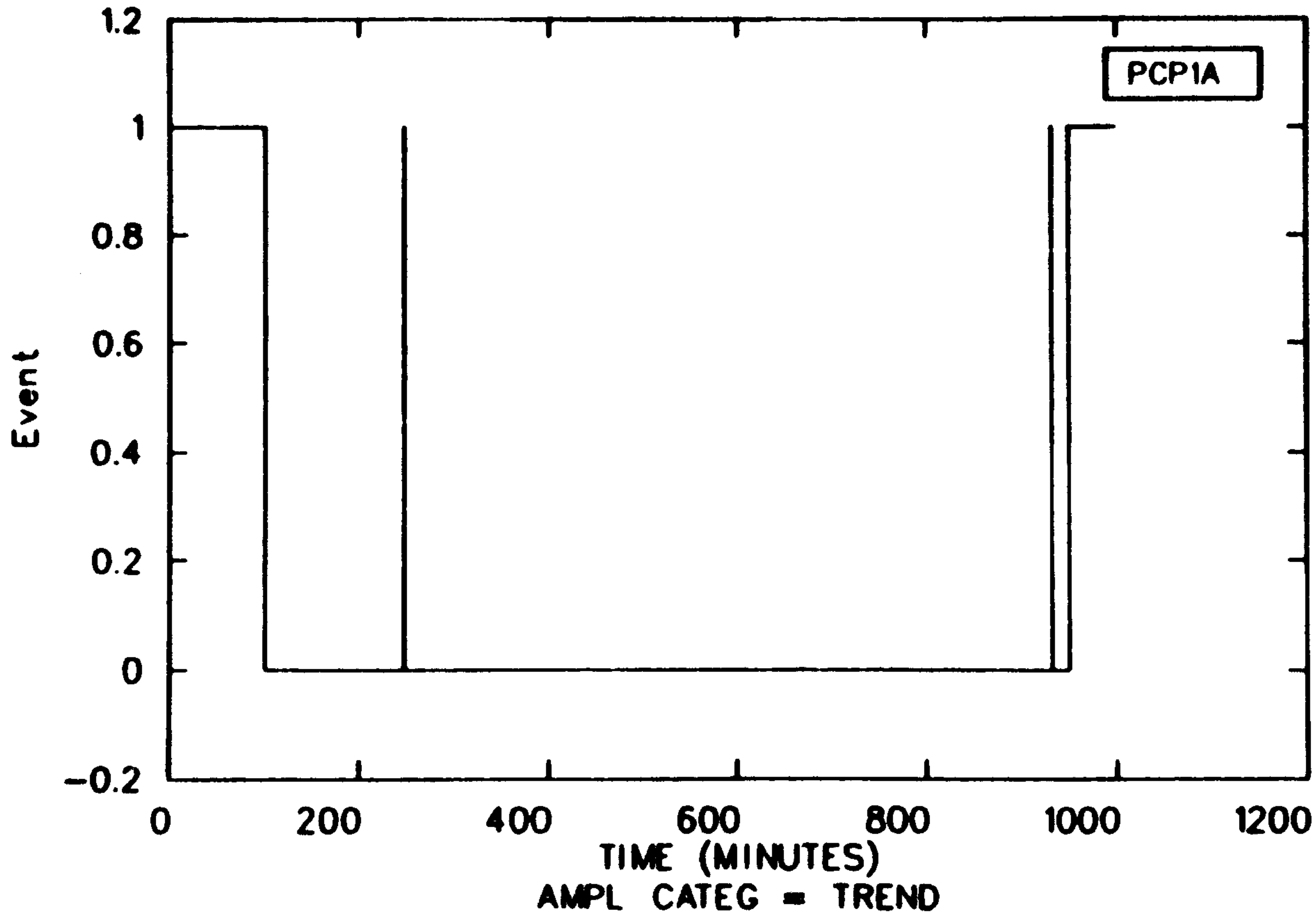


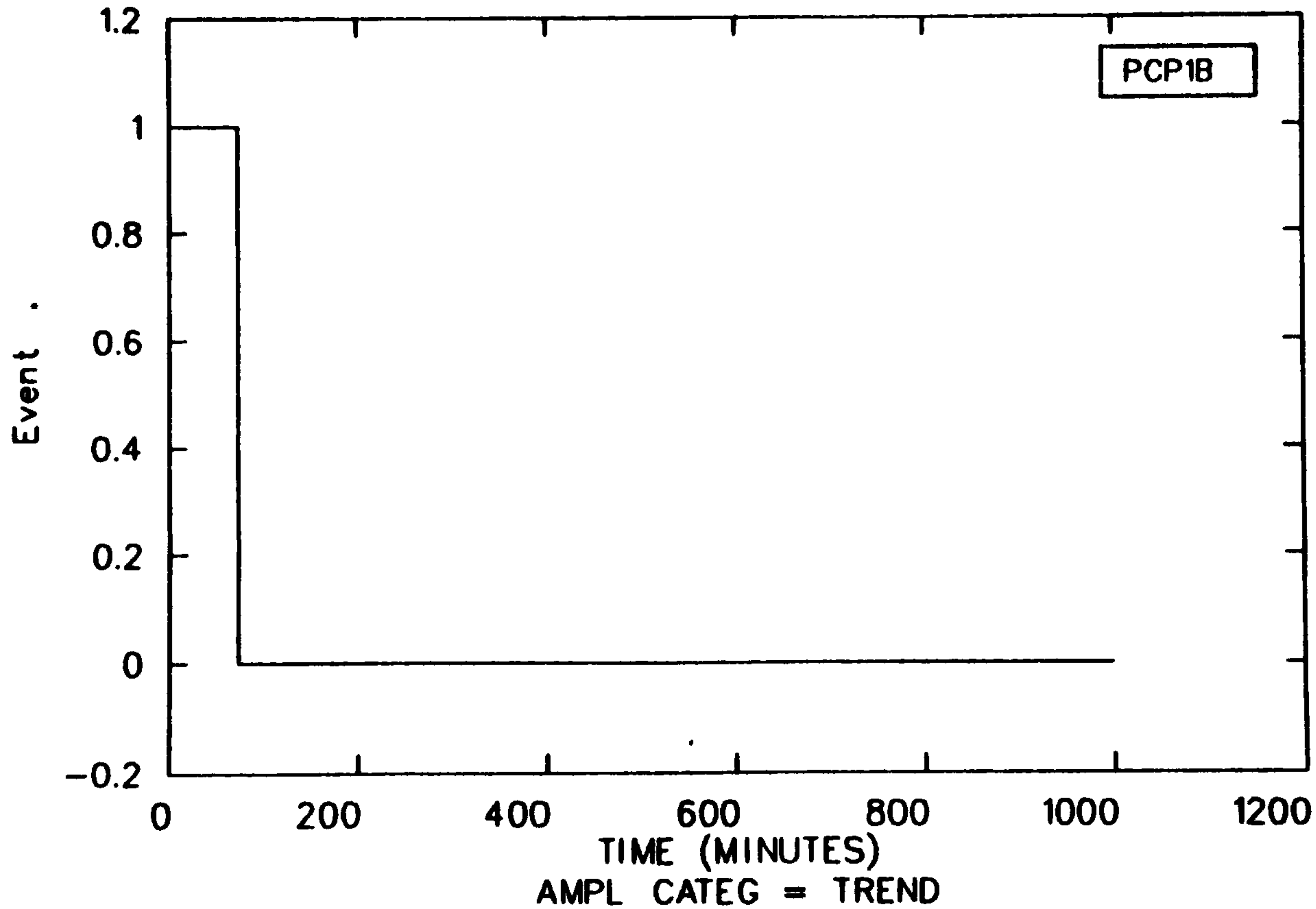
AMPL CATEG = QUALIFIED

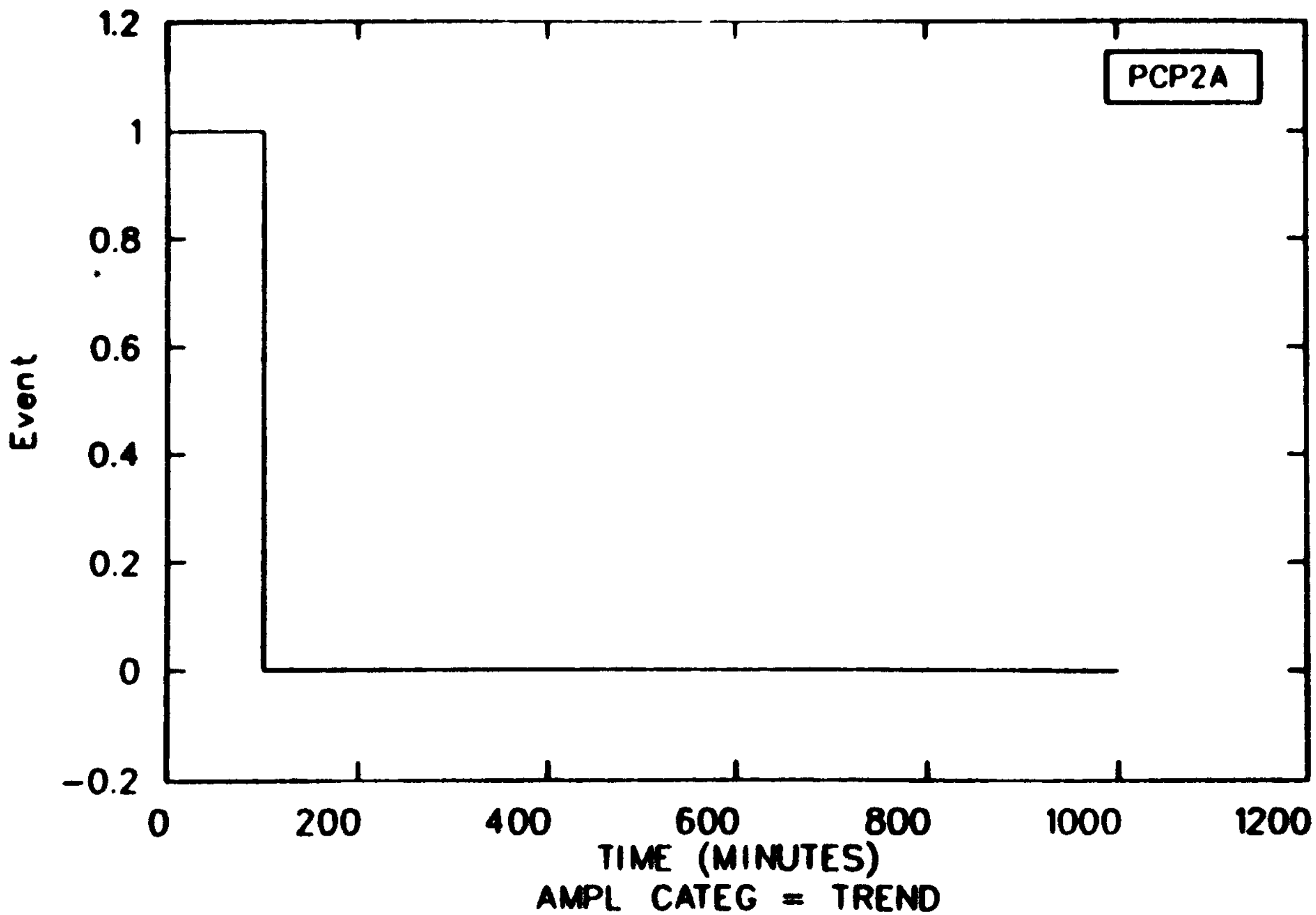

AMPL UNC = +/- 5.5 DEG F
TIME UNC = -3/+3 SEC
TSAT-SG-A
Temperature (°F)
600
500
400
300
200
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

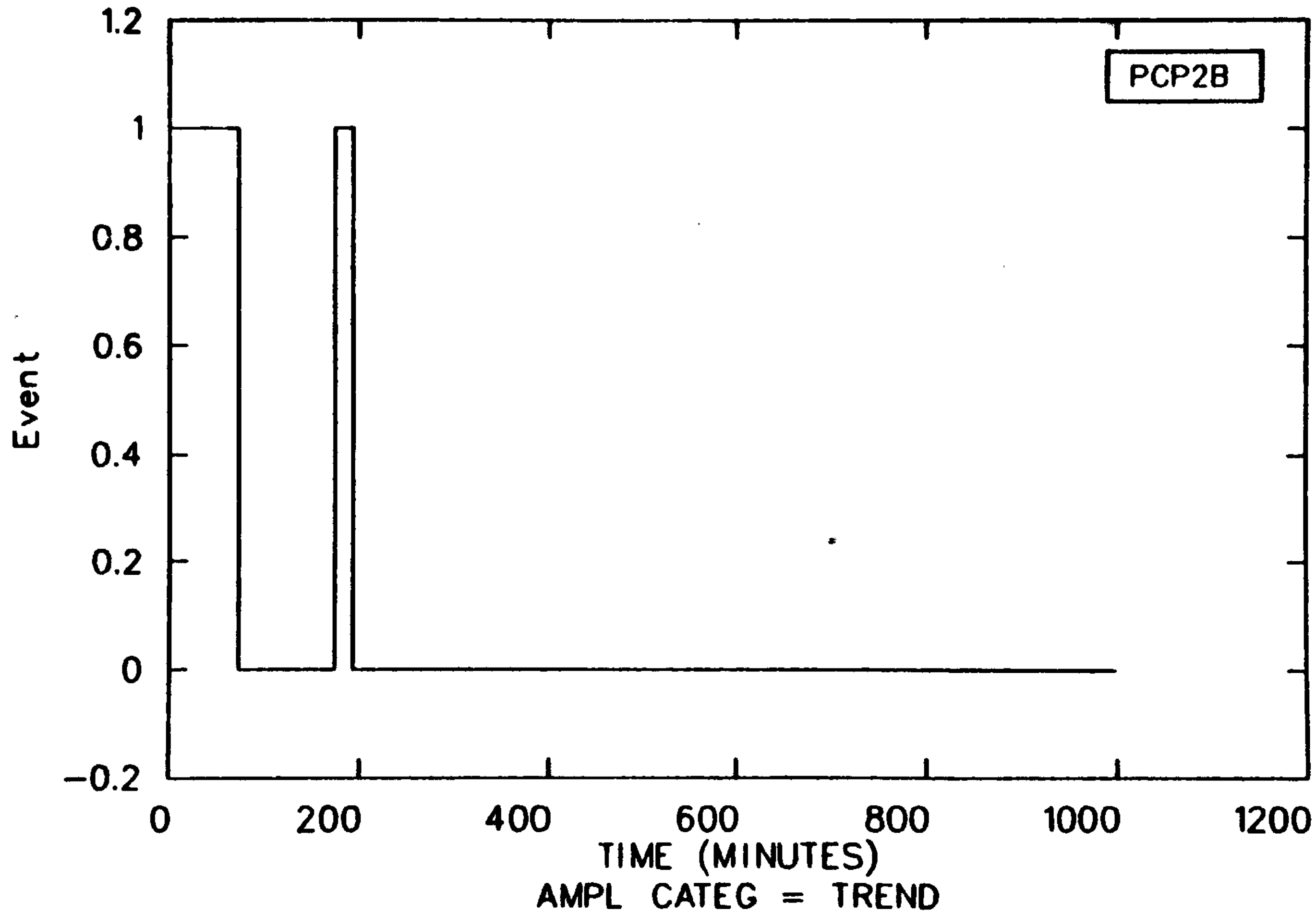

AMPL UNC = +/- 5.5 DEG F
TIME UNC = -3/+3 SEC
TSAT-SG-B
Temperature (°F)
600
500
400
300
200
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

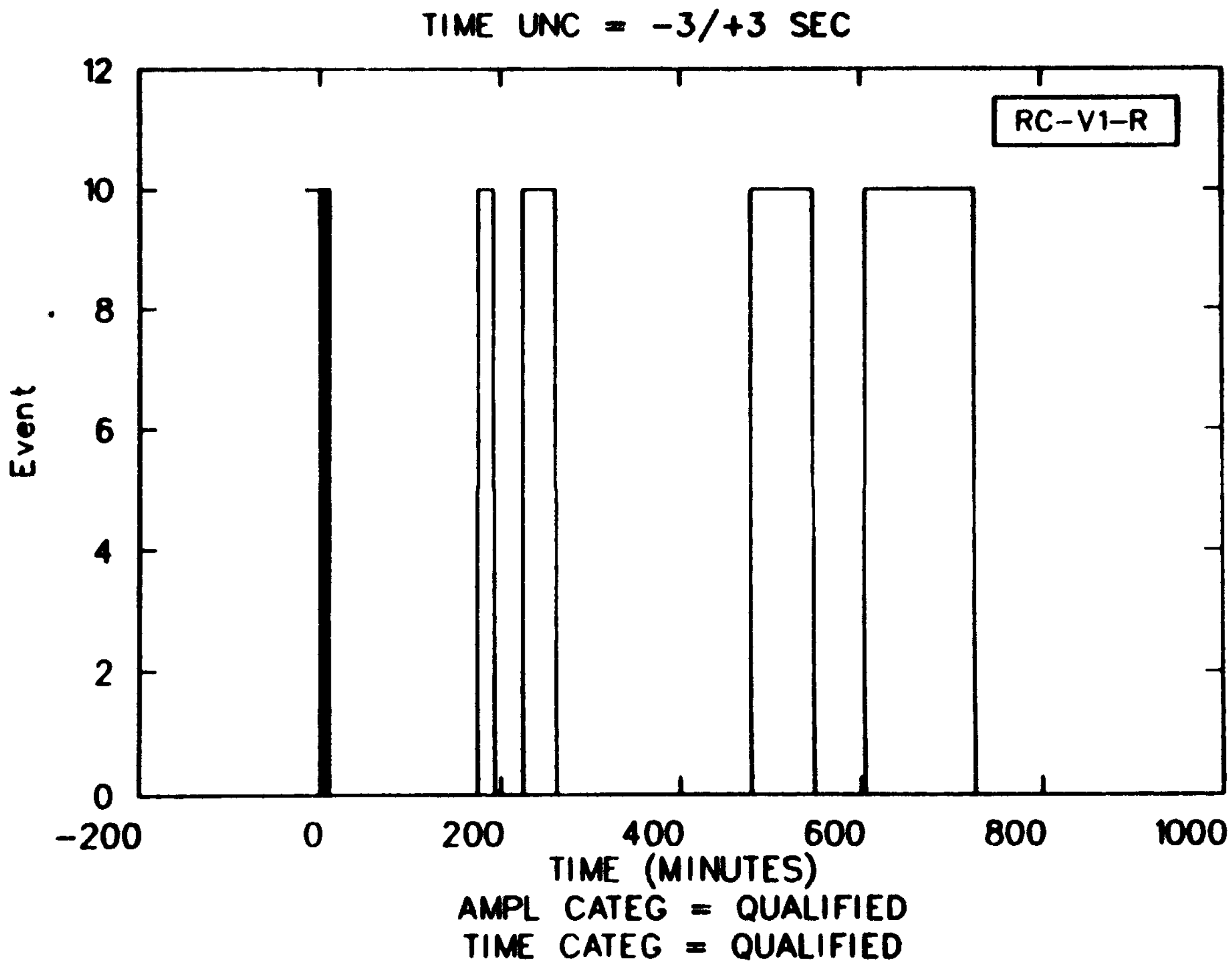

AMPL UNC = +/- 1.7 DEG F
TIME UNC = -30/+0 SEC
WDL-TE-1200-P
Fluid temperature (F)
210
200
190
180
170
500
600
700
800
900
1000
1100
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

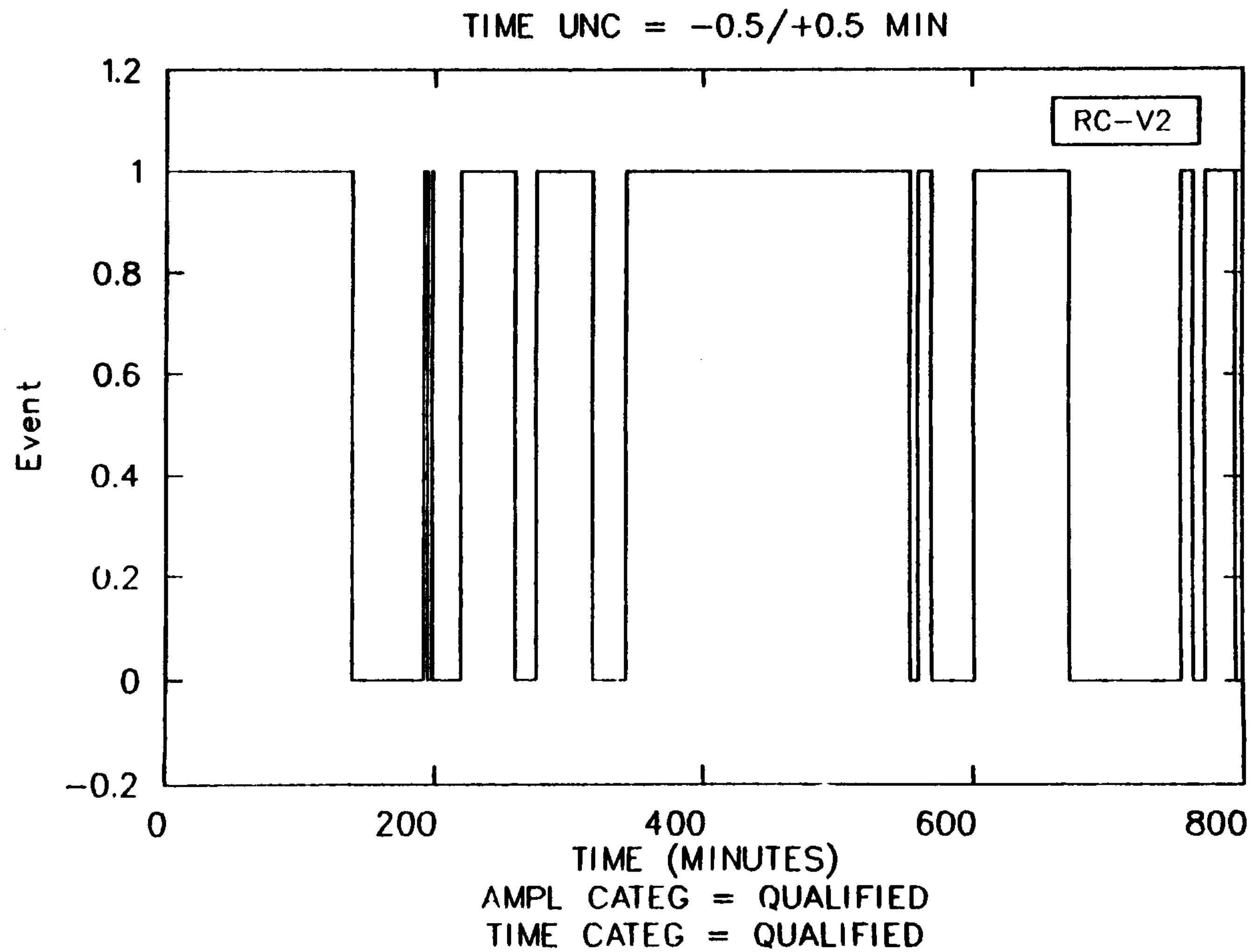

PCP1A
Event
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
200
400
600
800
1000
1200
TIME (MINUTES)
AMPL CATEG = TREND


PCP1B
Event
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
0
200
400
600
800
1000
1200
TIME (MINUTES)
AMPL CATEG = TREND


PCP2A
Event
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
0
200
400
600
800
1000
1200
TIME (MINUTES)
AMPL CATEG = TREND


PCP2B
Event
TIME (MINUTES)
AMPL CATEG = TREND
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
0
200
400
600
800
1000
1200


TIME UNC = -3/+3 SEC
RC-V1-R
Event
12
10
8
6
4
2
0
-200
0
200
400
600
800
1000
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED


TIME UNC = −0.5/+0.5 MIN
RC−V2
Event
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
0
200
400
600
800
TIME (MINUTES)
AMPL CATEG = QUALIFIED
TIME CATEG = QUALIFIED

APPENDIX A

DATA REVIEW TASK

The purpose of the data review task was to provide a single source of TMI-2 measurement data which had been systematically analyzed and corrected. These data were then put into a dedicated TMI-2 data base along with the associated uncertainties.

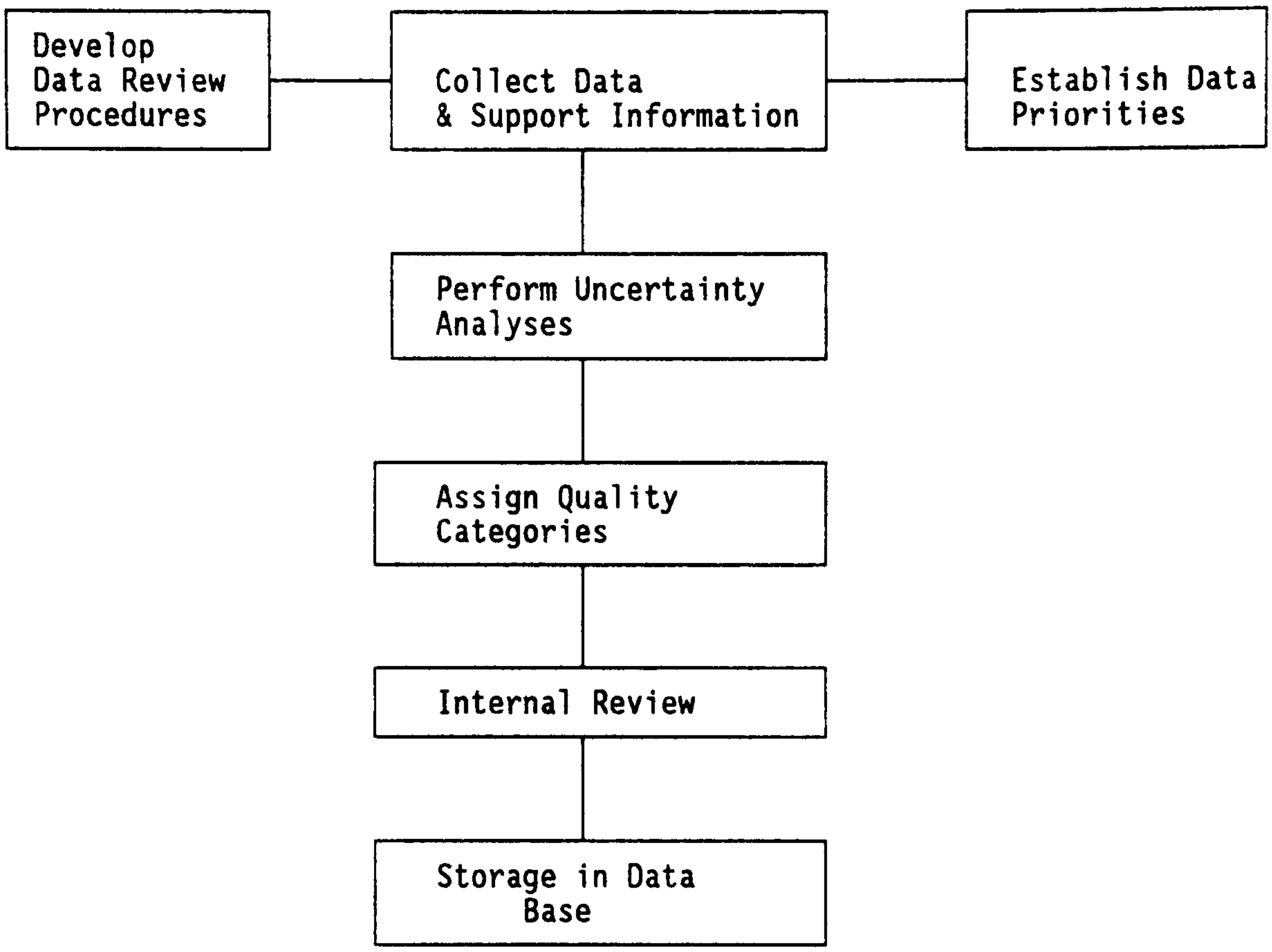
The Data Review Task was a direct result of the Analysis Exercise which required a common and sole source of measurement data for all participants. The primary elements of the task can be seen on the flow chart on Figure A-1. Because of the limited time available for performing this task, the three items on the top of the chart were performed at approximately the same time, i.e., develop procedures, collect data, and establish priorities. An associated task done at this time was the development of the Data Base. The TMI-2 Data Base is discussed briefly in Appendix B.

1. Establishing Priorities and Procedures

There were some 3000 measurements being made at TMI-2, however, not all of these were being recorded at the same time. The analysts who were setting up the structure of the Analysis Exercise found about 300 measurements of interest and then selected and prioritized 170. This extensive list containing more information that was essential to the

Figure A-1

DATA REVIEW TASK FLOW CHART



Analysis Exercise. The 170 selected measurements were prioritized from 1 to 4 in order of importance. Measurements were added to and moved within the priority structure as the task progressed and priorities changed. Approximately half of these measurements had been analyzed and put into the data base at the task completion.

It was necessary to prepare the methodology for performing the uncertainty analyses on the data, the criteria for determining the data quality categories, and the internal review process. These procedures were prepared at the beginning of the program and were modified as the realities of the task dictated.

2. Data Collection and Support Information

Measurements at TMI-2 were recorded from typical process instruments on various media, i.e., computer printouts, magnetic tapes, analog stripcharts (both multipoint and single line). Most of these instruments continued to operate throughout the accident and actually very little recorded data were lost. In several cases, stripchart recorders had paper jams which were not corrected for several hours. In other instances, the measurement systems were over ranged by abnormally large input signals which caused the electrical systems to saturate.

After the accident all records were impounded at TMI and access was allowed only for copying or study. By the time this task began (some six years after the accident) a rather extensive library of microfiche and film of the recorded data was available. These were obtained for the data review task along with copies of magnetic tapes. This was the extent of the data sources for the task except for some color photographs of multipoint stripcharts which were requested.

Most support documentation for the uncertainty analyses was obtained by request. These were items such as instrument calibrations, manufacturers specifications, operating manuals, etc. Unfortunately it was not possible to obtain the quantity and types of information necessary to do a classical uncertainty analyses and data qualification on most of the data. The result was that the uncertainty methodology was modified to accommodate the information available and the use of estimates and engineering judgment was greatly increased.

Data were extracted and stored on a main frame computer. This process was accurate for computer printouts and magnetic tapes. Stripchart data had to be digitized which increased the uncertainty in that data. Major problems were encountered in identifying printed numbers on the multipoint recordings even when extensive use was made of enlarged color photographs of the recordings.

3. Data Uncertainty Analysis

For this task we have defined data uncertainty as the maximum probable amount of error in the data. Because of the unavailability of support documentation, some major simplifications were necessary in our approach to determine uncertainties. The method decided upon was derived from that advocated by Abernathy[A-1]. One major change was that we treated all errors as being bias-range errors. In those cases where this was obviously not true, conservative substitutions were made. The reason for this was two-fold - we wanted to simplify the analyses and presentation of the uncertainties and we found very little error information that was not a function of bias. The use of an error as a function of range rather than reading is a conservative approach. Much error information came from calibration sheets which gave only the error tolerance of the circuits which are bias errors.

The following two equations, therefore, were the basis for our analyses. The first is the basic equation for determining the uncertainty in a measurement and the second is for a calculated parameter with three independent variables.

$$B = \left[\sum_{i=1}^{n} b_i^2 \right]^{1/2}$$

$$B_w^2 = \left(\frac{\partial w}{\partial x} B_x\right)^2 + \left(\frac{\partial w}{\partial y} B_y\right)^2 + \left(\frac{\partial w}{\partial z} B_z\right)^2$$

where w = f(z,y,z), a generic function of three independent variables

B = measurement uncertainty or error bounds

b = elemental measurement error.

4. Determining Data Quality Categories

It was found convenient in this program to assign a quality category or label to each data set to generically describe its relative quality. This makes it possible for a user of the data to gain some concept of the data quality without referring to the uncertainty values in the data base. The terms Qualified, Trend and Failed were used to describe the data sets. Qualified data was defined as data which accurately represented the physical phenomenon being measured and had reasonably sized uncertainty. Trend data are defined as data which only approximately represented the physical phenomena being measured and had uncalculable or unreasonably large uncertainties (these data do contain some useful information). Failed data contained no useful information and was not retained in the data base. The quality category was assigned after reviewing the data and associated uncertainty analysis. If it was not possible to do an uncertainty analysis on the data, it was automatically categorized as Trend.

An internal review was made of the uncertainty analysis and categorization process by a Data Integrity Review Committee (DIRC). This committee was made up mostly of individuals working on the TMI-2 data review task but outside specialists were brought in as needed.

Generally, the individual who performed the analyses presented his work to the DIRC and sought their approval. Very often it was necessary for the analyst to try several times before getting DIRC approval of his analysis and assigned quality category. After DIRC approval the data were put into the dedicated TMI-2 Data Base.

REFERENCES

A-1. R. B. Abernethy, R. P. Benedict, "Measurement Uncertainty: A Standard Methodology," ISA Transactions, Vo. 24, Number 1, 1985, pp. 75.

APPENDIX B

DATA BASE SUMMARY

There are four TMI-2 data bases[2] which provide access to the Accident Sequence of Events (SOE)[3], the plant measurements during the accident (ICBC)[3], the core end state (CCB)[4], and the results of sample examinations (CSE)[5]. These data bases were developed to function on a personal computer CIBM compatible and are described in detail in the references.

The reviewed data described in this report has been placed in the initial and boundary conditions (SCBC) data base. This data base presents the data in either graphical or tabular formats at the user's discretion. This data base, also, provides the user with the compatibility to manipulate the data. Possible manipulations include for example the addition, subtraction, multiplication or division of two data channels, addition, subtraction, multiplication or division by a constants differentiation and integration.

A user can upload his own data or calculational results into the data base for graphical comparison to the TMI-2 data.

Two additional data bases are maintained on the INEL mainframe computers. The first data base, TMIRAW, includes all the reactimeter data and the strip and multipoint recorder charts which have been digitized. No corrections or modifications have been made to the data in TMIRAW. The second data base (TMIQUAL) contains the reviewed data. These data may have had corrections applied or be composite data (e.g., composite of strip chart and reactimeter data). The only difference between TMIQUAL and ICBC is that data downloaded to the personal comptuer environment may have been decimated. Decimation of the data was done to improve the efficiency of the ICBC data base.

APPENDIX C

SOURCES OF DATA AND SUPPORT INFORMATION

The Data Review Task required not only the instrument measurement data recorded at TMI-2 but a great deal of supporting information on the reactor system and facility physical configurations. The sources of data and support information were documents ranging from formal reports to microfische. A TMI-2 library was setup at INEL where reports, papers, drawings, etc., were gathered. Included were over 100 microfilms and four books of microfiche. The microfilm contained most of the stripchart data used in this task as well as copies of computer printouts. The support information consisted of items such as design specifications, instrument calibration sheets, manufacturers equipment instruction sheets, drawings and schematics. Often additional support information needed for an analysis had to be requested from TMI-2 after an analysis was started.

Basic information on the instrument systems was generally available, i.e., items such as system diagrams and manufacturers instruction sheets. The result was that the analyst usually knew and understood how the measurement systems worked. The major information lacking was calibration information on the measurement systems and components, especially near the accident date. It was often impossible to find detailed information on items such as the exact location of a transducer or the functional details of a particular circuit. The lack of support information was responsible for the uncertainty analysis methodology choosen. The methodology ultimately used was a simplified version which was somewhat less rigorous than a classical approach.

The remainder of this appendix gives details on the sources of measurement data which were contained in the documentation reviewed for this task.

1. Reactimeter

The reactimeter was a high quality 24 channel data acquisition system provided by Babcock & Wilcox. Its name was derived form its capability to record reactor core reactivity, however, this function was normally used only during reactor startup testing. The reactimeter also recorded some of the key reactor parameters, and it was the availability of these data that made the reactimeter recordings particularly valuable to the Accident Evaluation Program.

The 24 channels of data were recorded on magnetic tape in the form of voltage readings. These voltages were directly proportional to the parameters being monitored, e.g., pressure, temperature and flow. The parameters which were being monitored at the time of the accident are listed in Table C-1. The data signals going to the reactimeter originated from the same detectors which provided signals for normal plant monitoring and safety systems actuation.

The reactimeter data obtained by INEL was in engineering unit form, i.e., the conversions had already been made from the voltage recorded on the originated tapes. We requested and obtained the list of conversion

TABLE C-1

REACTIMETER LOGGED PARAMETERS

Channel	
1	Power range level--nuclear instrument-5 (0-125%)
2	Loop A hot leg temperature--narrow range (520-620^{o}F)
3	Loop B hot leg temperature--narrow range (520-620^{o}F)
4	Loop A cold leg temperature--wide range (50-650^{o}F)
5	Loop B cold leg temperature--wide range (50-650^{o}F)
6	Loop A reactor coolant flow--temperature compensated (0-90 MPPH)*
7	Pressurizer level--temperature compensated (0-400 in.)
8	Makeup tank level (0-100 in.)
9	Pressurizer spray valve position (open-closed)
10	Drain tank pressure (0-250 psig)
11	Loop B reactor coolant pressure--narrow range (1700-2500 psig)
12	Reactor trip (run-trip)
13	Loop B reactor coolant flow--temperature compensated (0-90 MPPH)*
14	Feedwater temperature (0-500^{o}F)
15	Turbine header pressure--Loop A (600-1200 psig)
16	Steam generator A operate level--temperature compensated (0-100%)
17	Steam generator A start-up level (0-250 in.)
18	Feedwater flow--Loop A (0-6500 KPPH)+
19	Feedwater flow--Loop B (0-6500 KPPH)+
20	Turbine trip (run-trip)
21	Steam generator A steam pressure (0-1200 psig)
22	Steam generator B steam pressure (0-1200 psig)
23	Steam generator B operate level--temperature compensated (0-100%)
24	Steam generator B startup level (0-250 in.)

*MPPH: Million pounds per hour.

+KPPH: Thousand pounds per hour.

functions which had been used on those tapes. Data was received for 16 hours prior to the beginning of the accident to about 27 hours afterwards. There was one time interval where about four minutes of data were lost when the tape was being changed.

The reactimeter could sample each channel on any time interval from 0.2 second to 12.6 seconds. At the time of the accident it was set to sample each channel on a 3 second interval, that is, it sampled all 24 channels in two 1.6 millisecond intervals once every three seconds.

The reactimeter was physically located in the Unit 2 Cable Spreading Room. The only attention it normally required was changing the magnetic tape about every 26 hours. The magnetic tapes that were produced by the reactimeter can be directly read by a computer which displays the data in the form of tables or graphs. Because of the accurate, continuous, retrievable nature of the reactimeter data, it is considered to be the most reliable data available on those parameters it was montoring. For this reason, it is being used as a reference baseline against which to measure the accuracy of other data sources pertaining to the TMI-2 accident.

2. Analog Strip Charts

Many of the primary and secondary plant parameters were continuously recorded on strip chart recorders located in the control room. These recorders allowed the operators to observe trends in the monitored parameters and they created a historical record of the trends.

There were basically two types of recorders used in the control room -- pen recorders which employed an ink pen to produce a continuous line plot of the parameter's value, and the multipoint recorder which monitored several parameters and printed a code number identifying each parameter, as it was scanned. The code number was printed at a location on the strip chart representing the parameter's value.

Legibility was normally the biggest problem encountered in trying to extract information from strip charts. This was especially true of the multipoint recorders, when several parameter traces were printed on top of each other, and when the printed numbers were not readable. The problem of legibility was compounded by the slow speed at which the strip charts travelled (normally 1 inch/hour for the pen plotters). A large amount of data was compressed into a small linear space. Also, if the strip charts were not properly annotated when removed from the recorder, problems occurred in recovering the time frame of the plots.

Differences between strip chart and reactimeter values for the same parameters indicated that strip chart data was generally less accurate than reactimeter data. However, the strip charts were calibrated periodically and had acceptable accuracy for most purposes -- especially as a source of trend information.

All time series data put into the TMI-2 Data Base had to be in digital form, therefore, all the analog stripchart data had to be digitized. A special digitizing apparatus was used where the stripchart was mounted on an accurate x-y axis board. The x and y coordinate values were then fed directly into the computer by following the curve with a stylus which was periodically triggered. In order to reduce errors due to optical distortion in the microfiche, the stripchart was sometimes digitized in segments and then reassembled.

Enlarged color photographs were made of the multipoint recordings which were to be digitized, primarily for the first few hours. This was done to facilitate identification of the printed numbers. For long times after the accident, black and white microfilm could often be used once print identification had been made.

The first step in digitizing multipoint recorded data was to identify the channel number on the recording corresponding to each particular measurement channel. Using the color photographs it was possible to identify many of the blurred and partially printed numbers. In some cases the known color sequence of the numbers was used to aid in identification, although the color renditions were poor. In other instances it was necessary to search through the photographs to find one identifiable number then to literally follow the color print back and forth to identify its track. In still other cases the microfilm had to be used to find a clearly printed number which was then carefully followed and backward in time. Some channel numbers never were found and some channels were found which were not shown on the measurement lists. There were cases where knowledge of the physical location of a monitor was used to find a comparable identified channel known to respond similarly. The most difficult part of digitizing the multipoint recordings was identifying the channel numbers.

The time base of each data set was undefined until the print frequency and paper speed were determined. Often the print frequencies varied somewhat between recorders even when they were running at the same speed. Generally it was necessary to establish speed and frequency using time notations written on the stripcharts. Occasionally some plant event could be used as a timing mark also but care had to be taken that lag-time was not significant. Some multipoint data had gaps where recorders had malfunction, paper had torn, etc. Many data sets originating from the multipoint recorders had to be reconstructed from a great deal of detective work both on the amplitude and time base.

3. Plant Computer

The plant computer system at TMI-2 utilized a Bailey 855 computer linked with a smaller NOVA computer to form one integral system. The NOVA computer was an addition made by Metropolitan Edison Company to provide more capacity for balance-of-plant monitoring. The principal function of the computer system was to monitor plant parameters (approximately 3000) and to display them along with any related calculations. The parameter input signals were either analog or digital.

In performing its monitor function, the computer scanned 960 digital and 80 analog inputs every second. An analog parameter could be scanned on 1, 5, 15, 30, or 60 second intervals depending on its relative importance. Each second the computer scanned all the 1 second scan points, 1/5 of the 5 second scan points, 1/15 of the 15 scan points, and so on.

The computer had two output modes for the points it scanned -- an alarm printer and a utility printer. These were both automatic typewriters, and if either failed its output was automatically transferred to the other. A small cathode ray tube display was also provided which duplicated the output of the printers.

4. Alarm Printer

For all monitored parameters that had an alarm function, the alarm printer automatically printed an alarm message when the parameter had gone into an alarm condition, i.e., exceeded an alarm setpoint or changed state.

The printed alarm time was the real clock time when the computer scanned the parameter and found it in an alarm condition. Note, that a parameter on a 60 second scan rate which exceeded its alarm setpoint immediately after a scan would be in the alarm condition for 60 seconds before the computer recorded the alarm. If a parameter were to exceed its alarm setpoint and then return within the setpoint between two consecutive scans, the computer would not record the alarm condition.

The alarm inputs were stored by the computer in an alarm-backup-buffer until they were printed. This buffer could store up to 1365 alarm inputs before it was filled. The alarm printer could only print one alarm every 4.2 seconds. If alarms were occurring at a faster rate, the printer got further and further behind, and the alarms would be printed minutes after they were recorded. (At one point during the TMI-2 accident the alarm printer was at least 161 minutes behind.) After the buffer was filled (i.e., 1365 alarms were waiting to be printed) the computer program was designed to print the message "Alarm Monitor Holdup" indicating that future alarms would not be stored until some of the 1365 backlogged alarms were printed. These unstored alarm would never be printed. The operator did have the option of suppressing the alarm sequence. This erased all old alarms from the computer memory and caused it to start printing new alarms which originated after the suppression. At one point in the accident this is exactly what happened.

5. Utility Printer

The utility printer provided output on request. The value or condition of any monitored parameter could be requested. Special subroutines allowed the operator to request output values in specific preprogrammed groups called "Operator Special Summaries" or to trend output values in preprogrammed groups called "Operator Group Trends".

The computer was also programmed to record automatically all changes in state of a predesignated group of parameters called "Sequence of Events" inputs. These event inputs were stored in the computer and could be printed on request. This particular computer function did not use the scan process described above, but used a continuous monitoring process which enabled it to print the exact time that the "Sequence of Events" inputs occurred. The sequence was started by any one of the "Sequence of Events" inputs changing state and continued until printed by the operator.

Another feature programmed into the computer was the "Memory Trip Review". Triggered by a reactor or turbine trip, this routine recorded a set of predesignated parameter inputs for 15 minutes before and 15 minutes after the trip. This information was stored until the operator requested that it be printed.

The plant computer provided the operator with an efficient means of keeping logs and showing trends on a large number of plant parameters under normal operating conditions. The computer was not designed to accommodate the data needs of the operator in an accident situation. Using the computer in an accident situation required that the operator to leave his control panels in order to request computer output; it took the computer several seconds to supply the requested output; and the automatic alarm printout was often several minutes behind real time. All of these tended to limit the computer's usefulness in an accident situation.

6. Periodic Log

Data from the plant computer were also recorded on the periodic log which was printed out once each hour. Some very useful data were extracted from the periodic log although some of it was also printed out elsewhere. The periodic log data were automatically printed out every hour and annoted to the minute.

APPENDIX D

METHODOLOGY FOR DATA QUALIFICATION AND UNCERTAINTY

The determination of the data quality category and the uncertainty analysis are the two basic steps necessary to fully describe any data set. These two functions are interrelated in performance as well as in presentation of the data. The quality category of the data cannot be determined until the uncertainty has been determined or it has been decided that uncertainty is uncalculable. This appendix is not intended to explain the methodology. Reference D3 gives a very detailed explanation of the methodology along with examples of how to use it. The purpose of this section is to give a brief overview of the analysis method for individuals who are familiar with uncertainty analyses methods.

A first step in determining data quality and uncertainty is to inspect the data of interest. Although this may seem obvious, it often saves the detailed labor of doing an uncertainty analysis. Detailed examination of the data can reveal such things as offsets, enigmas, and gross inconsistencies. Before doing an uncertainty analysis one should make a value judgment about the uncertainty in the components which make up the measuurement circuit. For example, if there are no calibrations available for a stripchart recorder and no redundant data for comparison, it may be that the uncertainty in that data would be extremely large or uncalculable. Another example might be that an uncertainty analysis would be inappropriately expensive on a particular measurement and an alternate measurement should be sought. In other words, the determination of data quality and uncertainty is not a rote process but is one where a preliminary review of the data should be made before work begins.

If the preliminary investigations reveal that the data is of poor quality but does contain some useful information, the quality category will be Trend and no further effort need be expended.

The purpose of assigning quality categories to all the data sets was to provide generic descriptors for the data user. These descriptors tell the user about the quality of the data without his having to look up the specific uncertainty values. These main data quality descriptor terms are "Qualified" and "Trend". It is unfortunate that the word "Qualified" was selected because there is sometime confusion between the descriptor "Qualified", the adjective "quality" and the verbs "qualified" and "qualifying".

1. Uncertainty Analyses

The usefulness of any data obtained by measurement of physical phenomena depends upon a knowledge of the degree of uncertainty in the data. There are a number of acceptable methods of determining and presenting uncertainty and the method advocated by Dr. R. B. Abernathy[D-1,D-2,D-3] for the basis of our work. In doing the uncertainty analyses on TMI-2 data we found a serious shortage of support information was encountered, e.g., circuit diagrams, calibration schedules, instrument manufacturer specifications, and block diagrams. In addition, it was nearly impossible to obtain any statistical error information. In most cases the individual circuit errors had to be taken from TMI-2 Instrument Calibration Sheets which merely specified a "tolerance" for the circuit, i.e., a bias error. As work progressed it became obvious that nearly all the errors being found could be interpreted as bias error. In addition, many errors had to be estimated and these also fell into the bias error category. It was expedient, therefore, to treat all errors as bias which were a function of range. This greatly simplified the calculation of uncertainty and also simplified the presentation of uncertainty in the data base.

There were several cases, such as the hot leg mass flowrate measurement, where uncertainty had to be expressed as a function of time. This was a result of the calculated nature of the data and uncertainties due to other parameters (such as voiding in the hot leg).

2. Analysis Procedure

Separate uncertainty bounds have to be generated for measurement data and for any parameters calculated using these data. A measurement system generally consists of a transducer, a signal conditioning unit, and a data acquisition and recording system (which are called elemental components). The analysis for determining measurement uncertainties, therefore, consists of determining the elemental component errors and combining them properly. When uncertainty is determined for a calculated parameter, the individual measurement data uncertainties are combined to give the total uncertainty. The general procedure to follow in performing measurement and parameter uncertainty analyses is as follows:

1. For each measurement, list every source of error, e.g., calibration errors, data acqusition errors, data reduction errors.

2. The elemental error of a measurement should be converted to a bias error and given as a function of instrument range. A conservative substitution may have to be made to replace a statistical error with a bias error. A bias error usually must be established by nonstatistical methods.

3. Calculate the bias error (B) at the elemental level.

4. Calculate the elementary data uncertainty.

5. Analyze the equation by which the final answer will be obtained. It is necessary to propagate the errors for a calculation parameter.

6. Propagate the bias limit to the desired result using the Taylor series expansion and root sum square (RSS) technique.

7. Calculate the uncertainty.

3. Definitions

Measurement Error. All measurements contain errors which are defined as the difference between the measured values and the true values. These errors in measurements usually contain two separate components - a bias (also called fixed or systematic) component (B) and a random or sample standard deviation component (S). As mentioned previously, the uncertainty analyses was done only with bias errors.

Bias Error. In practice most measurements will have many sources of bias error; e.g., data acquisition, data reduction and calibration. All bias errors which are known and can be economically removed are removed. This leaves bias errors which are not well defined but must be accounted for in the calculation of data uncertainty. In practice bias errors for elemental sources are often estimated. As long as none of the biases are extremely large relative to each other, the root-sum-square is a very good approximation of the total bias error effect.

$$B = \sqrt{\sum_{i=1} B_i^2}$$

In most cases the bias error is equally likely to be either plus or minus from the measurement. Whether the bias error is positive or negative is not known, and the estimate reflects this. The bias error is estimated to be the extremes of the possible bias error range.

Determination of the exact bias value in a measurement requires a comparison of the true value with the measured value. Because the true value is never known, such a comparison is virtually impossible. Therefore, the bias errors are estimated and are taken from nonstatistical special tests and data where obtainable.

Deciding whether a particular error should be considered random or bias is sometimes difficult. An acceptable criterion is: any error that has to be estimated is bias and any error determined statistically is random. This definition assumes that all known bias errors have been removed if possible.

Uncertainty. Uncertainty is a description of the numerical bounds of a measurement error. The true value of a measurement is predicted with some confidence to lay within the bounds. Uncertainty is an aribtrary substitute for a statistical confidence interval and can be interpreted as the largest expected error.

A rigorous calculation of confidence level or the coverage of the true value by the interval is not possible in this work because the distribution of bias errors and limits, based on judgment, cannot be rigorously defined. Monte Carlo simulation of the intervals can provide approximate coverage based on assuming various bias error distributions and bias limits. As actual bias error and bias limit distributions are seldom known, simulation studies performed were based on a range of assumptions[A-3]. The result of these studies indicated that the methodology used in the TMI data analysis gives a reasonably accurate confidence level of 95% that the true value of a measurement would fall within the uncertainty interval.

Propagation of Uncertainty. The Taylor series and the RSS method are used to propagate measurment errors when calculating a parameter from measurement data; e.g., $Z = f(x,y)$. The assumptions made when using the equations derived from the Taylor series presented in this summary are:

1. $Z = f(x,y)$ and the functions to be considered are restricted to smooth curves in a neighborhood of the point with no discontinuities.

2. The combined bias errors each have approximately a normal distribution.

3. The variables x and y are independent.

See Reference 3 for details. The equations in Table D-1 can be used in the uncertainty analyses provided all the assumptions are met.

TABLE 1

UNCERTAINTY ANALYSIS EQUATIONS

Elemental bias (b)	Judgment supported by special test data	Estimated to a 95% confidence limit for bias error
Measurement bias (B)	Elemental bias	$B = \sqrt{\sum_{i=1}^{n} b_i^2}$
Parameter bias (B_z from Taylor series)	Measurement bias values and the parametric function $z = f(x,y)$	$B_z = \sqrt{(\frac{\partial f}{\partial x} B_x)^2 + (\frac{\partial f}{\partial y} B_y)^2}$

4. Data Categorization

Determining the data qualification category and uncertainty analysis are tasks which in practice are often interwoven. An uncertainty analysis generally must be made before the qualification process can proceed but sometimes the obvious quality of the data may preclude having to perform an uncertainty analyses. Generally the same analyst performed the uncertainty analysis and assigned the data quality category. The Data Integrity Review Committee (DIRC) reviewed all work by the individual analyst. The DIRC had the responsibility for allowing only properly reviewed and approved data to be put into the TMI-2 data base.

The process for determining the qualification levels of the remaining data consisted of several functions which were not necessarily performed in the order given here: (1) the uncertainty analyses results were reviewed and in most cases the analysis itself supplied useful information or insight on the measurement, (2) the single measurement channel was reviewed to determine whether the measurement channel output represented the expected, predicted or required response, (3) the data were examined for consistency with single channel analysis criteria, i.e., range and noise limits, time response and correlation with significant plant events, consistent with preaccident data, etc., (4) a comparison was made where possible between the measurement and thermal-hydraulic theory, (5) the redundant data was compared. These comparisons took the form of:

1. Direct redundancy--Comparisons of multiple measurment of the same physical phenomena. Direct comparison is limited by factors such as physical state, measurement environment, spatial proximity of sensors, and transducer response characteristics.

2. Analytical redundancy--Dissimilar measurements can be compared when data transformations into a common reference frame are possible. An example is the comparison of differential pressure and fluid velocity data after their conversion to mass flow rate.

3. Historical redundancy--Past performance of individual or groups of measurements under given operating conditions is a powerfuel asset in identifying anamalous measurement performance.

As a result of examination, one or more of the categories or qualification levels defined below was assigned to each measurement, as a function of time, by the DIRC with input from appropriate analysts and data integrity specialists.

<u>Qualified Data</u>

Data that are qualified have met the following criteria:

1. All calibration corrections have been applied.

2. The data have been compared with independent redundant data and found to agree within the specified uncertainty limits.

3. The data have been verified to represent the physical parameter being measured.

4. Engineering unit conversions have been made.

5. Uncertainties have been established for the 95% confidence level when possible.

Trend Data

Data have been verified to approximately represent the absolute level in the phenomenon measured because of one or more of the following:

1. Instrument calibrations do not adequately represent the environment which the transducer measures.

2. The calibration or performance of the measurement channel is suspect but the data still contains some useful information.

3. Uncertainty limits cannot be adequately quantified.

4. The measurement channel performance is thought to be relatively correct, but there are some anomalies in the data.

5. Environmental effects cannot be adequately compensated.

Failed Data

The failed classification is applied to data from which useful information is irretrievable due to a failure in the measurement system such as:

1. Transducer failure.

2. Signal conditioning failure.

3. Inadequate rejection of extraneous noise, transients, or frequencies.

4. Loss of sync, data channel, continuity, etc.

5. Enigmas in the data.

Failed data will never be presented.

Not Reviewed Data

Data which were not reviewed received this notation. This classification occurs when a measurement has no relevance to analyses objectives. This category will be found only on the Measurement Data List (MDL) contained in Appendix E.

REFERENCES

D-1. R. B. Abernathy, R. P. Benedict, "Measurement Uncertainty: A Standard Methodology," ISA Transactions, Vol. 24, Number 1, 1985.

D-2. R. B. Abernathy, et. al., "Measurement Uncertainty Handbook," AEDC-TR-73-5, Revised 1980.

D-3. Measurement Uncertainty for Fluid Flow in Closed Conduits, ANSI/ASME MFC-2M-1983.

APPENDIX E

DATA UNCERTAINTY ANALYSES AND QUALITY CATEGORIES

This appendix contains letter and reports that give details of the uncertainty analyses made of specific data sets. These documents are all technically nonreferencable, i.e., they have not been published or distributed. Regular TMI-2 referencable documents are not contained herein because they are already available to users of this Data Summary Report. The TMI-2 Data Base references material both in this appendix and published documents. This appendix also includes an abbreviated Measurements Data List (Table E-1) which shows which of the TMI-2 measurement data were reviewed and which were not.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: Sept 15, 1987

To: D. W. Golden

From: Yasushi Nomura

Subject: NEW EVALUATION OF UNCERTAINTIES FOR ESTIMATION OF LETDOWN COOLER VOLUMETRIC FLOWRATE - YN-3-87

Recently R. D. McCormick cited in his letter, QUALIFICATION OF TMI-2 DATA -RDMC-15-87, that the uncertainty values of letdown cooler outlet temperature, MU-TE-739-M and MU-TE-740-M, were estimated to be ±10% based on data from the strip chart recorder MP-010. I have reviewed throughly the previous report on estimation of the letdown cooler flowrate, in which data uncertainty was given 2% for the letdown cooler outlet temperature. Subsequently, I performed uncertainty calculations for the letdown cooler flowrates at every minute. The maximum uncertainty was found to be some 24.6% at 95% confidence level throughout 300 min into the accident as shown in the attached document.

Attachment:
As Stated

cc:
J. M. Broughton
J. L. Anderson
R. D. McCormick
R. W. Brower
E. L. Tolman
P. Kuan
N. Ohnishi
Y. Momura File
Central File

NEWLY EVALUATED UNCERTAINTY FOR LETDOWN COOLER VOLUMETRIC FLOWRATE

September 15, 1987
Yasushi Nomura

1. INTRODUCTION

Estimated results on the Letdown Cooler (LC) flowrates during the TMI-2 accident up to 300 min were reported in the document, YN-4-86, issued on December 10, 1986. In that document, uncertainty analyses were performed with limited knowledge of error sources, taking a few representative time-points to calculate propagation of errors to the letdown cooler flowrates. Recently, error estimation for the letdown cooler outlet temperature was made and the results show that the error attributed to the outlet temperature should be replaced from 2% to 10%. Consequently, uncertainty analyses for the letdown cooler flowrates were performed with the newly evaluated input-data errors. Results of the uncertainty analyses for every 1-minute time-point are shown in this report.

2. UNCERTAINTY ANALYSIS

It is assumed that the heat removed in each cooler is calculated from the following equation for a counter-flow heat-exchanger

$$q = UA \cdot [(Tti - Tso) - (Tto - Tsi)] / Ln[(Tti - Tso)/(Tto - Tsi)] \qquad (1)$$

where q = heat transfer in each cooler

UA = overall conductance

Tti = letdown-cooler (tube-side) inlet-temperature

Tto = letdown-cooler (tube-side) outlet-temperature

Tsi = cooling-water (shell-side) inlet-temperature

Tso = cooling-water (shell-side) outlet-temperature

A heat balance on the tube side becomes as follows.

$$q = W_{ld} \cdot C_{pt} \cdot (T_{ti} - T_{to}) \qquad (2)$$

where W_{ld} = letdown mass flowrate
C_{pt} = letdown (tube-side) water specific heat

Similarly, a heat balance equation on the shell side can be derived as follows.

$$q = W_c \cdot C_{ps} \cdot (T_{so} - T_{si}) \qquad (3)$$

where W_c = cooling-water mass flowrate
C_{ps} = cooling (shell-side) water specific heat

Uncertainty of the estimation of the LC flowrate is related with propagation of errors of measured data and assumed data given in the equations (1) ~ (3). Possible error sources and their values are evaluated as follows to give 95% confidence levels.

- Overall conductance UA (0.8×10^5 Btu/hr°F) has an error of 10% from engineering judgement.
- Uncertainty of the letdown cooler inlet-temperature T_{ti} (supposed to be the cold-leg 1A temperature RC-5A-TE2-R), is 2%.
- The letdown cooler outlet-temperature were measured on MU-TE-739-M and MU-TE-740-M. These measurement data were from the strip chart recorder MP-010 for which very little elaboration information existed. As a result, It was estimated that uncertainty values of the letdown cooler outlet-temperature were 10%.
- The cooling water inlet-temperature T_{si} was assumed to be 45°F based on measurement data of the intermediate cooling water temperature (45.6°F) at 237 min into the accident. Uncertainty value for the assumed cooling-water inlet-temperature is evaluated to be 30% based on comparison between calculation and measurement.

• Uncertainty of the assumed letdown-water specific-heat Cpt (1.20 Btu/lbm° F) is 20% according to the ASME steam tables referred with the temperature/pressure variation realized in the letdown cooler (70° F ~ 600° F, 600 psig ~ 2300 psig).
• The cooling-water mass flowrates were assumed to be a constant value 25 kg/s, which is a design level. Its uncertainty is 10% from engineering judgement.
• Uncertainty of the cooling water specific heat Cps (1.002 Btu/lbm° F) is 1% based on the ASME steam table referred with the temperature/pressure variation realized in the cooling system.

In addition to the above error-sources and uncertainties, uncertainty of the specific volume Sv ($0.16\ ft^3/lbm$) is 1% based on the ASME steam table referred to the real variation of temperature/pressure of letdown fluid.

Combining Eqs. (1),(2),(3), one can see that the letdown cooler volumetric flowrate V is basicly expressed to be an explicit function of the above-mentioned variables as follows.

$$V = f(Sv, Tti, Tto, Tsi, UA, Wc, Cpt, Cps) \qquad (4)$$

Then, uncertainty analyses for the letdown flowrate are to be done by the following equation.

$$\begin{aligned} \delta V^2 = {} & [(\partial V/\partial Sv)\cdot\delta Sv]^2 + [(\partial V/\partial Tti)\cdot\delta Tti]^2 + \\ & [(\partial V/\partial Tto)\cdot\delta Tto]^2 + [(\partial V/\partial Tsi)\cdot\delta Tsi]^2 + \\ & [(\partial V/\partial UA)\cdot\delta UA]^2 + [(\partial V/\partial Wc)\cdot\delta Wc]^2 + \\ & [(\partial V/\partial Cpt)\cdot\delta Cpt]^2 + [(\partial V/\partial Cps)\cdot\delta Cps]^2 \end{aligned} \qquad (5)$$

Right-hand side of Eq. (5) consists of several square terms of product of partial derivative and variation concerning a variable. Actually this product is evaluated by obtaining the difference of the letdown flowrate values from Eqs. (1),(2),(3) with assuming the nominal and nominal-plus-error to the particular variable. The uncertainty thus obtained for the letdown cooler volumetric flowrate is associated with 95% confidence level as a result of the derivation method described above.

Calculated results of the letdown cooler flowrates are shown in Table 1 with errors accompanying with the flowrate values at every 1 minute in the accident. Since the letdown cooling system is comprised of two identical coolers with different outlet temperatures, calculations were made for each unit and then, sumed to obtain the total letdown cooler flowrate together with the accompanying error.

Table 1 Total Letdown Cooler Volumetric Flowrate versus Time (Tsi=45°F)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	+-Error (gpm)	
0	66	0	66	16	
1	65	0	65	16	
2	65	0	65	16	← Max.
3	0	0	0	0	
4	0	0	0	0	
5	0	0	0	0	
6	0	0	0	0	
7	55	54	109	19	
8	65	59	124	22	
9	76	66	142	24	
10	76	70	146	25	
11	74	68	142	24	
12	71	67	138	24	
13	68	66	134	23	
14	65	65	130	22	
15	66	65	131	22	
16	67	65	132	23	
17	67	66	133	23	
18	69	66	135	24	
19	70	67	137	24	
20	71	69	140	24	
21	72	71	143	25	
22	71	72	143	25	
23	71	70	141	24	
24	70	69	139	24	
25	69	67	136	24	
26	68	64	132	23	
27	67	63	130	22	
28	65	62	127	22	
29	65	61	126	22	
30	66	61	127	22	
31	66	61	127	22	
32	67	61	128	23	
33	68	62	130	23	
34	69	63	132	23	
35	69	63	132	23	
36	69	64	133	23	
37	70	64	134	23	
38	70	64	134	23	
39	67	64	131	23	
40	64	62	126	22	
41	62	61	123	22	
42	60	59	119	21	
43	58	57	115	20	
44	58	56	114	20	
45	57	55	112	20	
46	58	55	113	20	
47	58	56	114	20	
48	59	57	116	21	
49	61	58	119	21	
50	63	59	122	21	
51	64	60	124	21	
52	64	61	125	22	
53	64	61	125	22	
54	64	62	126	22	
55	63	62	125	21	
56	64	62	126	22	
57	64	61	125	22	
58	64	61	125	22	
59	66	62	128	22	
60	67	63	130	22	

Table 1 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	+-Error (gpm)
61	67	63	130	22
62	68	64	132	23
63	68	64	132	23
64	68	65	133	23
65	68	65	133	23
66	69	65	134	23
67	69	65	134	23
68	69	65	134	23
69	69	65	134	23
70	69	65	134	23
71	70	65	135	24
72	70	66	136	23
73	72	67	139	24
74	73	67	140	24
75	73	68	141	24
76	72	68	140	24
77	70	68	138	24
78	66	65	131	23
79	62	62	124	22
80	60	60	120	21
81	59	59	118	21
82	59	58	117	21
83	60	58	118	21
84	61	58	119	21
85	63	59	122	22
86	64	61	125	22
87	64	62	126	22
88	64	62	126	22
89	63	62	125	22
90	61	61	122	22
91	59	59	118	21
92	58	58	116	20
93	57	57	114	20
94	59	56	115	20
95	63	58	121	21
96	67	60	127	22
97	69	62	131	23
98	72	64	136	24
99	73	66	139	24
100	73	66	139	24
101	73	67	140	24
102	72	67	139	24
103	72	68	140	24
104	71	68	139	24
105	71	68	139	24
106	70	68	138	24
107	69	68	137	24
108	69	67	136	24
109	70	67	137	24
110	70	68	138	24
111	71	68	139	24
112	70	68	138	24
113	70	67	137	24
114	70	68	138	24
115	70	68	138	24
116	70	68	138	24
117	69	68	137	24
118	69	68	137	24
119	69	67	136	24
120	69	67	136	24
121	69	67	136	24

Table 1 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	+-Error (gpm)
122	68	67	136	24
123	68	68	137	24
124	69	67	136	24
125	69	67	136	24
126	67	66	133	24
127	65	65	130	23
128	63	64	127	23
129	60	61	121	21
130	58	58	116	21
131	57	57	114	21
132	56	56	112	20
133	55	55	110	20
134	55	55	110	20
135	55	55	110	20
136	55	55	110	20
137	55	55	110	20
138	55	55	110	19
139	55	54	109	20
140	54	54	108	20
141	53	53	106	20
142	53	52	105	20
143	52	51	103	19
144	51	51	102	19
145	46	50	96	18
146	39	50	89	18
147	37	50	87	19
148	42	48	90	18
149	45	45	90	18
150	47	46	93	18
151	49	47	96	18
152	50	49	99	18
153	51	50	101	19
154	52	51	103	20
155	53	51	104	19
156	53	52	105	19
157	53	52	105	19
158	54	53	107	19
159	54	53	107	20
160	54	54	108	20
161	55	54	109	20
162	57	55	112	21
163	60	57	117	21
164	63	59	122	22
165	66	62	128	23
166	70	65	135	24
167	72	68	140	25
168	74	70	144	26
169	75	72	147	26
170	75	72	147	26
171	75	73	148	26
172	76	74	150	26
173	77	74	151	27
174	84	81	165	30
175	78	75	153	27
176	78	75	153	27
177	79	76	155	27
178	80	76	156	28
179	81	77	158	28
180	81	77	158	28
181	81	78	159	28
182	80	77	157	28

Table 1 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	+-Error (gpm)
183	79	76	155	28
184	79	76	155	27
185	79	75	154	28
186	79	75	154	27
187	77	74	151	27
188	76	73	149	26
189	75	72	147	26
190	75	71	146	26
191	74	71	145	25
192	74	70	144	25
193	74	71	145	25
194	74	71	145	25
195	75	71	146	26
196	74	71	145	26
197	74	71	145	26
198	73	71	144	25
199	73	71	144	25
200	73	71	144	25
201	73	70	143	25
202	74	71	145	26
203	74	71	145	26
204	75	72	147	27
205	76	73	149	27
206	76	73	149	27
207	77	74	151	27
208	78	75	153	27
209	79	77	156	28
210	78	77	155	28
211	75	76	151	27
212	73	74	147	27
213	72	72	144	27
214	70	70	140	26
215	68	68	136	26
216	67	66	133	25
217	65	64	129	25
218	64	63	127	25
219	63	62	125	24
220	63	61	124	24
221	62	60	122	24
222	60	58	118	24
223	57	56	113	23
224	56	54	110	23
225	50	48	98	20
226	51	50	101	20
227	53	51	104	20
228	54	52	106	20
229	55	53	108	20
230	56	54	110	21
231	57	56	113	21
232	58	57	115	22
233	59	58	117	22
234	60	59	119	22
235	62	60	122	23
236	0	0	0	0
237	0	0	0	0
238	0	0	0	0
239	0	0	0	0
240	0	0	0	0
241	67	65	132	25
242	68	67	135	26
243	69	67	136	27

Table 1 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	+-Error (gpm)
244	70	69	139	28
245	70	68	138	27
246	70	68	138	27
247	70	68	138	27
248	70	68	138	27
249	66	65	131	26
250	65	64	129	26
251	60	64	124	24
252	54	65	119	24
253	52	65	117	24
254	60	66	126	25
255	66	65	131	26
256	68	66	134	26
257	70	67	137	27
258	71	68	139	27
259	71	70	141	27
260	72	72	144	28
261	76	76	152	29
262	81	80	161	31
263	86	89	175	34
264	90	100	190	37
265	98	112	210	41
266	117	121	238	47
267	138	129	267	54
268	146	140	286	59
269	147	140	287	59
270	151	143	294	61
271	154	147	301	63
272	157	152	309	65
273	149	158	307	65
274	140	165	305	64
275	136	166	302	64
276	132	141	273	56
277	126	121	247	50
278	115	109	224	45
279	106	101	207	41
280	103	95	198	40
281	101	93	194	39
282	100	91	191	38
283	99	89	188	38
284	99	88	187	38
285	99	87	186	37
286	99	87	186	38
287	90	87	177	36
288	78	87	165	34
289	71	85	156	33
290	78	83	161	34
291	87	81	168	36
292	87	78	165	35
293	86	77	163	35
294	85	76	161	35
295	86	76	162	35
296	87	76	163	35
297	75	76	151	33
298	64	76	140	32
299	65	75	140	32
300	76	75	151	33

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: December 10, 1986

To: D. W. Golden

From: Yasushi Nomura

Subject: LETDOWN COOLER VOLUMETRIC FLOWRATE VERSUS TIME -YN-4-86

Attached is a final copy of the data estimation document for the letdown cooler volumetric flowrates. Calculation of the LC flowrates is performed by using simple heat-balance equations derived from a calculational model of a counter-flow shell/tube heat-exchanger. Estimated LC flowrates are improved by considering operator interviews and referring to alarm printer data.

yn

Attachment:
As Stated

cc: J. M. Broughton
R. D. McCormick
J. L. Anderson
R. W. Brower
H. E. Knauts
P. Kuan
E. L. Tolman
A. Takizawa
cc:
Y. Nomura File
Central File

"Providing research and development services to the government"

FORM EG&G-954
(Rev. 05-84)

ESTIMATION OF THE LETDOWN COOLER VOLUMETRIC FLOWRATE VERSUS TIME

December 1986

Yasushi Nomura

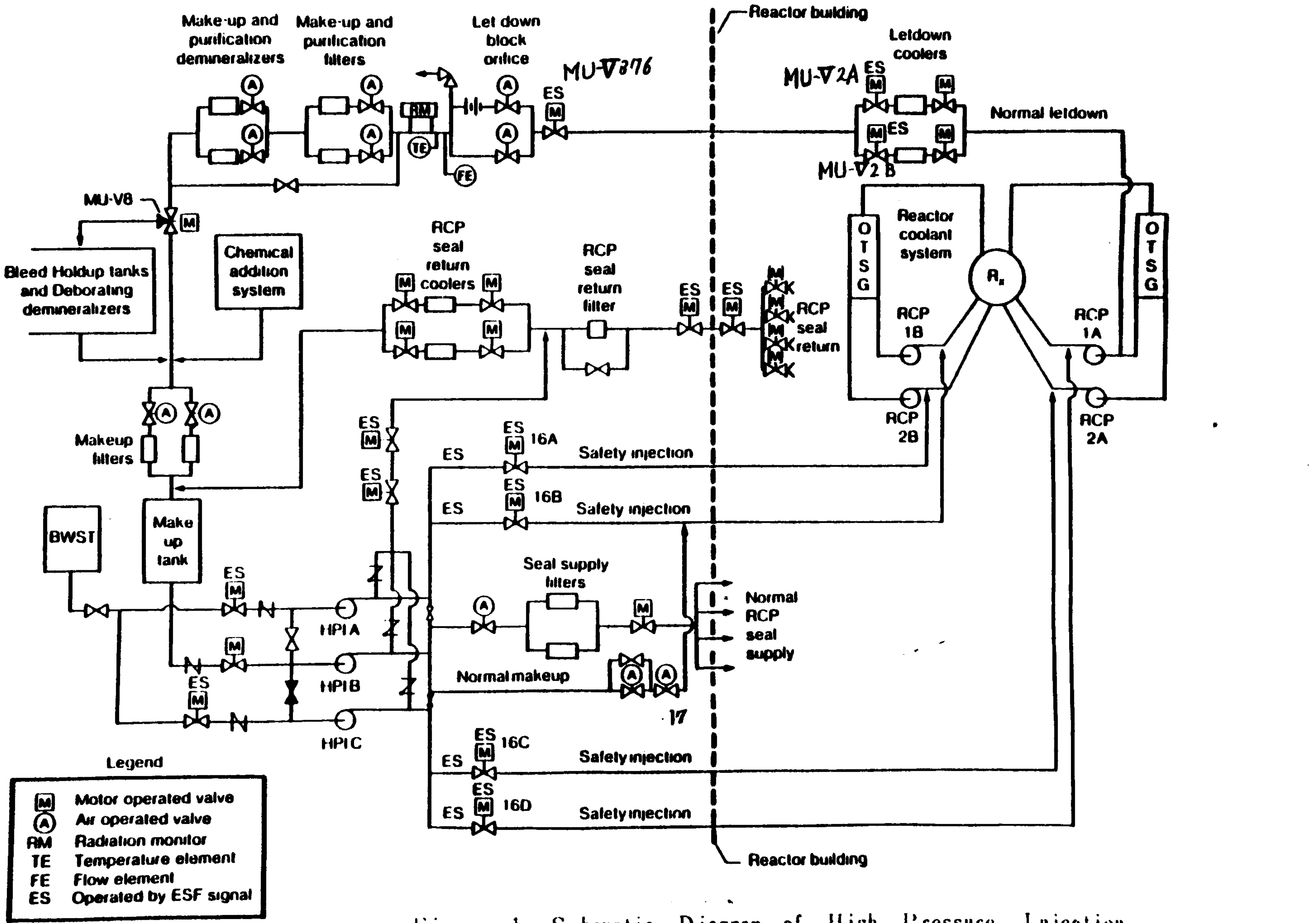


Figure 1 Schematic Diagram of High Pressure Injection Makeup and Purification System

to the temperature suitable for demineralization. Heat in the letdown coolers is rejected to the intermediate closed cooling water systems.

The intermediate closed cooling water system is a closed loop system that provides cooling water for various components in the reactor building. The components are 2 letdown coolers, 4 reactor coolant pump cooling jackets and 8 coolers, and 69 control rod drive coolers. Heat is transfered in those components and rejected to the river water cooling system in the intermediate coolers.

When two out of three pressure switches are tripped, signifying high reactor building pressure, the components included in the actuation trains for reactor building isolation and cooling will automatically go to their engineered safety features (ESF) position. When this occurs, MU-V2A and MU-V2B located on the outlets of the letdown coolers together with MU-V376 shown in figure 14 will be closed, thus resulting in fluid stagnation in the letdown line. During the accident up to 300min., the ESF actuation due to high reactor pressure was initiated at 235.6min. for some five min. according to the SOE table.

3. ESTIMATION PROCEDURE

It is assumed that the heat removed in each cooler is calculated from the following equation for a counter-flow heat-exchanger[1].

$$q = UA \cdot \{(T_{ti} - T_{so}) - (T_{to} - T_{si})\} / Ln\{(T_{ti} - T_{so}) / (T_{to} - T_{si})\} \qquad (1)$$

where q = heat transfer in each cooler

UA = overall conductance

T_{ti} = letdown-cooler (tube-side) inlet-temperature

T_{to} = letdown-cooler (tube-side) outlet-temperature

T_{si} = cooling-water (shell-side) inlet-temperature

T_{so} = cooling-water (shell-side) outlet-temperature

A heat balance on the tube side becomes as follows.

$$q = Wld \cdot Cpt \cdot (Tti - Tto) \quad (2)$$

where Wld = letdown mass flowrate
Cpt = letdown (tube-side) water specific heat

Similarly, a heat balance equation on the shell side can be derived as follows.

$$q = Wc \cdot Cps \cdot (Tso - Tsi) \quad (3)$$

where Wc = cooling-water mass flowrate
Cps = cooling (shell-side) water specific heat

An iteration of Tso is performed with equations (1) and (2), first assuming the design specification (175° F) for Tso. In this case, Tti (supposed to be the cold-leg 1A temperature) and Tto are given by the measurement data. Measured Tto's are shown in Fig. 2.

Tsi is assumed to be 45° F based on the measurement data of the intermediate cooling water temperature (45.6° F) at 237min. into the accident. This assumption might be reasonable in consideration of cold river-water at the accident time, i. e., March.

The design value of the conductance UA is 1.25×10^5 Btu/hr° F, but due to the possibility of fouling, the actual value of 0.3×10^5 Btu/hr° F [2] obtained prior to the accident is used in the calculation. Cooling-water mass flowrate Wc is assumed to be design level of 25kg/s (1.984×10^5 lbm/hr) [2]. Cooling-water specific heat Cps is fixed at 1.002 Btu/lbm° F, taken as a 45° F-200psig value (design pressure value) from the ASME steam tables[3].

Convergence of the iteration is rapid and gives a precise value of Tso with convergence allowance of 1° F. Subsequently, the letdown mass flowrate Wld is obtained from equation (2) with the converged

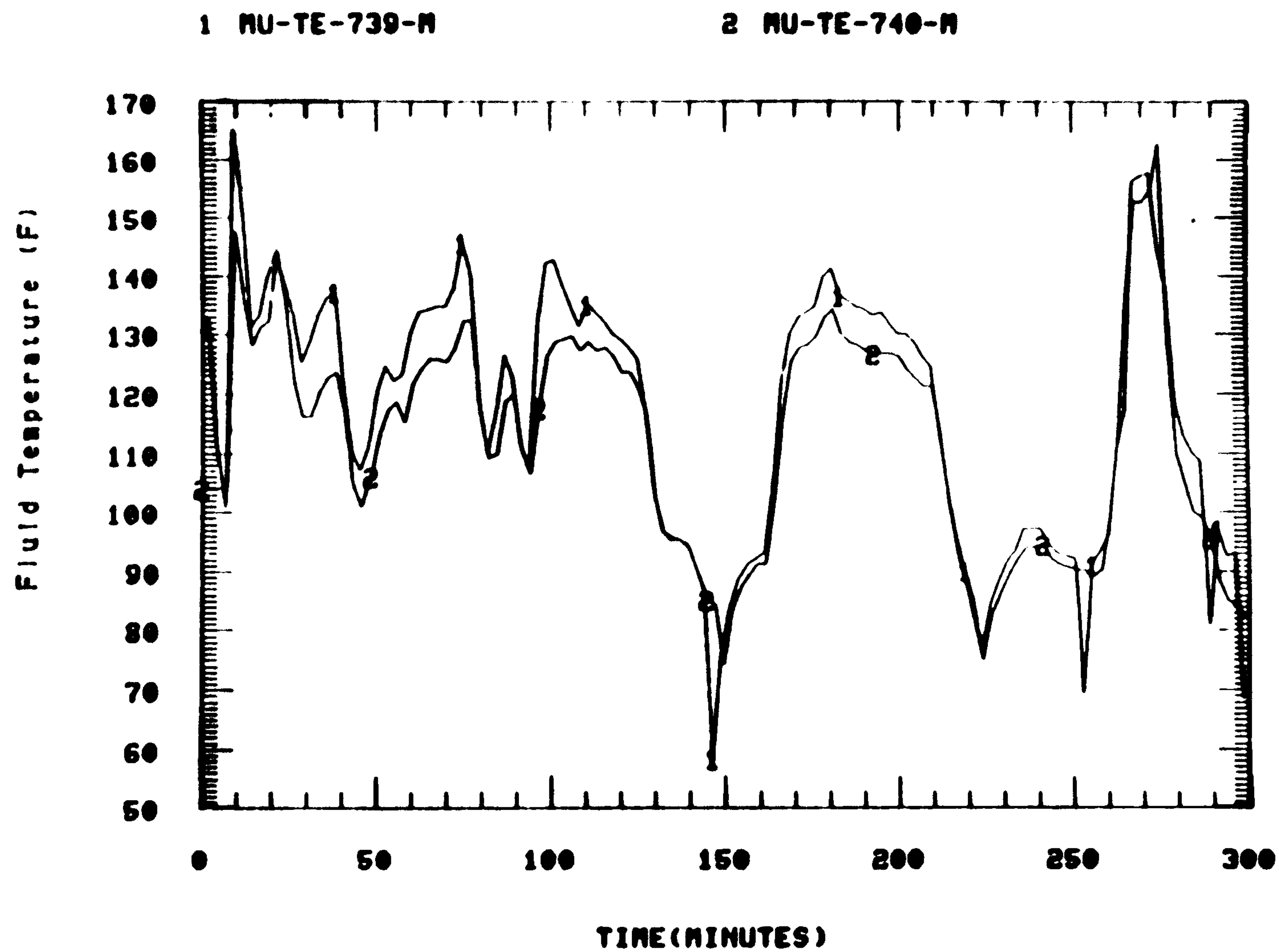


Fig. 2 LETDOWN COOLER OUTLET TEMPERATURES
1 - A COOLER 2 - B COOLER

q value. In this equation, letdown water specific heat Cpt is fixed at 1.20 Btu/lbm·°F, taken as an average value from the ASME steam tables in consideration of variation of temperature and pressure inside tubes of the letdown cooler.

Specific volume Sv for use in conversion from mass flowrate to volume flowrate is fixed at 0.016 ft³/lbm, taken from the ASME steam tables. This is supposed to be an average value at the outlet of letdown cooler.

A computer program using BASIC language has been developed to facilitate the calculational procedure described above.

4. ESTIMATED RESULTS

Estimated results of the LC-1A flowrates together with the measured LC inlet/outlet temperatures and the calculated CW outlet temperatures are listed in Table 1 at every minute after the initiation of the accident. In the same way, estimated results of the LC-1B flowrates are listed in Table 2. Total letdown cooler flowrates are obtained as the sum of the two LC flowrates to be net fluid-flowrates through the letdown line, and listed with the mixed-fluid temperatures in Table 3.

Comparison of the total flowrates with those predicted by Leung [2] using an assumed CW inlet-temperature of 35°C (95°F) is shown in Fig. 3. One can see that the present calculation predicts slightly greater flowrates than Leung does. Major differences are as follow. Leung's letdown flowrates take zero value during some periods of time, when the LC outlet-temperatures become lower than his assumed CW inlet-temperature of 95°F. On the other hand, the present calculation assumes 45°F for the CW inlet-temperature, which is always lower than the measured LC outlet-temperature. The LC flowrates are assumed to be zero in the present calculation when the letdown flow-line isolation valves MU-V2A, MU-V2B and MU-V376 are closed by the ESF actuation.

Table 1 Letdown Cooler 1A Volumetric Flowrate versus Time (Tsi=45°F)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVFlow.(gpm)	
0	561	131	132	66	
1	576	131	132	65	
2	579	130	132	65	
3	579	122	45	C	
4	579	114	45	0	Note [illegible]
5	581	108	45	0	
6	584	104	45	0	
7	589	108	125	55	
8	595	134	135	65	
9	594	161	143	76	
10	589	160	143	76	Note 6
11	587	155	142	74	
12	585	148	140	71	
13	582	139	137	68	
14	576	131	133	65	
15	569	132	133	66	
16	565	133	133	66	
17	563	135	133	67	
18	560	137	133	69	
19	557	140	133	70	
20	554	142	133	71	
21	552	143	133	72	
22	551	142	133	71	Note 6
23	550	140	133	71	
24	550	138	133	70	
25	550	136	132	69	
26	549	134	131	68	
27	549	130	130	66	
28	549	127	129	65	
29	548	126	128	65	
30	547	127	128	65	
31	547	129	128	66	
32	546	131	128	67	
33	545	133	129	68	
34	545	134	130	68	
35	545	135	130	69	
36	546	136	130	69	
37	546	137	130	70	
38	546	137	131	70	Note 6
39	546	131	130	67	
40	546	124	128	64	
41	546	119	126	62	
42	545	114	124	60	
43	545	110	123	58	
44	545	109	122	58	
45	545	107	121	57	
46	545	108	121	58	
47	544	110	121	58	
48	543	112	122	59	
49	542	116	123	61	
50	542	120	124	63	
51	542	122	125	64	
52	543	124	126	64	
53	544	124	126	64	
54	545	123	126	64	
55	546	122	126	63	
56	547	122	126	64	
57	548	123	126	64	
58	548	125	127	64	
59	549	128	128	66	
60	548	130	129	67	

Table 1 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
61	549	132	129	67	
62	549	133	130	68	
63	548	134	130	68	
64	548	134	130	68	
65	546	134	130	68	
66	545	134	130	69	
67	544	135	130	69	
68	543	135	130	69	
69	543	135	130	69	
70	543	135	130	69	
71	543	137	130	70	
72	543	138	131	71	
73	542	141	132	72	
74	541	145	132	73	
75	542	144	132	73	Note 6
76	543	142	132	72	
77	545	137	132	70	
78	547	128	129	66	
79	549	119	126	62	
80	551	115	125	60	
81	549	112	123	59	
82	547	111	123	59	
83	545	114	123	60	
84	545	117	124	61	
85	547	121	125	63	
86	549	125	127	64	
87	551	125	127	64	
88	552	124	127	64	Note 6
89	554	121	127	62	
90	555	116	126	60	
91	556	112	124	58	
92	556	110	123	58	
93	558	108	123	57	
94	560	112	123	59	
95	556	122	127	63	
96	551	132	130	67	
97	547	136	130	69	
98	543	141	131	72	
99	539	142	131	73	
100	535	142	131	73	
101	533	142	131	73	Note 6
102	530	140	131	72	
103	529	138	130	72	
104	528	137	130	71	
105	527	135	129	70	
106	527	134	128	70	
107	526	132	128	69	
108	525	131	127	69	
109	524	133	127	70	
110	523	134	127	70	
111	522	135	127	71	
112	521	134	127	70	
113	520	133	127	70	
114	519	133	127	70	
115	517	132	127	70	
116	516	131	127	70	
117	514	131	126	69	
118	512	130	125	69	
119	509	129	125	69	
120	507	129	125	69	
121	504	128	124	69	

Table 1 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CNOu.Temp.(F)	LCVflow.(gpm)	
122	501	128	124	68	
123	497	127	123	69	
124	494	126	122	69	
125	494	125	122	68	Note 6
126	494	122	121	67	
127	494	118	120	65	
128	494	113	118	63	
129	494	107	116	60	
130	493	103	114	58	
131	492	100	113	57	
132	491	97	112	55	
133	490	96	111	55	
134	489	95	111	55	
135	488	95	111	55	
136	488	95	111	55	
137	488	95	111	55	
138	488	95	111	55	
139	488	95	111	55	
140	488	93	110	54	
141	488	92	109	53	
142	488	90	109	52	
143	488	89	108	52	
144	488	87	108	51	
145	488	77	103	46	
146	488	65	96	39	
147	488	62	94	37	Note 4
148	488	69	97	42	
149	488	76	101	45	
150	488	79	103	47	
151	488	82	104	49	
152	488	85	106	50	
153	488	87	106	51	
154	496	89	107	52	
155	485	90	107	53	
156	485	91	108	53	
157	483	91	108	53	
158	483	92	108	54	
159	481	92	108	54	
160	476	93	108	54	
161	474	93	108	55	
162	476	98	110	57	
163	473	103	111	60	
164	470	109	113	63	
165	468	116	115	66	
166	469	123	117	70	
167	466	126	118	72	
168	462	129	119	74	
169	457	131	119	75	
170	462	132	119	75	
171	464	133	120	75	
172	455	133	120	76	
173	451	134	120	77	
174	400	134	114	84	
175	450	134	119	76	
176	455	136	120	79	
177	452	138	120	79	
178	452	140	121	80	
179	451	140	121	81	
180	450	141	121	81	
181	448	140	121	81	
182	447	138	121	80	

Table 1 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
183	446	136	120	79	
184	446	136	120	79	
185	446	136	120	79	
186	447	135	120	78	
187	455	135	120	77	
188	463	134	120	76	
189	470	134	121	75	
190	476	134	122	75	
191	480	134	122	74	
192	483	133	122	74	
193	478	133	122	74	
194	475	133	122	74	
195	473	133	122	75	
196	472	133	122	74	
197	473	132	122	74	
198	474	131	122	73	
199	473	130	122	73	
200	474	130	122	73	
201	474	130	122	73	
202	467	130	121	73	
203	458	129	120	74	
204	448	129	118	75	
205	438	128	117	76	
206	429	127	115	76	
207	419	126	114	77	
208	407	125	112	78	
209	398	125	111	79	Note 6
210	391	121	109	77	
211	386	116	107	75	
212	380	112	105	73	
213	370	108	102	72	
214	364	104	100	70	
215	359	100	99	68	
216	354	97	97	66	
217	348	94	96	65	
218	346	92	95	64	
219	336	90	93	63	
220	330	88	92	62	
221	325	86	90	61	
222	324	83	89	59	
223	322	79	87	57	
224	323	78	87	56	
225	453	81	100	50	
226	452	84	101	51	
227	449	86	102	52	
228	445	88	102	54	
229	436	89	102	55	
230	429	90	102	56	
231	424	92	102	57	
232	419	92	102	58	
233	412	93	102	59	
234	403	95	102	60	
235	397	96	101	61	
236	393	97	45	0	
237	387	97	45	0	Note 5
238	375	97	45	0	
239	363	97	45	0	
240	354	97	45	0	
241	348	97	96	67	
242	333	96	94	68	
243	321	95	93	69	

Table 1 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
244	308	94	91	70	
245	308	93	91	70	
246	307	93	91	69	
247	305	93	90	70	
248	303	93	90	70	
249	329	92	92	66	
250	333	92	92	65	
251	329	85	90	60	
252	326	75	87	54	
253	321	73	85	52	
254	318	82	87	60	
255	318	91	90	66	
256	315	92	90	68	
257	307	93	90	70	
258	303	94	90	71	
259	311	95	91	71	
260	315	97	91	72	
261	317	103	94	76	
262	319	109	96	81	
263	307	113	96	86	
264	301	115	96	90	
265	298	122	96	98	
266	296	139	100	117	
267	297	155	104	138	
268	289	156	104	146	
269	288	157	104	147	
270	285	157	104	150	
271	280	157	103	154	
272	277	157	102	157	
273	275	152	101	148	Note 6
274	275	146	100	139	
275	273	143	99	135	
276	272	140	98	131	
277	270	135	97	125	
278	270	128	95	115	
279	267	120	93	106	
280	265	117	92	103	
281	263	114	91	101	
282	261	112	90	100	
283	260	111	90	99	
284	257	110	89	98	
285	254	109	89	98	
286	253	109	89	98	
287	250	101	86	90	
288	247	90	83	78	
289	246	93	80	70	
290	243	99	81	78	
291	239	96	82	87	
292	238	96	82	87	
293	236	94	82	85	
294	233	93	82	85	
295	232	93	81	86	
296	230	93	81	86	
297	228	83	79	75	
298	226	73	75	63	
299	224	74	75	65	
300	222	83	76	77	

Table 2 Letdown Cooler 1B Volumetric Flowrate versus Time (Tsi=45°F)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
0	561	104	45	0	
1	576	104	45	0	
2	579	104	45	0	
3	579	104	45	0	Note 2
4	579	104	45	0	
5	581	104	45	0	
6	584	104	45	0	
7	589	104	124	54	
8	595	118	130	59	
9	594	136	136	66	
10	589	146	138	70	
11	587	141	138	68	
12	585	136	136	67	
13	582	133	135	65	
14	576	130	133	64	
15	569	129	132	65	
16	565	130	132	65	
17	563	131	132	66	
18	560	132	132	66	
19	557	132	131	67	
20	554	136	131	69	
21	552	141	132	71	
22	551	143	133	72	Note 6
23	550	139	133	70	
24	550	135	132	69	
25	550	130	130	66	
26	549	125	128	64	
27	549	121	127	63	
28	549	118	126	62	
29	548	116	125	61	
30	547	116	125	61	
31	547	116	125	61	
32	546	117	125	61	
33	545	119	125	62	
34	545	120	125	63	
35	545	121	125	63	
36	546	122	126	64	
37	546	123	126	64	
38	546	123	126	64	
39	546	122	126	64	
40	546	120	126	62	
41	546	117	125	61	
42	545	112	123	59	
43	545	107	121	57	
44	545	104	120	56	
45	545	102	119	55	
46	545	101	119	55	
47	544	104	119	56	
48	543	106	120	57	
49	542	108	120	58	
50	542	111	121	59	
51	542	114	122	60	
52	543	115	123	61	
53	544	117	124	61	
54	545	118	124	62	
55	546	118	124	62	
56	547	118	124	62	
57	548	116	124	61	
58	548	115	124	60	
59	549	118	125	62	
60	549	121	126	63	

Table 2 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CROu.Temp.(F)	LCVflow.(gpm)	
61	549	122	126	63	
62	549	123	126	64	
63	548	124	127	64	
64	548	125	127	65	
65	546	125	127	65	
66	545	126	127	65	
67	544	126	127	65	
68	543	125	127	65	
69	543	125	127	65	
70	543	125	127	65	
71	543	126	127	65	
72	543	127	127	66	
73	542	129	128	67	
74	541	131	128	67	
75	542	132	129	68	
76	543	132	129	68	
77	545	132	128	68	Note 6
78	547	126	129	65	
79	549	120	127	62	
80	551	115	125	60	
81	549	112	124	59	
82	547	109	122	58	
83	545	109	122	58	
84	545	109	122	58	
85	547	112	122	59	
86	549	116	124	61	
87	551	119	125	62	
88	552	119	126	62	
89	554	119	126	62	
90	555	116	126	60	
91	556	112	125	59	
92	556	109	124	58	
93	558	108	123	57	
94	560	107	123	56	
95	556	[illegible]	123	58	
96	551	115	124	60	
97	547	120	125	62	
98	543	123	126	64	
99	539	126	126	66	
100	535	127	126	66	
101	533	128	126	67	
102	530	129	126	67	
103	529	129	126	68	
104	528	129	126	68	
105	527	129	126	68	
106	527	130	126	68	
107	526	129	126	68	
108	525	127	126	67	
109	524	127	126	67	
110	523	128	126	67	
111	522	128	126	68	
112	521	128	126	66	
113	520	127	126	67	
114	519	127	126	67	
115	517	127	126	68	
116	516	127	125	68	
117	514	127	125	68	
118	512	126	124	68	
119	509	125	124	67	
120	507	124	123	67	
121	504	124	123	67	

Table 2 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
122	501	124	123	67	
123	497	123	122	67	
124	494	122	121	67	
125	494	121	121	67	Note 6
126	494	119	120	66	
127	494	117	120	65	
128	494	115	119	64	
129	494	109	117	61	
130	493	103	114	58	
131	492	100	113	57	
132	491	98	112	56	
133	490	96	112	55	
134	489	96	111	55	
135	488	96	111	55	
136	488	95	111	55	
137	488	95	111	55	
138	488	95	111	55	
139	488	94	111	54	
140	488	93	110	54	
141	488	91	109	53	
142	488	89	109	52	
143	488	88	108	51	
144	488	86	107	50	
145	488	85	106	50	
146	488	84	106	50	
147	488	84	106	49	
148	488	80	104	47	
149	488	76	102	45	
150	488	76	102	45	Note 4
151	488	80	103	47	
152	488	83	105	49	
153	488	85	105	50	
154	486	87	106	51	
155	485	88	106	52	
156	485	88	107	52	
157	483	89	107	52	
158	483	90	107	53	
159	481	91	107	53	
160	476	91	107	54	
161	474	91	107	54	
162	476	93	108	55	
163	473	98	109	57	
164	470	102	111	59	
165	468	108	113	62	
166	469	114	115	65	
167	466	119	116	68	
168	462	122	116	70	
169	457	125	117	72	
170	462	126	118	72	
171	464	127	118	73	
172	455	128	118	74	
173	451	128	118	74	
174	400	128	112	81	
175	450	129	117	75	
176	455	130	118	75	
177	452	131	118	76	
178	452	132	118	76	
179	451	133	118	77	
180	450	134	118	77	
181	448	134	118	78	
182	447	132	118	77	

Table 2 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
183	446	130	118	76	
184	446	130	118	75	
185	446	129	118	75	
186	447	128	118	75	
187	455	128	119	74	
188	463	128	118	73	
189	470	128	119	72	
190	476	127	120	71	
191	480	127	120	71	
192	483	127	120	70	
193	478	127	120	71	
194	475	127	120	71	
195	473	127	120	71	
196	472	127	120	71	
197	473	127	120	71	
198	474	126	120	71	
199	473	126	120	71	
200	474	126	120	71	
201	474	125	120	70	
202	467	124	119	71	
203	458	124	118	71	
204	448	123	116	72	
205	438	122	115	72	
206	428	122	114	73	
207	419	121	112	74	
208	407	121	111	75	
209	398	121	110	76	
210	391	120	109	77	
211	386	117	107	75	Note 6
212	380	113	105	74	
213	370	108	103	72	
214	364	104	100	70	
215	359	99	98	67	
216	354	96	97	66	
217	348	92	95	64	
218	346	90	94	63	
219	336	88	92	62	
220	330	86	91	61	
221	325	83	89	60	
222	324	80	88	58	
223	322	78	87	56	
224	323	75	86	54	
225	453	78	99	48	
226	452	81	100	50	
227	449	83	101	[illegible]	
228	445	85	101	52	
229	436	86	101	53	
230	429	88	101	54	
231	424	89	101	55	
232	419	90	101	56	
233	412	91	101	58	
234	403	92	101	59	
235	397	93	100	60	
236	393	94	45	0	
237	387	94	45	0	
238	375	94	45	0	
239	363	94	45	0	Note 5
240	354	94	45	0	
241	348	95	96	[illegible]	
242	333	94	94	66	
243	321	93	92	67	

Table 2 (continued)

Time(min)	LCIn.Temp.(F)	LCOu.Temp.(F)	CWOu.Temp.(F)	LCVflow.(gpm)	
244	308	92	90	68	
245	308	91	90	68	
246	307	91	90	68	
247	305	91	90	68	
248	303	91	90	68	
249	329	90	91	65	
250	333	90	91	64	
251	329	90	91	64	
252	326	90	91	65	
253	321	90	91	65	
254	318	90	91	65	
255	318	89	91	65	
256	315	89	90	65	
257	307	90	89	67	
258	303	90	89	68	
259	311	94	90	70	
260	315	98	92	72	
261	317	103	94	76	
262	319	108	96	80	
263	307	115	96	89	
264	301	125	98	100	
265	298	135	100	112	
266	296	142	101	121	
267	297	149	103	129	
268	289	153	103	140	
269	288	153	103	140	
270	285	153	103	142	
271	280	153	102	147	
272	277	154	102	151	
273	275	157	102	157	
274	275	160	102	164	
275	273	160	102	166	← Note 6
276	272	146	99	141	
277	270	132	96	121	
278	270	123	94	109	
279	267	115	92	100	
280	265	109	90	94	
281	263	107	89	93	
282	261	105	88	91	
283	260	103	88	89	
284	257	101	87	88	
285	254	100	86	87	
286	253	99	86	87	
287	250	99	85	87	
288	247	97	85	86	
289	246	96	84	85	
290	243	93	83	83	
291	239	90	82	80	
292	238	88	81	78	
293	236	87	80	77	
294	233	85	80	76	
295	232	85	79	76	
296	230	84	79	76	
297	228	84	79	76	
298	226	83	78	75	
299	224	82	78	75	
300	222	82	77	75	

Table 3 Total Letdown Cooler Volumetric Flowrate versus Time (Tsi=45°F)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	Mix.Temp.(°F)	
0	66	0	66	131	
1	65	0	65	131	
2	65	0	65	130	
3	0	0	0	113	
4	0	0	0	109	
5	0	0	0	106	
6	0	0	0	104	
7	55	54	109	106	
8	65	59	124	126	
9	76	66	142	149	
10	76	70	146	153	Note 3
11	74	68	142	148	
12	71	67	138	142	
13	68	65	133	136	
14	65	64	129	130	
15	66	65	131	130	
16	66	65	131	131	
17	67	66	133	133	
18	69	66	135	134	
19	70	67	137	136	
20	71	69	140	139	
21	72	71	143	142	
22	71	72	143	142	
23	71	70	141	139	Note 6
24	70	69	139	137	
25	69	66	135	133	
26	68	64	132	129	
27	66	63	129	126	
28	65	62	127	123	
29	65	61	126	121	
30	65	61	126	122	
31	66	61	127	123	
32	67	61	128	124	
33	68	62	130	126	
34	68	63	131	127	
35	69	63	132	129	
36	69	64	133	129	
37	70	64	134	130	
38	70	64	134	130	
39	67	64	131	127	Note 6
40	64	62	126	122	
41	62	61	123	118	
42	60	59	119	113	
43	58	57	115	108	
44	58	56	114	106	
45	57	55	112	105	
46	58	55	113	105	
47	58	56	114	107	
48	59	57	116	[illegible]	
49	61	58	119	[illegible]	
50	63	59	122	115	
51	64	60	124	118	
52	64	61	125	119	
53	64	61	125	121	
54	64	62	126	120	
55	63	62	125	120	
56	64	62	[illegible]	120	
57	64	61	125	120	
58	64	60	124	120	
59	66	62	128	123	
60	67	63	130	126	

Table 3 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	Mix.Temp.('F)	
61	67	63	130	127	
62	68	64	132	128	
63	68	64	132	129	
64	68	65	133	129	
65	68	65	133	130	
66	69	65	134	130	
67	69	65	134	130	
68	69	65	134	130	
69	69	65	134	130	
70	69	65	134	130	
71	70	65	135	131	
72	71	66	137	133	
73	72	67	139	135	
74	73	67	140	138	Note 6
75	73	68	141	138	
76	72	68	140	137	
77	70	68	138	134	
78	66	65	131	127	
79	62	62	124	120	
80	60	60	120	115	
81	59	59	118	112	
82	59	58	117	110	
83	60	58	118	112	
84	61	58	119	113	
85	63	59	122	116	
86	64	61	125	120	Note 6
87	64	62	126	122	
88	64	62	126	121	
89	62	62	124	120	
90	60	60	120	116	
91	58	59	117	112	
92	58	58	116	110	
93	57	57	114	108	
94	59	56	115	109	
95	63	58	121	117	
96	67	60	127	124	
97	69	62	131	128	
98	72	64	136	132	
99	73	66	139	135	
100	73	66	139	135	
101	73	67	140	135	
102	72	67	139	135	
103	72	68	140	134	
104	71	68	139	133	
105	70	68	138	132	Note 6
106	70	68	138	132	
107	69	68	137	130	
108	69	67	136	129	
109	70	67	137	130	
110	70	67	137	131	
111	71	68	139	132	
112	70	68	138	131	
113	70	67	137	130	
114	70	67	137	130	
115	70	68	138	130	
116	70	68	138	129	
117	69	68	137	129	
118	69	68	137	128	
119	69	67	136	127	
120	69	67	136	127	
121	69	67	136	126	

Table 3 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	Mix.Temp.(°F)	
122	69	67	136	126	
123	69	67	136	125	
124	69	67	136	124	
125	68	67	135	123	Note 6
126	67	66	133	120	
127	65	65	130	118	
128	63	64	127	114	
129	60	61	121	108	
130	58	58	116	103	
131	57	57	114	100	
132	55	56	111	97	
133	55	55	110	96	
134	55	55	110	96	
135	55	55	110	95	
136	55	55	110	95	
137	55	55	110	95	
138	55	55	110	95	
139	55	54	109	94	
140	54	54	108	93	
141	53	53	106	91	
142	52	52	104	90	
143	52	51	103	88	
144	51	50	101	87	
145	46	50	96	81	
146	39	50	89	76	
147	37	49	86	74	
148	42	47	89	75	Note 4
149	45	45	90	76	
150	47	45	92	77	
151	49	47	96	81	
152	50	49	99	84	
153	51	50	101	86	
154	52	51	103	88	
155	53	52	105	89	
156	53	52	105	90	
157	53	52	105	90	
158	54	53	107	91	
159	54	53	107	92	
160	54	54	108	92	
161	55	54	109	92	
162	57	55	112	96	
163	60	57	117	100	
164	63	59	122	106	
165	66	62	128	112	
166	70	65	135	118	
167	72	68	140	122	
168	74	70	144	126	
168	75	72	147	128	
170	75	72	147	129	
171	75	73	148	130	
172	76	74	150	130	
173	77	74	151	131	
174	84	81	165	131	
175	78	75	153	132	
176	78	75	153	133	
177	79	76	155	134	
178	90	76	156	136	
179	81	77	158	137	
180	81	77	158	137	
181	81	78	159	137	
182	80	77	157	135	

Table 3 (continued)

Time(min)	1ALDmf.(gpm)	1BLDmf.(gpm)	Total LDmf.	Mix.Temp.(°F)	
183	79	76	155	133	
184	79	75	154	133	
185	79	75	154	132	
186	78	75	153	132	
187	77	74	151	132	
188	76	73	149	131	
189	75	72	147	131	
190	75	71	146	131	
191	74	71	145	130	
192	74	70	144	130	
193	74	71	145	130	
194	74	71	145	130	
195	75	71	146	130	
196	74	71	145	130	
197	74	71	145	129	
198	73	71	144	129	
199	73	71	144	128	Note 6
200	73	71	144	128	
201	73	70	143	128	
202	73	71	144	127	
203	74	71	145	127	
204	75	72	147	126	
205	76	72	148	125	
206	76	73	149	124	
207	77	74	151	124	
208	78	75	153	123	
209	79	76	155	123	
210	77	77	154	120	
211	75	75	150	117	
212	73	74	147	113	
213	72	72	144	108	
214	70	70	140	104	
215	68	67	135	100	
216	66	66	132	96	
217	65	64	129	93	
218	64	63	127	91	
219	63	62	125	89	
220	62	61	123	87	
221	61	60	121	84	
222	59	58	117	82	
223	57	56	113	79	
224	56	54	110	77	
225	50	48	98	79	
226	51	50	101	82	
227	52	51	103	85	
228	54	52	106	86	
229	55	53	108	88	
230	56	54	110	89	
231	57	55	112	90	
232	58	56	114	91	
233	59	58	117	92	
234	60	59	119	93	
235	61	60	121	94	
236	0	0	0	95	
237	0	0	0	96	Note 5
238	0	0	0	96	
239	0	0	0	96	
240	0	0	0	96	
241	67	65	132	96	
242	68	66	134	95	
243	69	67	136	94	

Table 3 (continued)

Time(min)	IALDmf.(gpm)	IBLDmf.(gpm)	Total LDmf.	Mix.Temp.(°F)	
244	70	68	138	93	
245	70	68	138	92	
246	69	68	137	92	
247	70	68	138	92	
248	70	68	138	92	
249	66	65	131	91	
250	65	64	129	91	
251	60	64	124	87	
252	54	65	119	83	
253	52	65	117	82	
254	60	65	125	86	
255	66	65	131	90	
256	68	65	133	91	
257	70	67	137	91	
258	71	68	139	92	
259	71	70	141	95	
260	72	72	144	97	
261	76	76	152	103	
262	81	80	161	109	
263	86	89	175	114	
264	90	100	190	120	
265	98	112	210	129	
266	117	121	238	140	
267	138	129	267	152	
268	146	140	286	154	
269	147	140	287	155	
270	150	142	292	155	
271	154	147	301	155	
272	157	151	308	156	
273	148	157	305	154	Note 6
274	139	164	303	154	
275	135	166	301	152	
276	131	141	272	143	
277	125	121	246	134	
278	115	109	224	125	
279	106	100	206	117	
280	103	94	197	113	
281	101	93	194	111	
282	100	91	191	109	
283	99	89	188	107	
284	98	88	186	106	
285	98	87	185	105	
286	98	87	185	104	
287	90	87	177	100	
288	78	86	164	94	
289	70	85	155	90	
290	78	83	161	91	
291	87	80	167	93	
292	87	78	165	92	
293	85	77	162	90	
294	85	76	161	89	
295	86	76	162	89	
296	86	76	162	89	
297	75	76	151	83	
298	63	75	138	78	
299	65	75	140	78	
300	77	75	152	82	

Notes for LC flowrates at Table 1, 2, 3

Note 1. Judging from behaviour of LC 1A outlet-temperature, LC 1A isolation valve MU-V2A had been closed during time-period from 2min. to 6.7min. into the accident.

Note 2. Judging from behaviour of LC 1B outlet-temperature LC 1B flowline had been stopped by closure of line-isolation valve MU-V2B for the first 6.7min. into the accident.

Note 3. According to the SOE tables, an operator initiated letdown flowrate at a rate greater than 160gpm in an attempt to reduce pressurizer level at 5min. into the accident. The estimated flowrates show there was some delay in the process reaction.

Note 4. Sharp decrease of LC outlet-temperature during time-period from 140min. to 160min. might indicate flow-line stagnation caused by isolation valve closure. But there are no such operational records as the valve closure.

Note 5. ESF was actuated due to reactor building high pressure at 235.6min. into the accident, and the operator defeated the ESF actuation at 240.2min. During this time period, the letdown flow was stagnated by the isolation valve closure.

Note 6. Sharp decrease of LC outlet-temperature at this time probably indicates a significant decrease in the letdown flow-rate as aresult of operator action. However, there are no operational records which would verify control valve closure at this time.

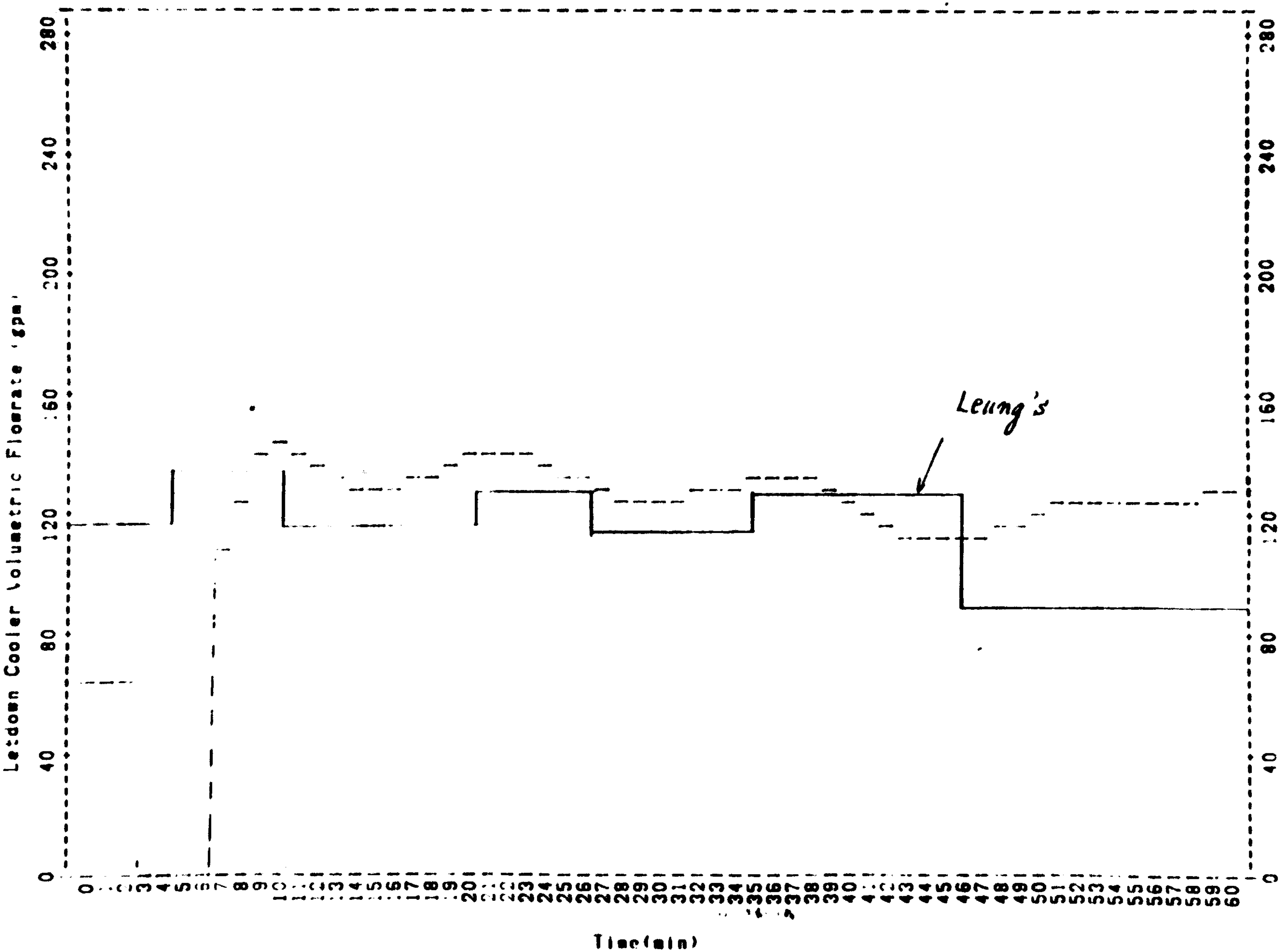


Fig. 3 Total letdown cooler volumetric flowrate versus time (Ts=45°F)

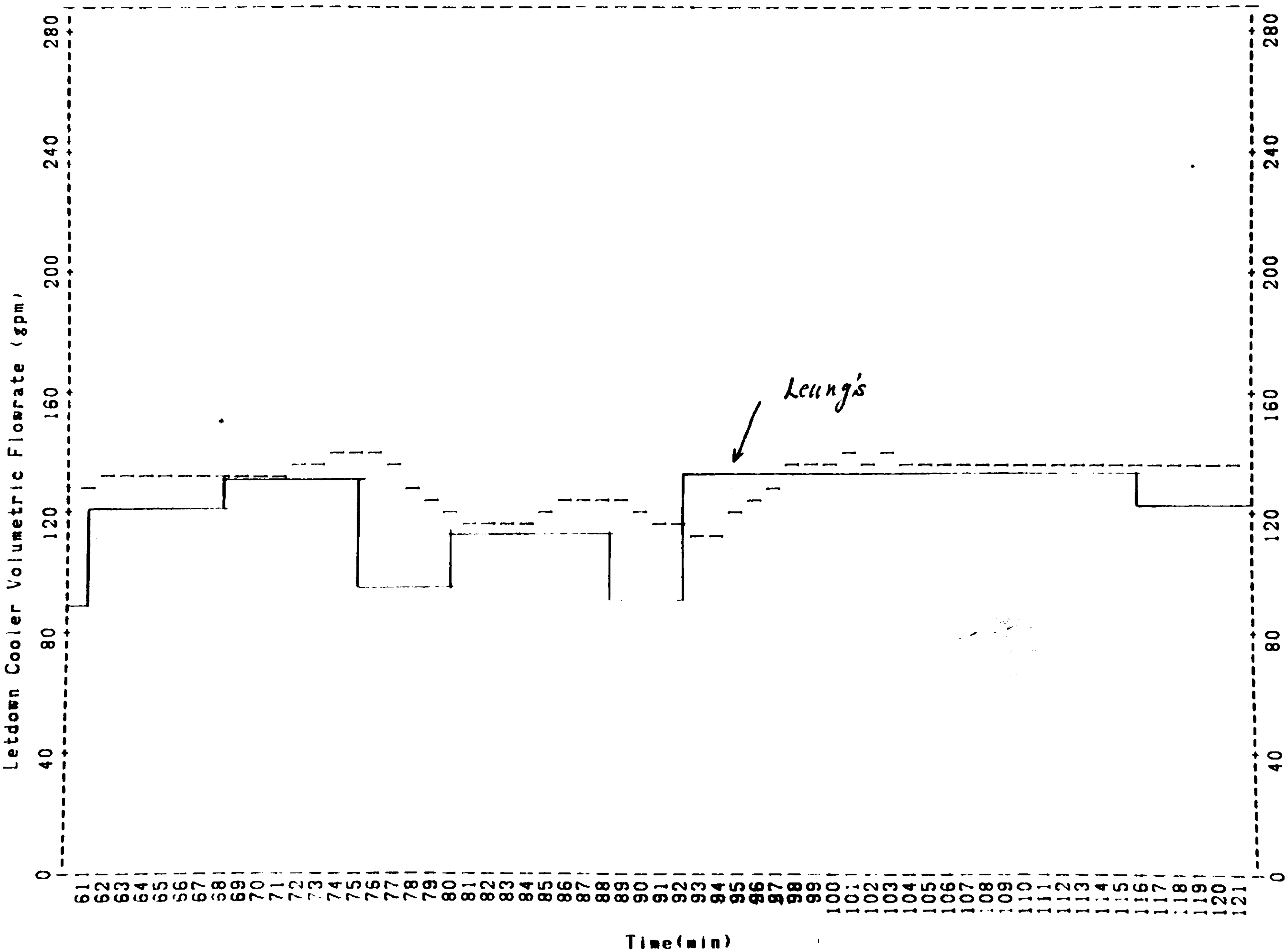


Fig. 3 (continued)

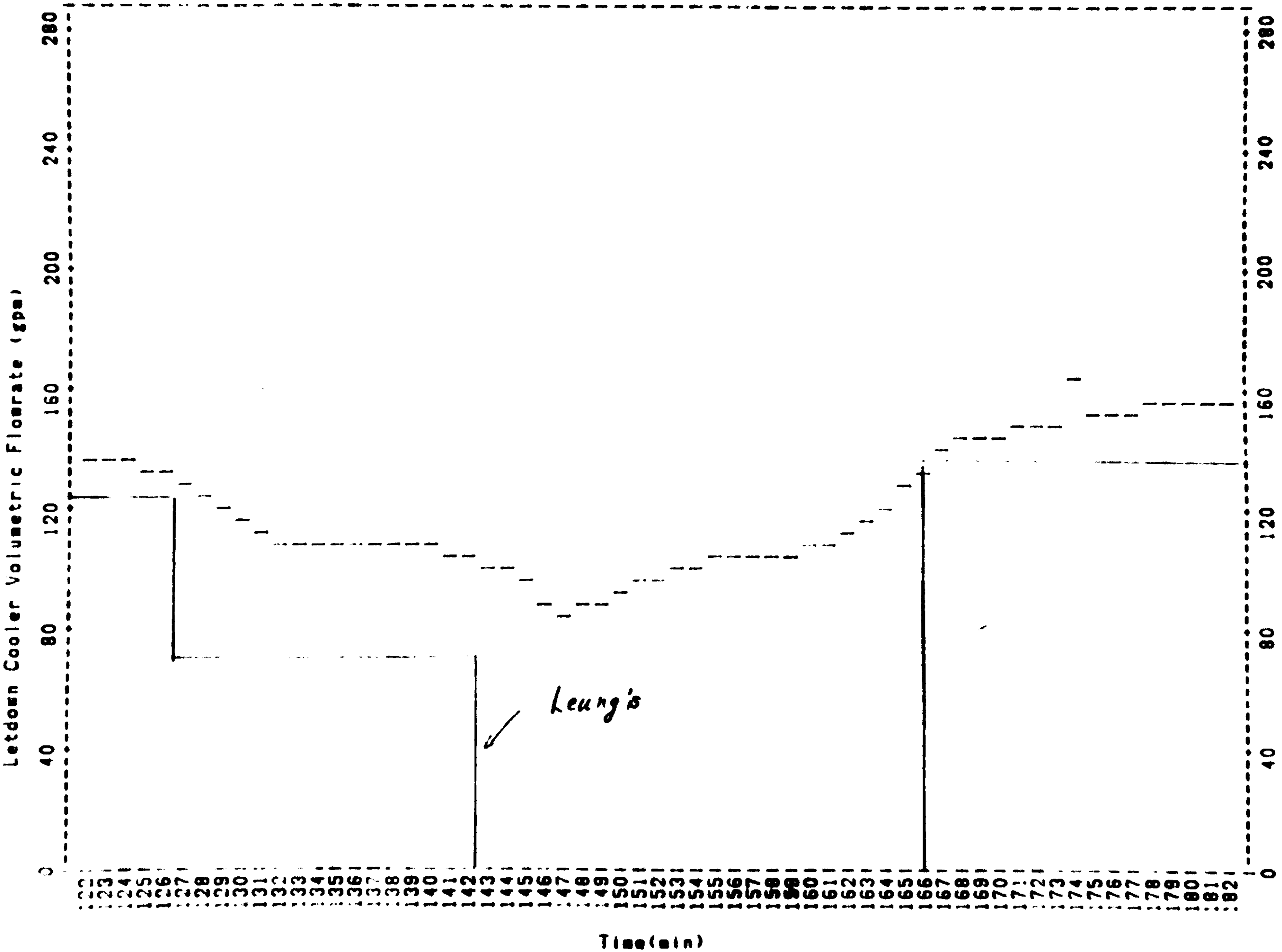


Fig. 3 (continued)

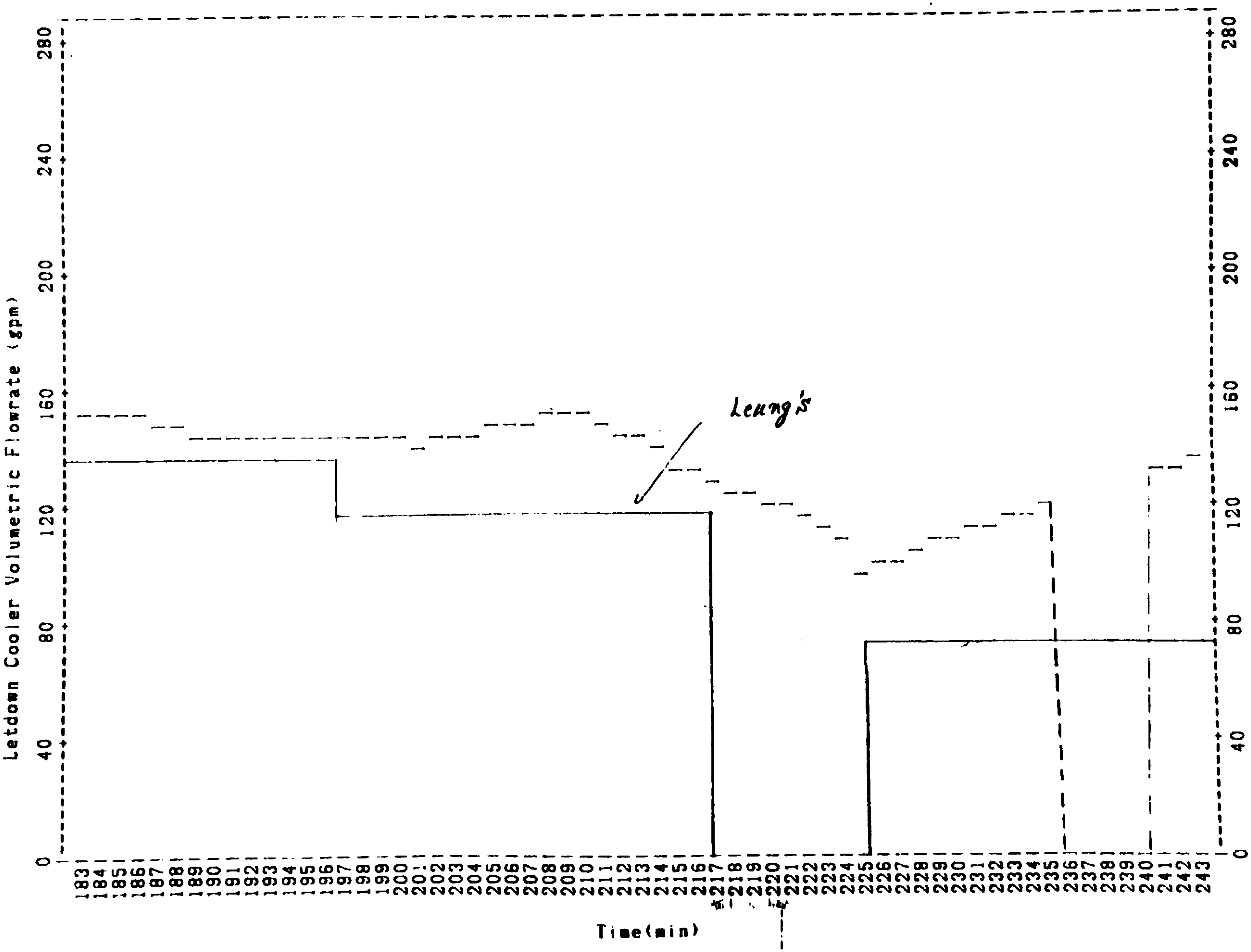


Fig. 3 (continued)

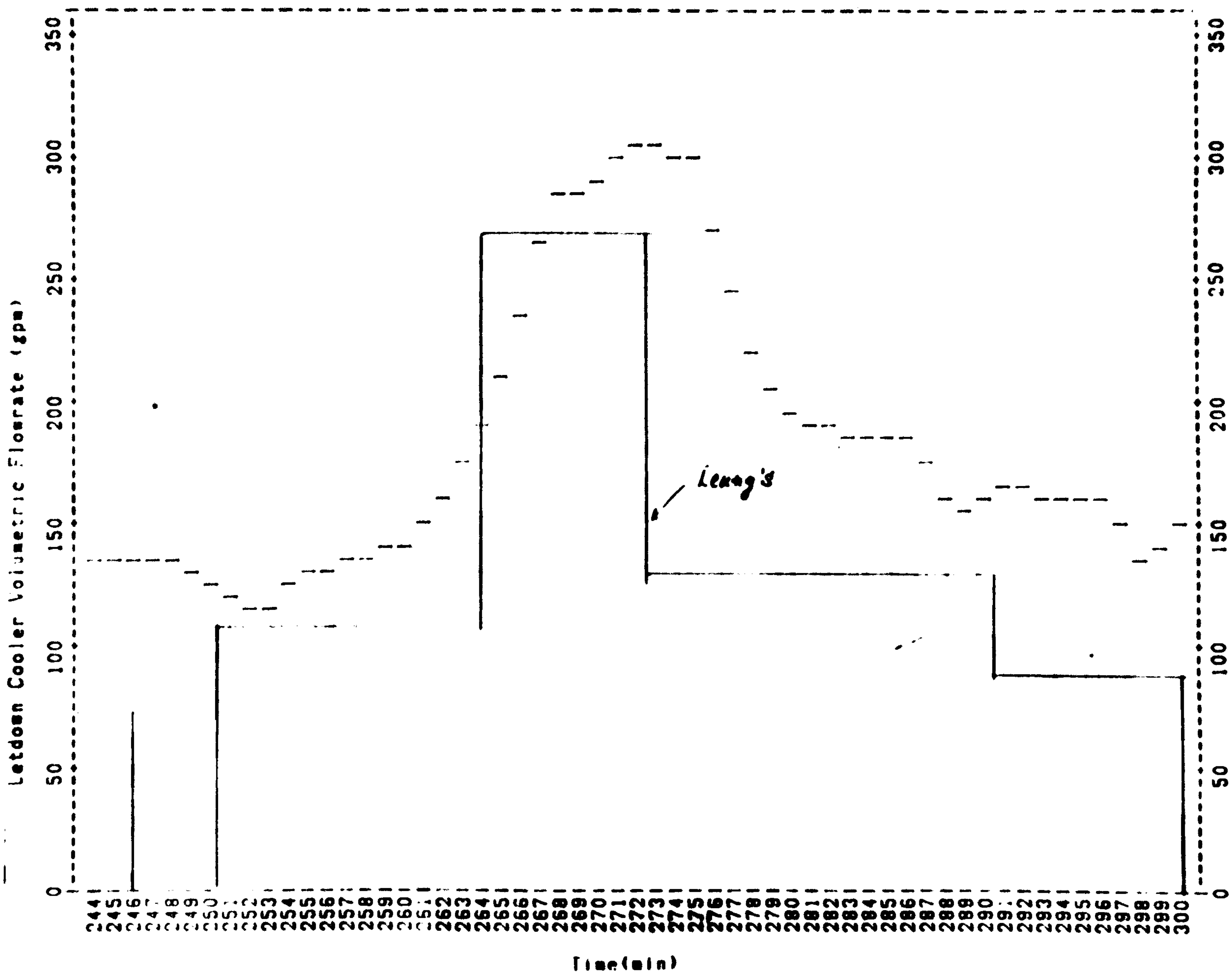


Fig.3 (continued)

5. UNCERTAINTY ESTIMATE

Uncertainty of the estimation of the LC flowrate is related with propagation of errors of measured data and assumed data used in the equations (1) ~ (3). Possible error-sources to be evaluated include the following.

1) Uncertainty of the letdown-cooler outlet-temperature T_{to} could be some 2% judging from the results of the primary loop temperature data review[4].
2) Uncertainty of the letdown-cooler inlet-temperature T_{ti} could be also some 2% by the same reason as described above.
3) Uncertainty of the assumed cooling-water inlet-temperature T_{si} is some 30% based on comparison between calculated results and measurement data.
4) Uncertainty of the conductance UA could be set as high as 10% from engineering judgement.
5) Uncertainty of cooling-water mass flowrate W_c could be also set some 10% from engineering judgement.
6) Uncertainty of cooling-water specific heat C_{ps} is as high as 1% based on variation of the steam-table value corresponding to the actual variation of temperature and pressure of the cooling water.
7) Uncertainty of letdown water specific heat C_{pt} is some 20% according to the ASME steam tables in consideration of rather wide range of actual variation of temperature and pressure (70°F~600°F, 600psig~2300psig) inside tubes of the letdown cooler.
8) Uncertainty of specific volume of letdown water is some 1% based on variation of the steam-table value corresponding to the actual variation of temperature and pressure of letdown water downstream.

After combining equations (1) ~ (3) and expressing the letdown mass flowrate Wld as an implicit function of (Tti, Tto, Tsi, UA, We, Cpt, Cps), the basic calculation of volumetric letdown-water flowrate Vld is as follows.

$$Vld = Sv \cdot F(Tti, Tto, Tsi, UA, We, Cpt, Cps) \tag{4}$$

Accordingly, uncertainty analysis equations are derived as follows,

$$\sigma^2_{Vld} = \left(\frac{\partial Vld}{\partial Sv}\cdot\sigma_{Sv}\right)^2 + \left(\frac{\partial Vld}{\partial Tti}\cdot\sigma_{Tti}\right)^2 + \left(\frac{\partial Vld}{\partial Tto}\cdot\sigma_{Tto}\right)^2 + \left(\frac{\partial Vld}{\partial Tsi}\cdot\sigma_{Tsi}\right)^2 + \left(\frac{\partial Vld}{\partial UA}\cdot\sigma_{UA}\right)^2 + \left(\frac{\partial Vld}{\partial We}\cdot\sigma_{We}\right)^2 + \left(\frac{\partial Vld}{\partial Cpt}\cdot\sigma_{Cpt}\right)^2 + \left(\frac{\partial Vld}{\partial Cps}\cdot\sigma_{Cps}\right)^2 \tag{5}$$

The coefficients such as,

$$\frac{\partial Vld}{\partial Tti},\quad \frac{\partial Vld}{\partial Tto},\quad \frac{\partial Vld}{\partial Tsi},\quad \frac{\partial Vld}{\partial UA},\quad \frac{\partial Vld}{\partial We},\quad \frac{\partial Vld}{\partial Cpt},\quad \frac{\partial Vld}{\partial Cps},$$

can be obtained by performing sensitivity study of the function Vld. These values are evaluated to be 0.075 gpm/°F, 0.45 gpm/°F, 0.39 gpm/°F, 8.6×10^{-4} gpm·hr·°F/Btu, 4.6×10^{-5} gpm·hr/lbm, 68 gpm·lbm·°F/Btu, 9.0 gpm·lbm·°F/Btu respectively. The coefficient $\partial Vld/\partial Sv$ is simply obtained from equation (4) to be a value of F, that is 8800 gpm·lbm/ft³ at the maximum.

After giving uncertainty σ's evaluated accoding to the items 1) ~ 8) to the equation (5), the total uncertainty σ concerning the estimation of LC volumetric flowrate is obtained as follows:

$$\sigma^2_{Vld} = (3300\times0.016\times0.01)^2 + (0.075\times600\times0.02)^2$$
$$+(0.45\times160\times0.02)^2 + (0.39\times45\times0.30)^2$$
$$+(3.6\times10^{-4}\times0.3\times10^5\times0.10)^2$$
$$+(4.6\times10^{-5}\times1.984\times10^5\times0.10)^2$$
$$+(63\times1.20\times0.2)^2 + (9.0\times0.999\times0.01)^2$$

$$\sigma_{Vld} = \sqrt{\begin{aligned}&(1.408)^2+(0.9)^2+(1.44)^2+(5.27)^2\\ &+(6.36)^2+(0.91)^2+(16.31)^2+(0.09)^2\end{aligned}}$$

$$= 19.6 \text{ gpm}$$

Uncertainty is an arbitrary substitute for a statistical confidence interval and can be interpreted as the largest expected error. The confidence level of the TMI-2 data uncertainty is approximately 95% as a result of the method used to calculate the total uncertainty.

After giving uncertainty σ's evaluated accoding to the items 1) ~ 8) to the equation (5), the total uncertainty σ concerning the estimation of LC volumetric flowrate is obtained as follows:

$$
\sigma^2_{Vld} = (8800\times0.016\times0.01)^2 + (0.075\times600\times0.02)^2 + (0.45\times160\times0.02)^2 + (0.39\times45\times0.30)^2 + (8.6\times10^{-4}\times0.8\times10^5\times0.10)^2 + (4.6\times10^{-5}\times1.984\times10^5\times0.10)^2 + (68\times1.20\times0.2)^2 + (9.0\times0.999\times0.01)^2
$$

$$
\sigma_{Vld} = \sqrt{(1.408)^2 + (0.9)^2 + (1.44)^2 + (5.27)^2 + (6.88)^2 + (0.91)^2 + (16.31)^2 + (0.09)^2}
$$

$$
= 19.6 \text{ gpm}
$$

Uncertainty is an arbitrary substitute for a statistical confidence interval and can be interpreted as the largest expected error. The confidence level of the TMI-2 data uncertainty is approximately 95% as a result of the method used to calculate the total uncertainty.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: D. W. Golden

From: R. D. McCormick

Subject: OTSG MASS FLOWRATE INITIAL CONDITION - RDMC-15-86 - Revision

The attachment to this letter contains an analysis of the main feedwater mass flowrate measurements immediately prior to the accident. This initial condition is presented along with the qualification and uncertainty analysis.

jlm

Attachment:
As Stated

cc: J. L. Anderson
J. M. Broughton
R. W. Brower
H. E. Knauts
Y. Nomura
R. D. McCormick File
Central File

STEAM GENERATOR
INITIAL CONDITION
MASS FLOWRATE DATA ANALYSIS

The steam generator main feedwater flows were disrupted at the beginning of the accident sequence and remainded off beyond the time of interest for initial conditions (174 minutes). Therefore, the flowrates which are reported herein are the average measurements for two minutes prior to the accident. Each of the steam generators had a mass flow rate meter (SP-8A-FT and SP-8B-FT) with corresponding temperature (SP-5A-TE and SP-5B-TE) and pressure (FW-1135-PT and FW-1132-PT) measurements.

The flowmeter consists of a velocity head detector, a signal conditioning and amplifying section, a coolant density computation section, and recording on the reactimeter. The detector was basically a flow tube connected to a differential pressure transducer. The electronics used many of the same components as the RC mass flowmeter systems. The density calculation circuitry information was unavailable, so it was assumed to be identical to the RC system for this analysis.

The differential pressure signal was put through a square root extractor and then multiplied by the square root of the coolant density (and an appropriate constant) to produce the mass flowrate measurement.

The coolant temperature measured by the RTD was used to determine the fluid density from a curve which represented the square root of steam table values around the normal operating point (1000 psi and 460°F). The loop coolant mass flowrate was continually computed according to the equation $\dot{m} = k\sqrt{\rho \Delta P}$. Figure 1 is a block diagram of the mass flow measurement circuit.

Table 1 lists the measurement identifiers, the quality classification, and the uncertainty of the mass flowrate data. The "Qualified Data" is data which have established uncertainties, have been corrected for all known errors, and are considered a reasonably repeatable representation of the physical phenomenon being measured, i.e., the mass flowrate at the detector location.

Uncertainty is a description of the numerical bounds of a measurement error, and the true value of a measurement is predicted with some confidence to lay within these bounds. Uncertainty is an arbitrary substitute for a statistical confidence interval and can be interpreted as the largest expected error. The confidence level of the TMI-2 data uncertainty is near 95% as a result of the method used to calcualte the total uncertainty. The uncertainty analysis provided the numerical error bounds of the data.

A formal system exists for determining the uncertainty in the measurement data[1-3]. Basically, this system consists of (1) compiling the useful data in a usable form, (2) gathering all available technical information on transducers, signal conditioning, and recording instruments, (3) gathering all available calibration data, (4) performing an uncertainty analysis on each measurement channel.

Information used in the uncertainty analysis came from Bailey Meter Company product instructions, TMI-2 calibration records, Rosemount Engineering Company specifications, and engineering estimates.

FIGURE 1

STEAM GENERATOR FEEDWATER FLOWMETER SYSTEM

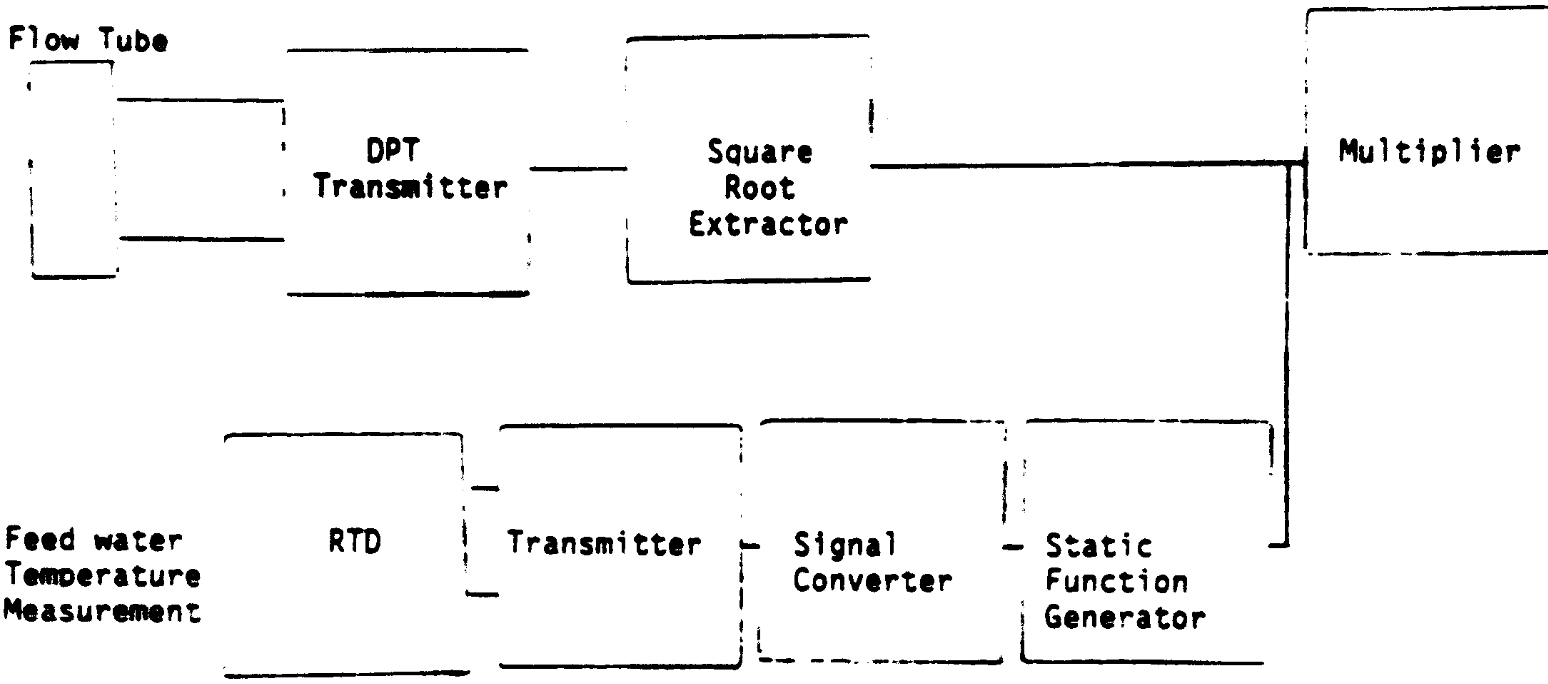


TABLE 1

FEEDWATER MASS FLOWRATES AT ZERO ACCIDENT TIME

Measurement	Time (min)	Value (MPh)*	Qualification Classification
OTSG-A (SP-8A-FT)	0	5.74 ± .106	Qualified
OTSG-B (SP-8B-FT)	0	5.69 ± .106	Qualified
Loop A + Loop B	0	11.43 ± .15	Qualified

*Units are millions of pounds mass per hour.

TABLE 2

UNCERTAINTY IN DIFFERENTIAL PRESSURE

Item	Error	Comment
Transmitter[a]	.25%	Range
Accuracy[b]	.30%	Range
Drift[b]	.25%	Range
Calibration[b]	.25%	Range
Temp Sensitivity[b]	.5%	Range
Square Root Extractor[a]	.5%	Range
Multiplier	.5%	Range
Fixed Signal[a]	.05%	Range
Reactimeter	.1%	Range

$$B^2 = (.25)^2 + (.3)^2 + (.25)^2 + (.5)^2 + (.5)^2 + (.5)^2 + (.05)^2 + (+.1)^2.$$

B = .9887% or .4198 psi.

a) Transmitter had maximum range of 42.46 psi or 1175.21 in. H_2O found in TMI-2 Instrument Calibration Data Sheets for SP-8A-DPT1 Type BMC 6241X-A. From the United Engineers Instrument Data Sheet was found the flow tube, a Badger Style PM-F 20 in. 0 to 6.5×10^6 lbm/hr. Both these sources are hard copy.

b) From microfiche of RC-14A- DPT1 which is assumed to be similar to SP-8A-DPT1. Design and performance specs and instrument calibration data sheets are sources. All specs were at 75°F. Reactor building was at 129°F and unit had a sensitivity of 0.01% range per °F.

TABLE 3

UNCERTAINTY OF DENSITY

Item	Error	Comment
Feedwater Temp[a]	.27%	Reading
Temp Compensation[b]	.25%	Reading
Function Generator[c]	.25%	Range[e]
Multiplier[c]	.5%	Range[e]

B[d] = .6693% or .342 lbm per ft^3

a) This error is due to the fact that the temperature compensation is made with a temp error in it. This is an estimate based on circuitry found in the RC mass flow meter and an error of ± 1.8 ^oF.

b) This is due to error in electronically fitting the steam table curve for calculating density from temperature.

c) From TMI-2 Instrumentation Calibration Data Sheets the Multiplier was included again because it is a dual input single output device.

d) The density was 51.1 lbm per cu ft.

e) Because the range of the density circuitry is unknown, it is expendient to treat all as reading errors.

TABLE 4

OTSG MASS FLOWRATE UNCERTAINTY

Equations

$$\dot{m} = k\sqrt{\rho \Delta p}$$

$$B^2_{\dot{m}} = \left(\frac{\partial \dot{m}}{\partial \rho} S_{\rho}\right)^2 + \left(\frac{\partial \dot{m}}{\partial \Delta p} S_{\Delta p}\right)^2$$

$$\frac{\partial \dot{m}}{\partial \rho} = \frac{\dot{m}}{2\rho} \qquad \frac{\partial \dot{m}}{\partial \Delta p} = \frac{\dot{m}}{2\Delta p}$$

$$B = \dot{m}\left[\left(\frac{S_{\Delta p}}{2\Delta p}\right)^2 + \left(\frac{S_{\rho}}{2\rho}\right)^2\right]^{1/2}$$

Operating condition immediately prior to accident

Loop A

$\dot{m} = 5.74 \times 10^6$ lb per hr, $\Delta P = 37.495$ psi, temp = 464°F

$\rho = 51.046$ lb per cu ft, $p = 1047$ psi

Loop B

$\dot{m} = 5.693 \times 10^6$ lb per hr, $\Delta P = 37.188$ psi, temp = 461°F

$\rho = 51.18$ lb per cu ft, $p = 985$ psi

Uncertainty Calculation

The estimated bias error in "k" is 1.5% assuming that it was determined theoretically.

$$B = 6.5 \times 10^1 \left[\left(\frac{.42}{2x42.46}\right)^2 + \left(\frac{.342}{2x51.1}\right)^2\right]^{1/2}$$

where 6.5×10^6 is the maximum flowmeter range, 42.46 is the maximum ΔP and 51.1 is the nominal fluid.

$B = .6\%$

$B_k = 1.5\%$

$U_n = [(1.5)^2 + (.6)^2]^{1/2} = 1.62\%$ of range

or

1.06×10^5 lbm per hr

REFERENCES

1. R. B. Abernethy, R. P.Benedict, "Measurement Uncertainty: A Standard Methodology ," ISA Transactions, Vol. 24, Number 1, 1985.
2. R. B. Abernethy, et. al., "Measurement Uncertainty Handbook," AEDC-TR-73-5, Revised 1980.
3. Measurement Uncertainty for Fluid Flow in Closed Conduits, ANSI/ASME MFC-2M-1983.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: August 26, 1986

To: D. W. Golden

From: J. L. Anderson JLA

Subject: DATA QUALIFICATION - SYSTEM PRESSURE - JA-16-86

Attached is a final copy of the data qualification document for the primary system pressure. This pressure is a composite created from several data sources (reactimeter, printer, and strip chart) and is the best available primary system pressure. The composite system pressure was assigned a qualification classification of QUALIFIED with an uncertainty of ± 40 psi by the Data Integrity Review Committee (DIRC) during the July 14, 1986 meeting, with the following note added to the data base records. Note: The stated uncertainty is the maximum calculated uncertainty for the composite pressure. Uncertainties for certain time periods are less. Refer to the data qualification document for further information.

jla

Attachment:
As Stated

cc: J. M. Broughton
R. W. Brower
P. J. Grant
H. E. Knauts
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PRIMARY SYSTEM PRESSURE

DATA QUALIFICATION DOCUMENT

August 1986

James L. Anderson

PRIMARY SYSTEM PRESSURE
DATA QUALIFICATION DOCUMENT

1. INTRODUCTION

One of the primary parameters required for thermal-hydraulic analysis of TMI-2 accident is the pressure of the primary system during the accident. The pressure is required for comparison to the large computer code predictions of the accident, in addition to the need for the pressure in order to obtain the phase properties of the fluid in any analysis effort. Unfortunately, no single data source is available which provides the pressure during the entire accident sequence. As a result, a composite of various data sources is required to obtain the primary system pressure. The presented composite primary system pressure has been reviewed by the Data Integrity Review Committee (DIRC) and assigned a qualification category of QUALIFIED, with a stated uncertainty of ± 40 psi[1]. This document will describe the various available data sources and how they were combined to obtain the composite pressure. The composite pressure will be presented and comparisons to the various data source will be made. In addition, an uncertainty analysis of the composite pressure will also be presented.

2. MEASUREMENT DESCRIPTION AND DATA SOURCES

In each hot leg of the TMI reactor are two penetrations for measuring the system pressure. These penetrations are at elevation of 354'9" (separated by 90°) and the locations are shown in an isometric of the TMI

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[1]The uncertainty record on the data base files has the following footnote appended. "The stated uncertainty is the maximum calculated uncertainty for the composite pressure. Uncertainties for certain time periods are less. Refer to the data qualification document for further information."

system in Figure 1. Connected to each of these penetrations, through ½-inch sense lines, are two pressure transmitters mounted in the reactor building basement at an elevation of 285'. One type of pressure transmitter is a Rosemount model 1152GP variable capacitance pressure transmitter (output 4-20 mADC) which was setup for a 1700-2500 psig measurement range, and referred to as the narrow range measurement[2]. The two narrow range transmitters in each loop were identified as RC-3B-PT1 & PT2 and RC-3A-PT1 & PT2. The other transmitter type connected to each sense line was a Foxboro model E11GH bourdon tube/electronic force balance pressure transmitter (output of 10-50 mADC) with a measurement range of 0-2500 psig, and referred to as the wide range measurement. The two wide range transmitters in each loop were identified as RC-3A-PT3 & PT4 and RC-3B-PT3 & PT4.

Output from one of the narrow range pressure transmitters in the B-loop (RC-3B-PT1-R)[3] was recorded on the reactimeter at a sample rate of one sample every 3 seconds. A block diagram for this measurement is shown in Figure 2. This data is considered to be the best available pressure data. However, following the reactor trip the primary system pressure quickly dropped below the minimum range for this measurement (by 2.2 minutes). With the exception of certain periods in which the system pressure increased to within the range of this transmitter, other data sources are required for obtaining the primary system pressure.

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[2]Although the narrow range measurement was set-up for a range of 1700-2500 psig, the measurement continued to produce readings slightly below 1600 psig. Therefore, the reactimeter data down to 1600 psig was used in the composite pressure.

[3]The TMI-2 Accident Evaluation Program uses the basic measurement identifications originally assigned by GPU. However, a suffix is typically added which identifies the recording device. For example; -R is added for measurements recorded on the Reactimeter; -S is added for measurements recorded on Strip charts; and -P is added for measurements recorded on either the utility or alarm printers.

Output from one of the wide range pressure transmitters installed in the A-loop (RC-3A-PT3) was recorded on the utility printer for two significant time periods. The first of these periods was from -15 min. to +15 min. of the reactor trip, which was recorded on the utility printer as the Memory Trip Review. The second time period started at 570 min. and continued throughout the remainder of the first day of the accident. This data was recorded on the utility printer as operator group trend C, recorded once every 2 minutes. Output from RC-3A-PT3 was also recorded on a strip chart mounted on one of the operators control panels (strip chart # 59). This strip chart has been digitalized. However, the resulting data is considered to be the least accurate data available, and was only used when no other data was available. Adjustment of this data was required to match the initial pressure and event timing in comparison to the reactimeter data. A block diagram of this measurement system is provided in Figure 3.

Knowledge of the thermal-hydraulic conditions in the reactor system, during the first 100 min., also allows the possibility of obtaining the system pressure from the measured hot leg temperature. By 6 min. into the accident, the system had depressurized to the point where a two-phase mixture was exiting the core and flowing through the entire primary system (both steam generators had boiled dry by this time). This observation is supported by the increasing output from the source range neutron detectors. During the period in which a two-phase mixture was flowing through the system, the system pressure had to have been at saturation pressure. The saturation pressure can be obtained from the steam tables using the measured hot leg temperature which was recorded on the reactimeter (RC-4A-TE1-R).

The aforementioned data sources were used to create a best estimate composite of the primary system pressure. The time segments over which each data source were used are listed in Table 1. The composite pressure is shown in Figure 4 for the first 300 min. of the accident. Comparisons of the various data sources are provided in Figures 5-14. The system pressure prior to the accident initiation (initial condition) was 14.91 MPa (2148 psig). Data values and uncertainties for the initial times of each phase of the standard problem (0, 100, 174, & 225 min.) are presented in Table 2.

3. UNCERTAINTY ANALYSIS

Estimates of the uncertainties from each data source are summarized in Table 3. Included are uncertainty estimates for each component of the measurement systems. Footnotes are provided for Table 3 detailing the sources of the component uncertainties and assumptions used. The methods used for combining uncertainty components are outlined in References 2 & 3.

4. REFERENCES

1. Rosemount Inc., Model 1152 Alphaline Pressure Transmitters for Nuclear Service, 1976.

2. R. D. McCormick, Data Qualification and Uncertainty Analysis, attachment to letter RDMc-4-86, "Final Data Analysis Plan", to J. M. Broughton, dated June 2, 1986.

3. Measurement Uncertainty for Fluid Flow in Closed Conduits, ANSI/ASME, MFC-2M-1983.

4. Foxboro Company, Installation/Operation/Maintenance for Model E11GH Pressure Transmitter, 20-220, Jan. 1969.

5. R. D. McCormick, "Initial Condition Temperatures of Primary Loop Coolant," attachment to letter RDMc-7-86 to D. W. Golden, dated August 19, 1986.

TABLE 1 DATA SOURCES AND TIME FRAMES FOR COMPOSITE PRESSURE

Time Frame (minutes)[a]	Data Source
-10. - 2.15	RC-3B-PT1-R, recorded on the Reactimeter
2.4 - 5.65	RC-3A-PT3-P, recorded on the Utility Printer as Memory Trip Review
6.0 - 100.	Saturation Pressure from RC-4A-TE1-R recorded on the Reactimeter
100.6 - 172.5	RC-3A-PT3-S, recorded on the strip chart
174.65 - 203.6	RC-3B-PT1-R, recorded on the Reactimeter
207. - 223.5	RC-3A-PT3-S, recorded on the strip chart
225.35 - 233.3	RC-3B-PT1-R, recorded on the Reactimeter
240.0 - 326.6	RC-3A-PT3-S, recorded on the strip chart
336.00 - 463.55	RC-3B-PT1-R, recorded on the Reactimeter
464. - 568.	RC-3A-PT3-S, recorded on the strip chart
570.3 - 869.6	RC-3A-PT3-P, recorded on the utility printer as operator group trend C
870.85 - 932.75	RC-3B-PT1-R, recorded on the Reactimeter
933.55	RC-3A-PT3-P, recorded on the utility printer
934.75 - 950.2	RC-3B-PT1-R, recorded on the Reactimeter
950.75 - 1000.	RC-3A-PT3-P, recorded on the utility printer

a. Timing uncertainties for the different data sources are as follows: Reactimeter = ±0.05 min.; Strip Chart = ± 3 min.; Utility Printer = +0, -0.5 min.

TABLE 2

PRIMARY SYSTEM PRESSURE INITIAL CONDITIONS

TIME (min.)	PRESSURE (psig)	DATA SOURCE	
0	2148 ± 11[4]	RC-3B-PT1-R	Reactimeter
0	2164 ± 29	RC-3A-PT3-P	Utility Printer
100	935 ± 16	P_{sat} from RC-4A-TE1-R	Reactimeter
174	1235 ± 40[5]	RC-3A-PT3-S	Strip Chart
225	1468 ± 40[6]	RC-3A-PT3-S	Strip Chart

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[4] The standard deviation of the reactimeter pressure data from -10 to 0 min. was 3.3 psi.

[5] The 2B pump restart at 174 minutes resulted in a rapid repressurization. The system was also repressurizing prior to 174 min. The stated value is the strip chart value prior to the rapid repressurization (at 171.8 min). An interpolated value at 174 min. is 1582 psig. Timing uncertainty for the strip chart is estimated to be ± 3 min.

[6] The minimum pressure prior to the rapid repressurization at 223.4 min. is stated. The pressure recorded on the strip chart at 225 ±3 min. was 1572 psig.

TABLE 3 PRIMARY SYSTEM PRESSURE - UNCERTAINTY ANALYSIS

DATA SOURCE[a]	UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[b] % of Range Span	Absolute (psig)
REACTIMETER[c]	Transmitter (Rosemount)[d]		
RC-3B-PT1-R	Accuracy	± 0.50%	± 4.0
(Range =	Temperature Sensitivity[n]	± 1.0%/100°F	± 4.8
1700-2500)	Stability	± 0.25% FS	± 6.3
	Electronics (Tolerance)[e]		
	$[=\sqrt{(.25\%^2+.75\%^2)}]$	± 0.79%	± 6.3
	Recorder[f]	± 0.11%	± 0.9
	TOTAL UNCERTAINTY[g]		± 10.9
UTILITY PRINTER[h]			
	Transmitter (Foxboro)[i]		
RC-3A-PT3-P	Accuracy	± 0.50%	± 12.5
(Range =	Temperature Sensitivity	1.0%/65°F	± 23.1
0-2500 psig)	Electronics (Tolerance)[e]	± 0.50%	± 12.5
	Recorder (Computer)[j]	± 0.11%	± 2.5
	TOTAL UNCERTAINTY		± 29.2
REACTIMETER-SATURATION PRESSURE[k]			
RC-4A-TE1-R	P_{sat} due to RTD uncertainty		± 16
STRIP CHART #59[l]			
	Transmitter (Foxboro)		
RC-3A-PT3-S	Accuracy	± 0.50%	± 12.5
(Range =	Temperature Sensitivity	1.0%/65°F	± 23.1
0-2500 psig)	Electronics (Tolerance)	± 0.50%	± 12.5
	Strip Chart Recorder[m]		
	Recorder Setup		± 25.
	Digitalization of Strip Chart		± 10.
	TOTAL UNCERTAINTY		± 39.7

TABLE 3. (continued)

a. Various data sources were used for creation of the composite primary pressure. The most accurate sources of data for each particular time segment were used.

b. The uncertainty estimates given were obtained from various sources, which are listed in the following footnotes. The uncertainty estimates are given for the 95% confidence level, and are all considered to be Bias estimates due to the lack of statistically significant data.

c. The narrow range pressure recorded on the Reactimeter (RC-3B-PT1-R) is considered to be the most accurate data source, and is used as the primary data source while within range.

d. The source of uncertainty estimates for the narrow range pressure transmitter is the Rosemount transmitter manual, Reference 1.

e. The acceptable tolerance limits stated in the instrumentation calibration sheets and the surveillance procedure data sheets are used as the uncertainty estimates for the signal conditioning electronics.

. The uncertainties associated with recording on the reactimeter are assumed to be the same as for recording on the plant computer. No uncertainty information on the reactimeter is available. This includes manuals, drawings, model number, and serial number of the unit installed by B&W during the accident.

g. Individual uncertainty components are combined using the Root-Sum-Square method outlined in References 2 & 3.

h. Wide range pressure (RC-3A-PT3-P) information recorded on the Utility Printer is considered to be the most accurate available data source during periods in which the narrow range pressure transmitter was below the lower bound, and is used whenever available. Available utility printer wide range pressure data is from the Memory Trip Review (± 15 minutes of reactor trip) and the operator group trend C data (starting at 570 minutes).

i. Uncertainty estimates for the wide range transmitter are based on the Foxboro transmitter manual, Reference 4.

j. The uncertainty estimate for the data recorded on the computer (via the utility printer) is based on the individual uncertainty components of the analog-to-digital convertor given in the Bailey 855 Computer manual, section 8.3.

TABLE 3. (continued)

k. The saturation pressure, obtained using the hot leg RTD temperature measurement recorded on the Reactimeter, is considered to be the most accurate data source during the period of pumped two-phase flow in the A-loop (6-100 minutes). Uncertainty in the RTD temperature measurement of ± 1.1°F (Reference 5) was used in conjunction with the ASME steam tables to obtain the stated uncertainty estimate.

l. Data obtained from the digitalization of the strip chart recorder is considered to be the least reliable data available, and was the last source of data used.

m. Uncertainty estimates for the strip chart recorder are based on engineering judgement.

n. A 60°F temperature increase in the containment building, near the location where the pressure transmitters were mounted, was used for obtaining the uncertainty estimate due to temperature sensitivity of the pressure transmitter during the first 300 minutes of the accident.

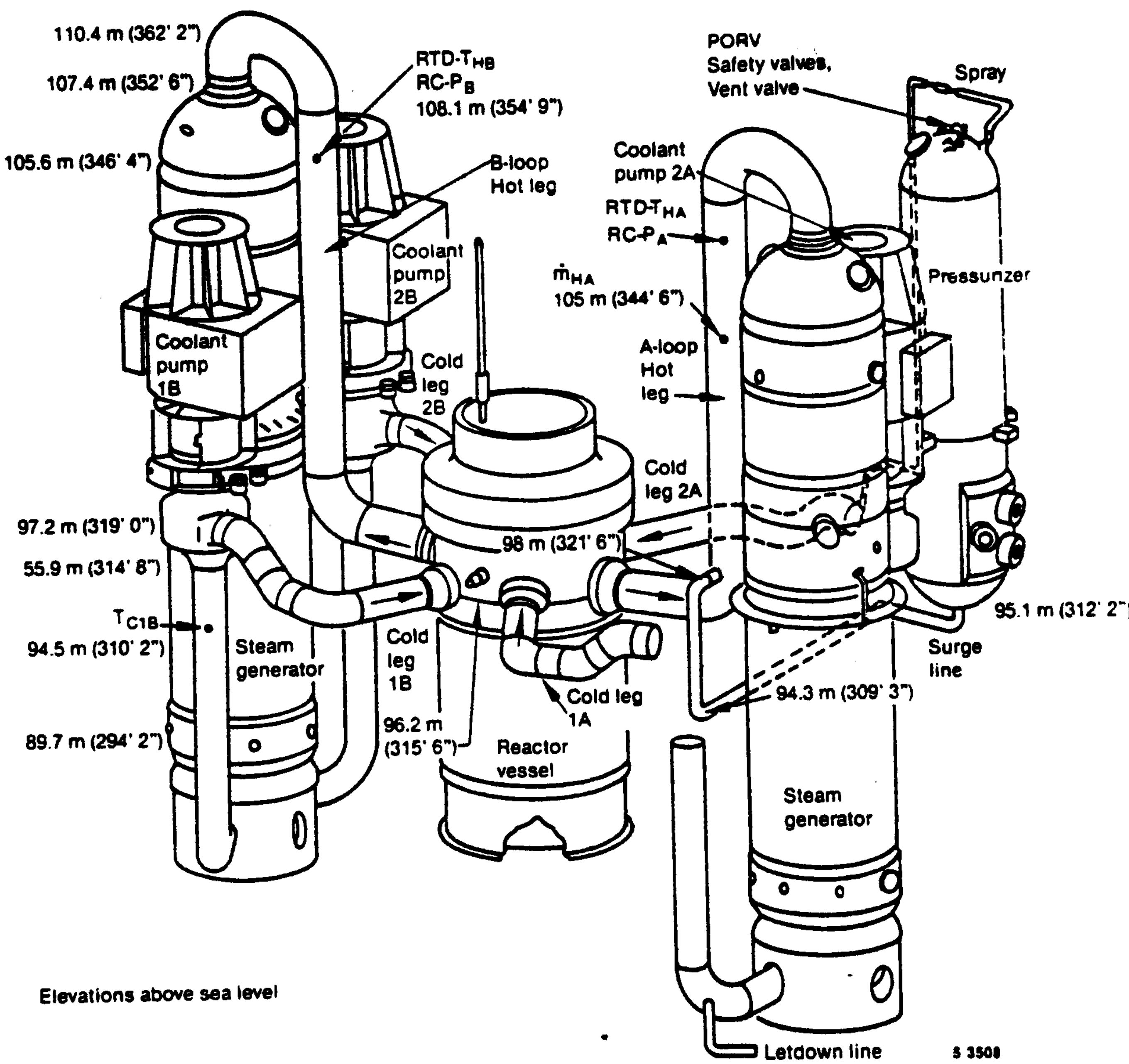
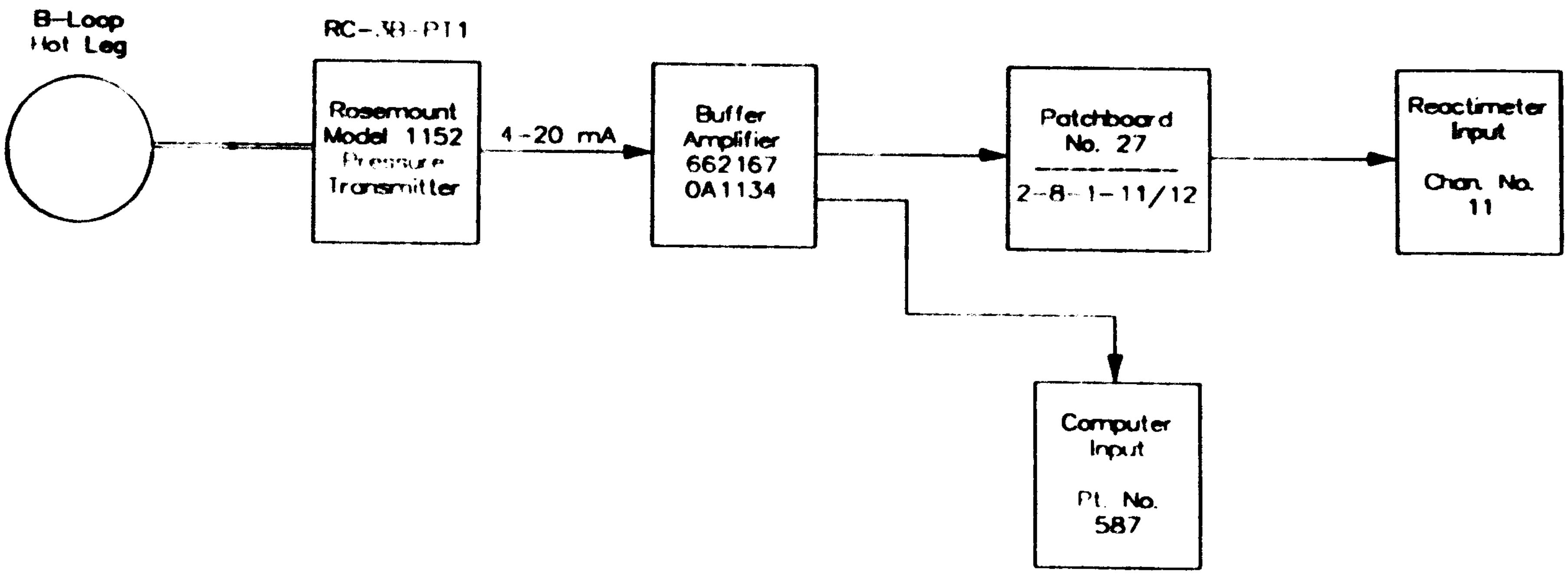


Figure 1. Isometric of the TMI-2 primary system.

Measurement Block Diagram

Narrow Range Reactor Coolant Pressure

RC-3B-PT1



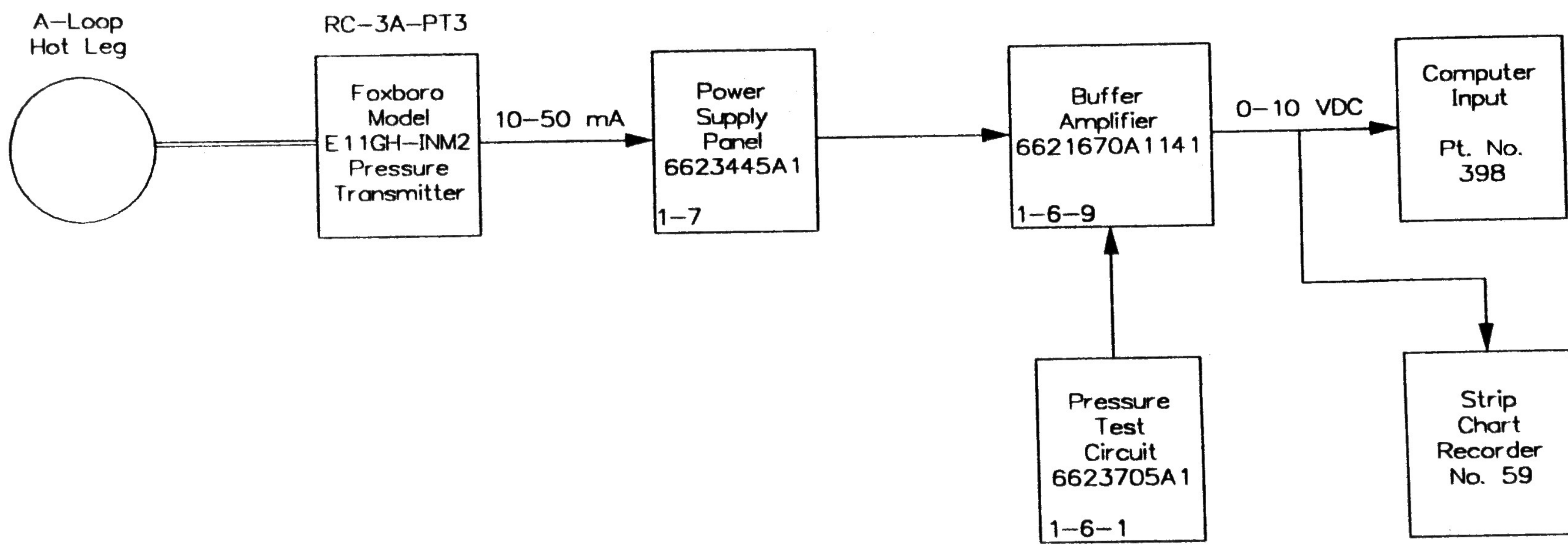
Reference: Bailey
Dwg 8047736G

Fig. 2. Narrow range reactor coolant pressure measurement block diagram

Measurement Block Diagram

Wide Range Reactor Coolant Pressure

RC-3A-PT3



Reference: Bailey Dwg 8047175E
& 8038486D

Fig. 3. Wide range reactor coolant pressure RC-3A-PT3 measurement block diagram

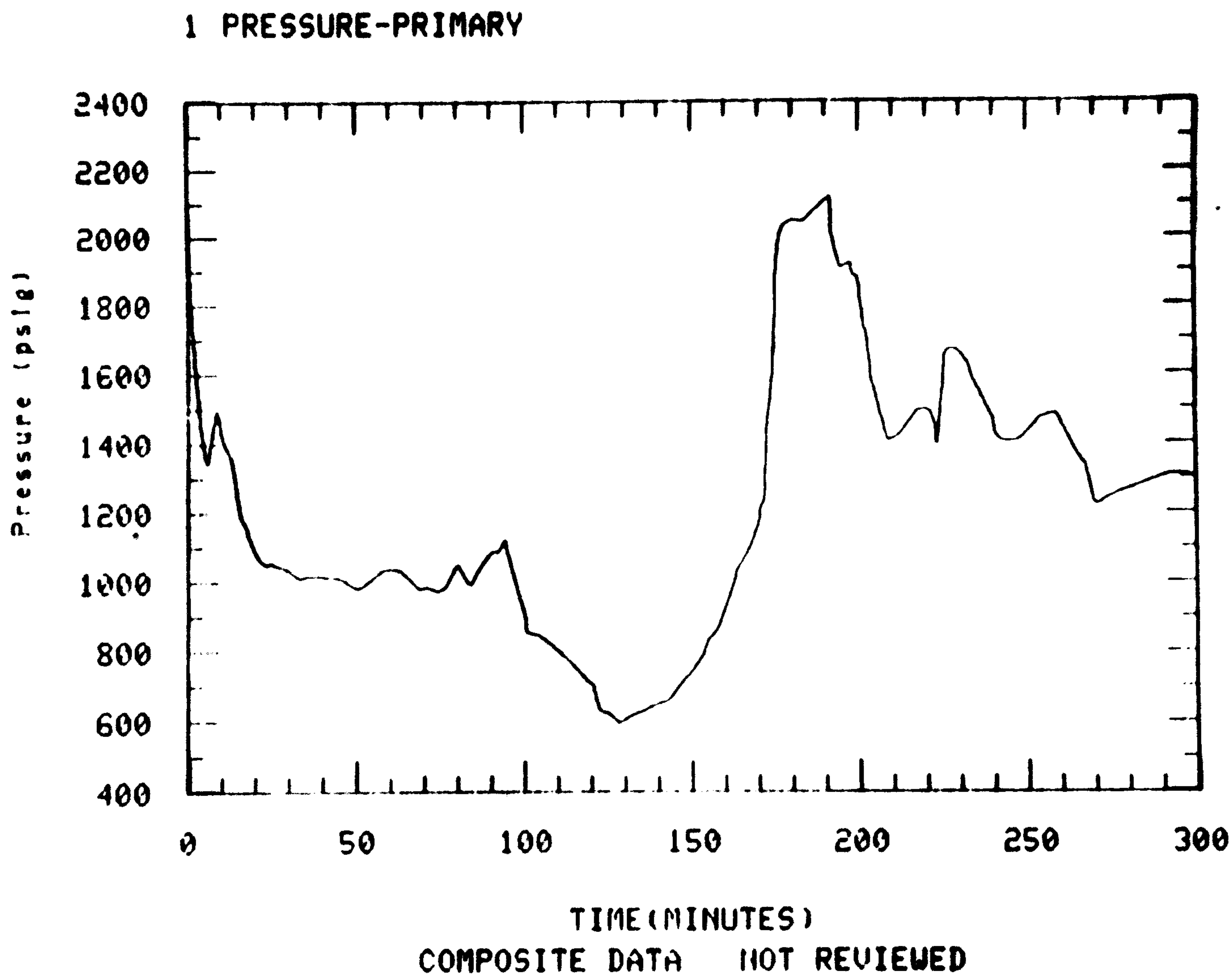


Fig. 4. Primary system pressure

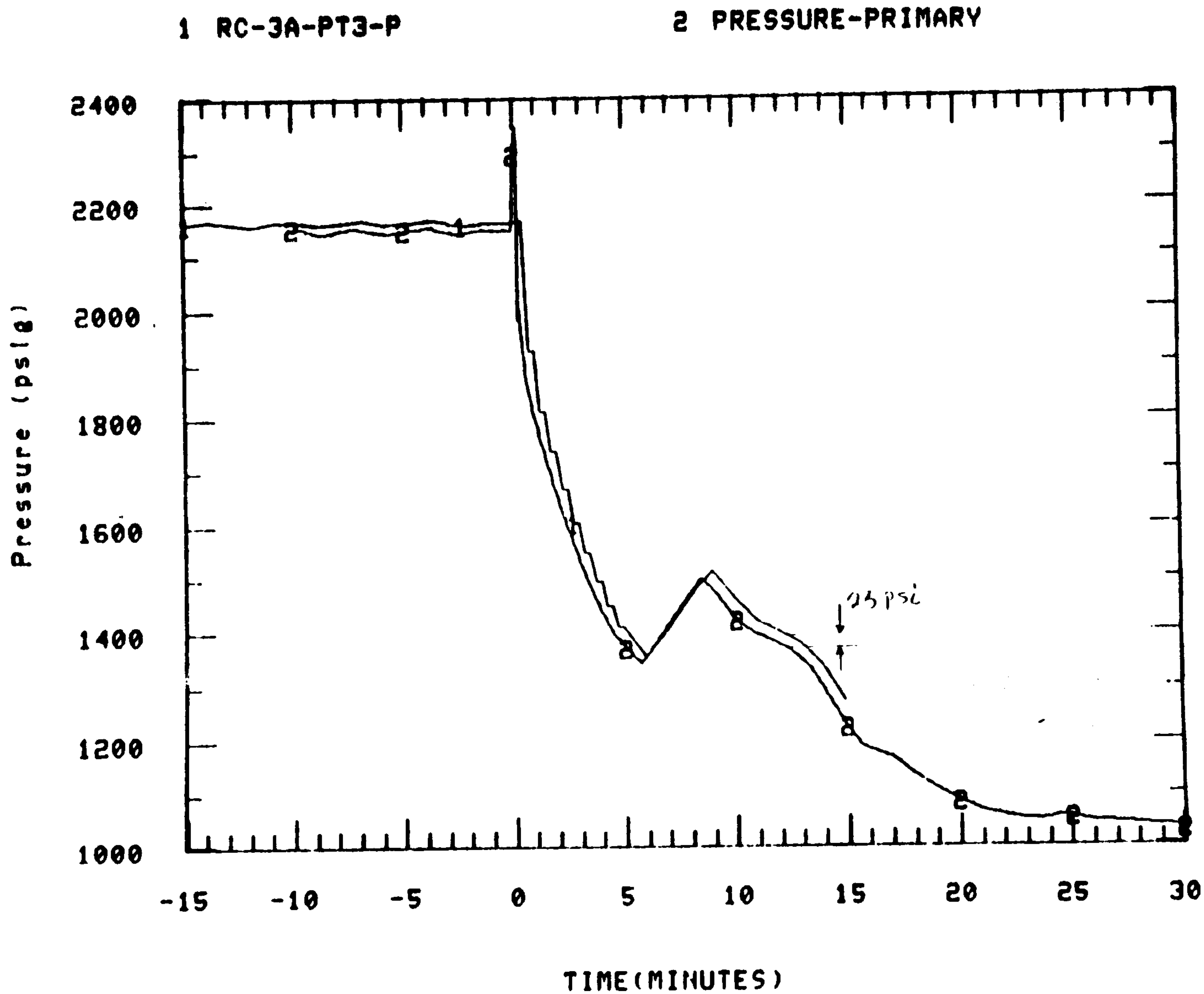


Fig. 5. Comparison of composite primary pressure and wide range pressure recorded on the utility printer memory trip review

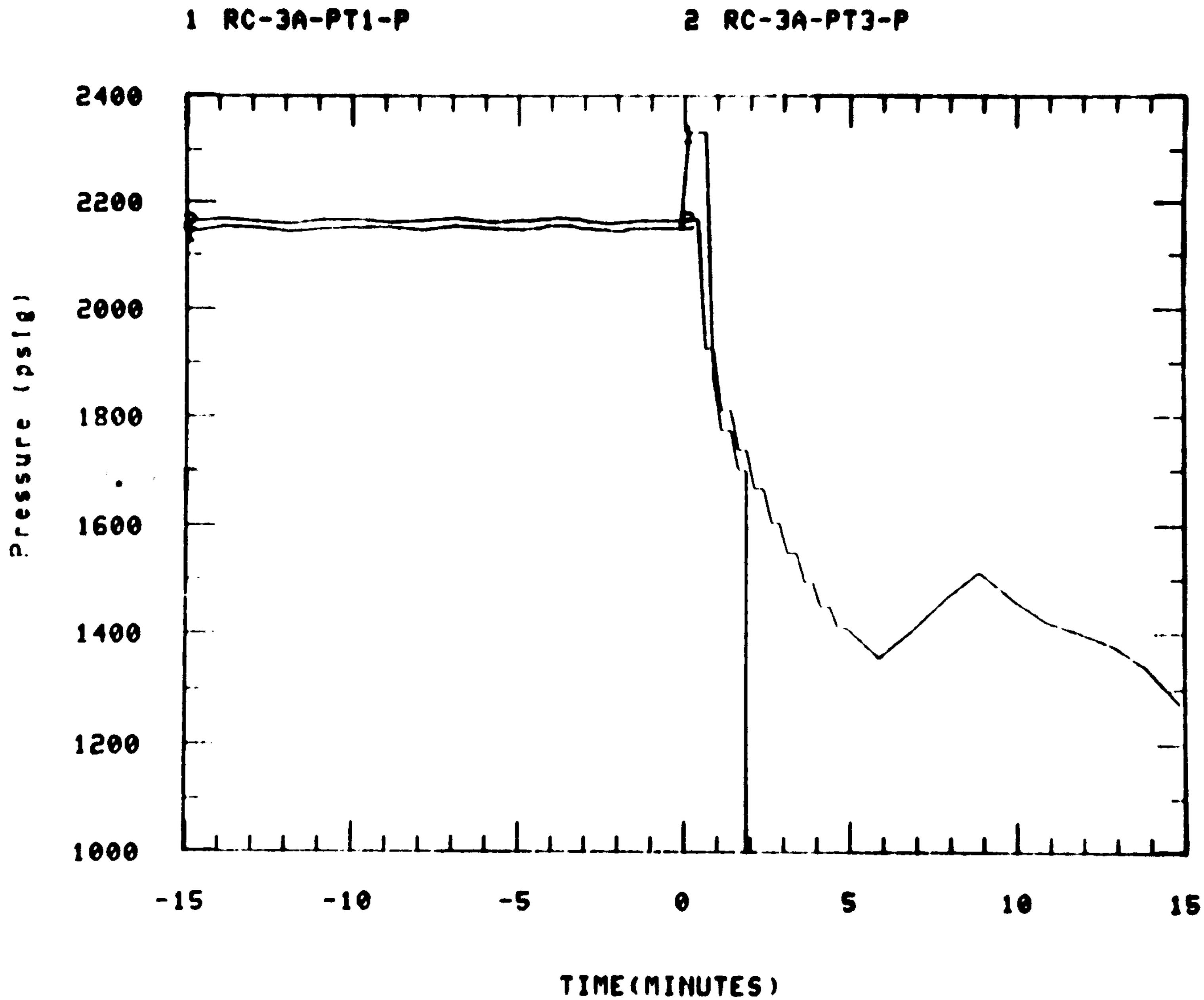


Fig. 6. Comparison A-loop narrow and wide range pressures recorded on the utility printer memory trip review

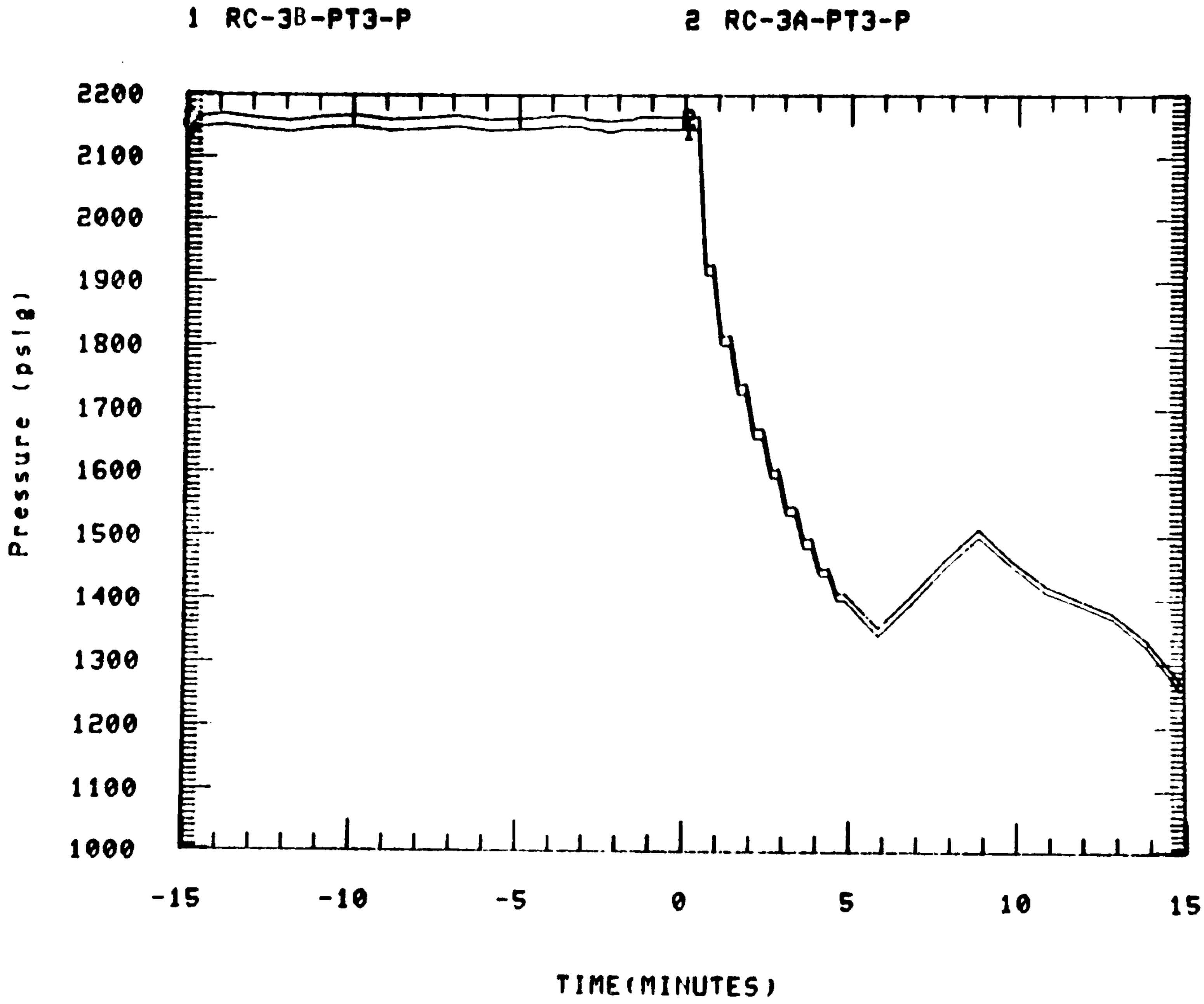


Fig. 7. Comparison of A and B loop wide range pressures recorded on the utility printer memory trip review

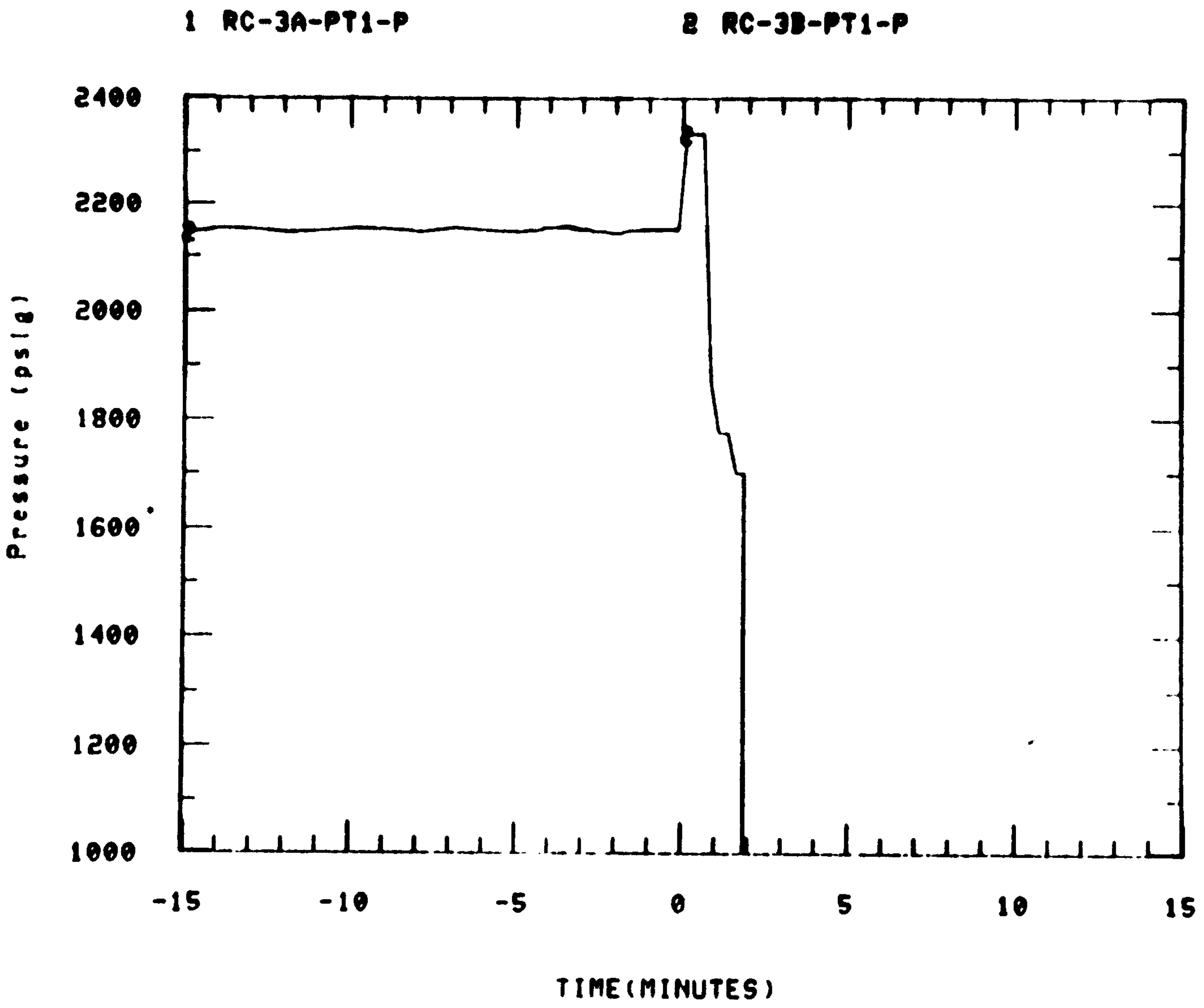


Fig. 8. Comparison of A and B loop narrow range pressures recorded on the utility printer memory trip review

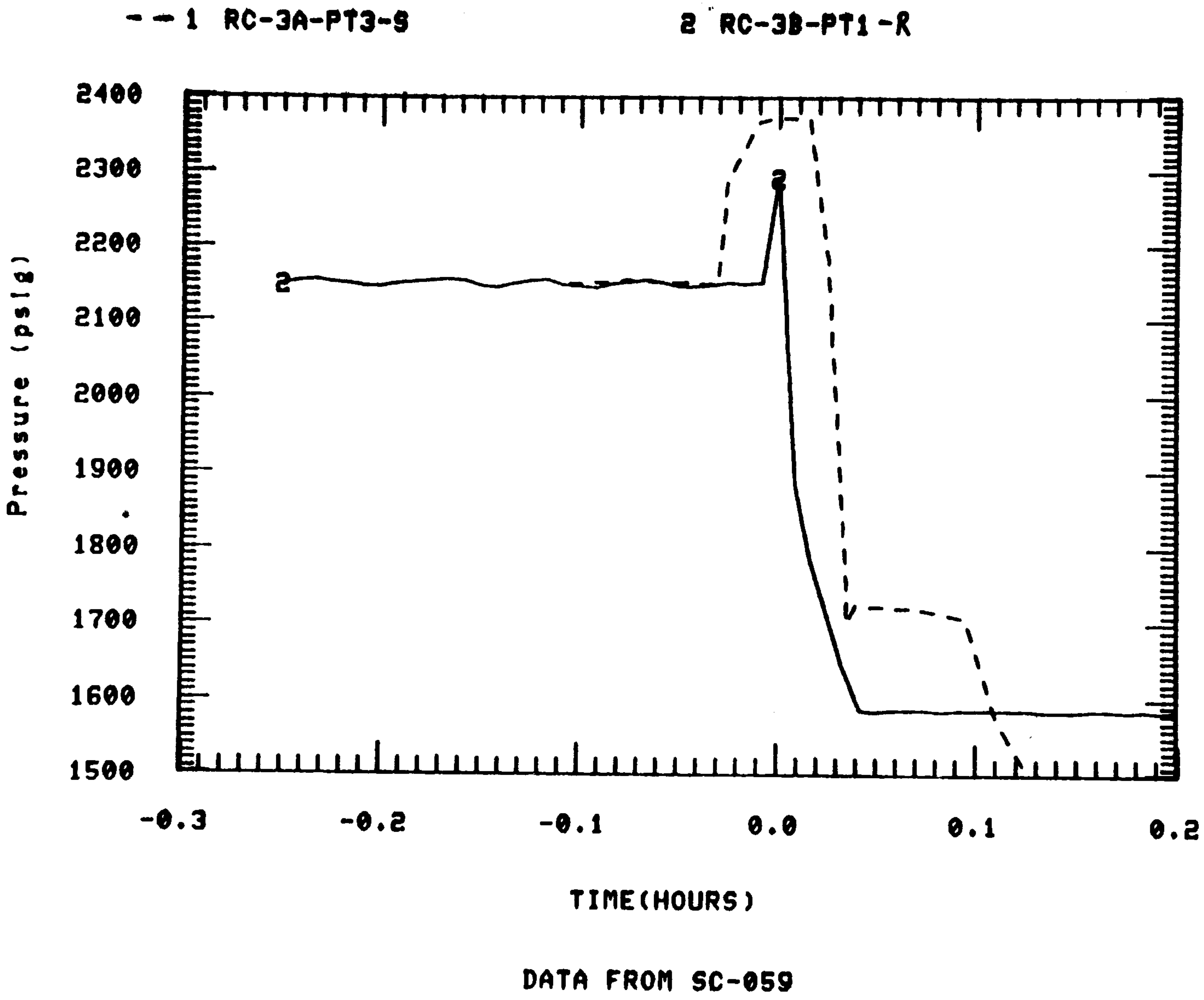


Fig. 9. Comparison of A-loop wide range pressure recorded on the strip chart No. 59 and the B-loop narrow range pressure on the reactimeter

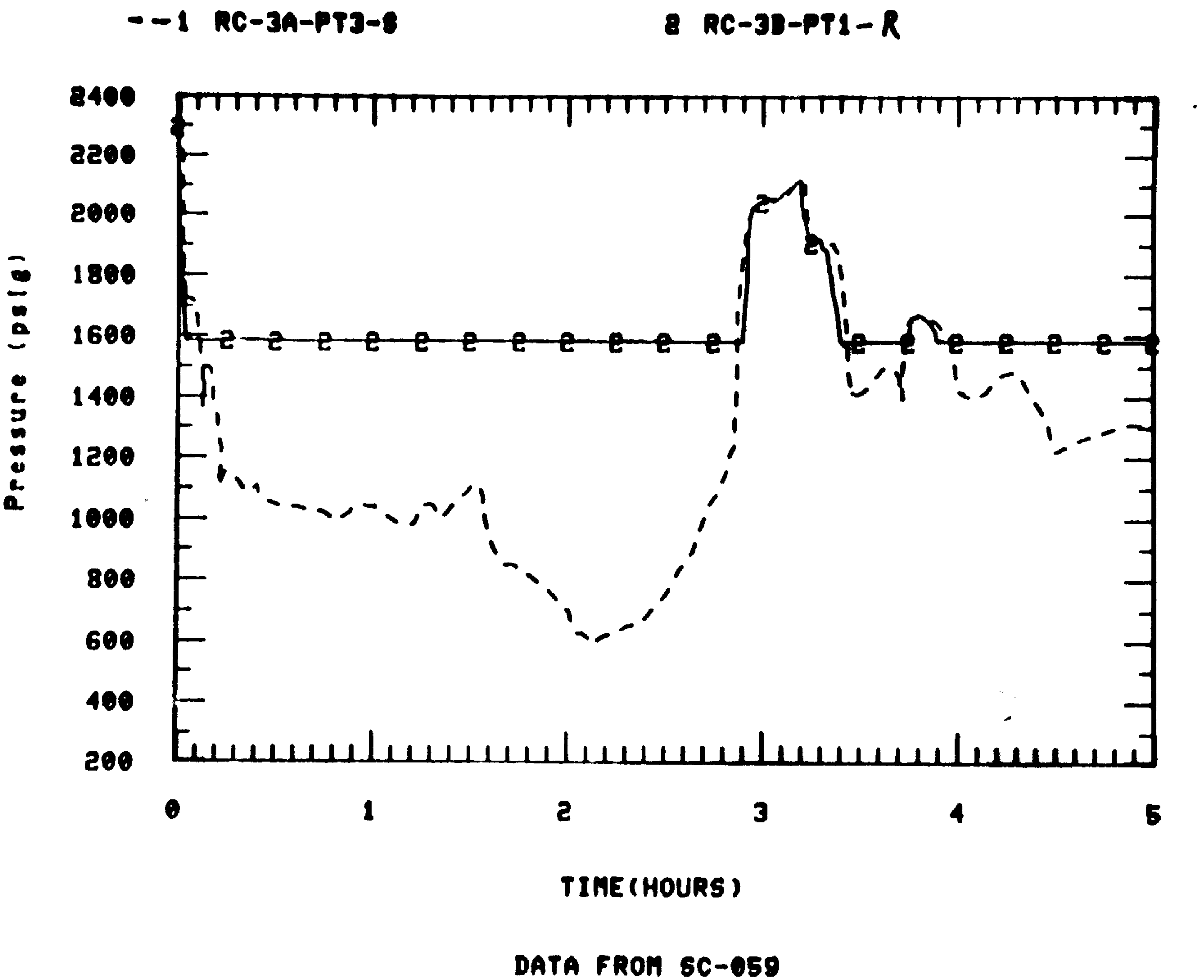


Fig. 10. Comparison of A-loop wide range pressure recorded on the strip chart No. 59 and the B-loop narrow range pressure on the reactimeter

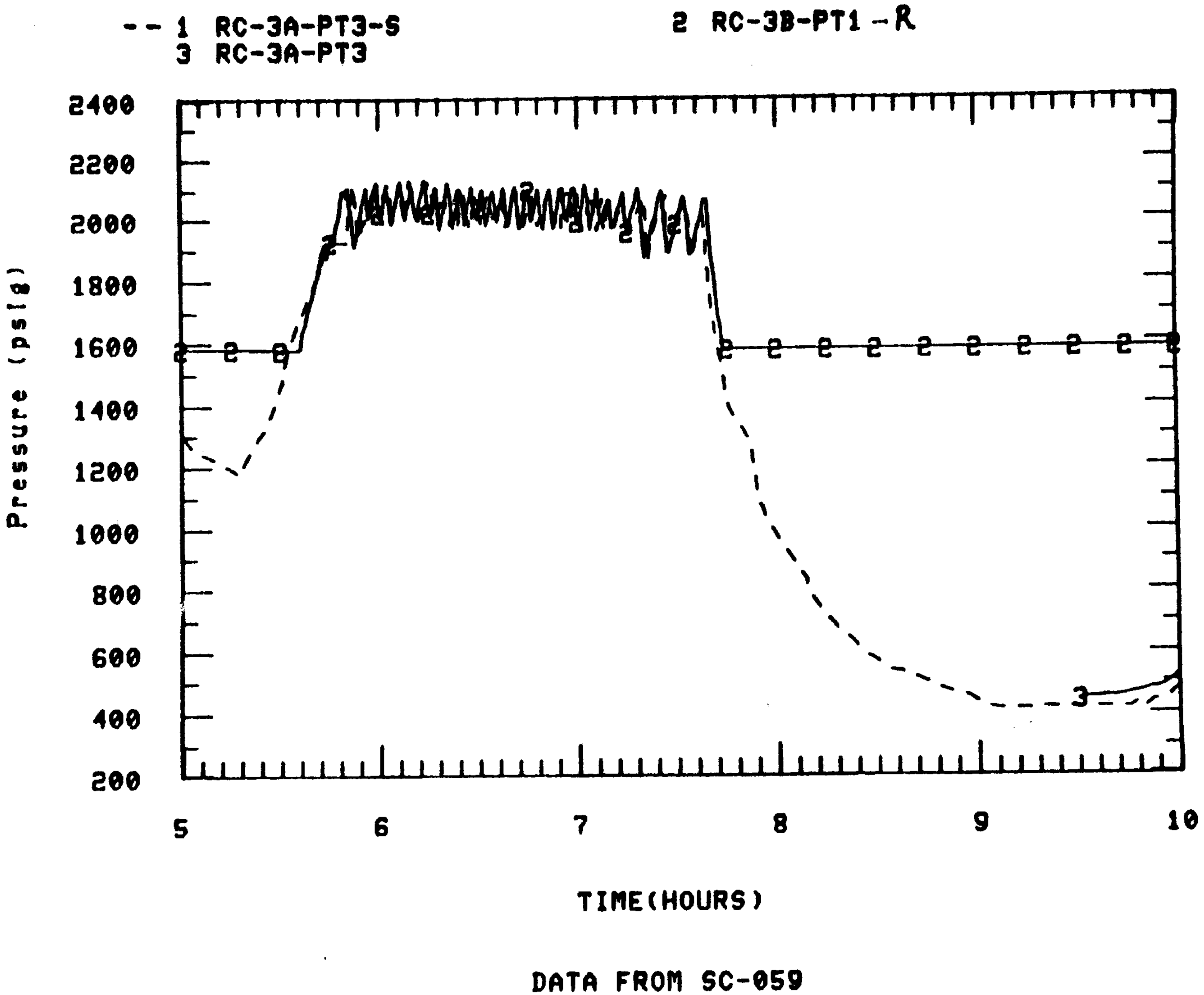
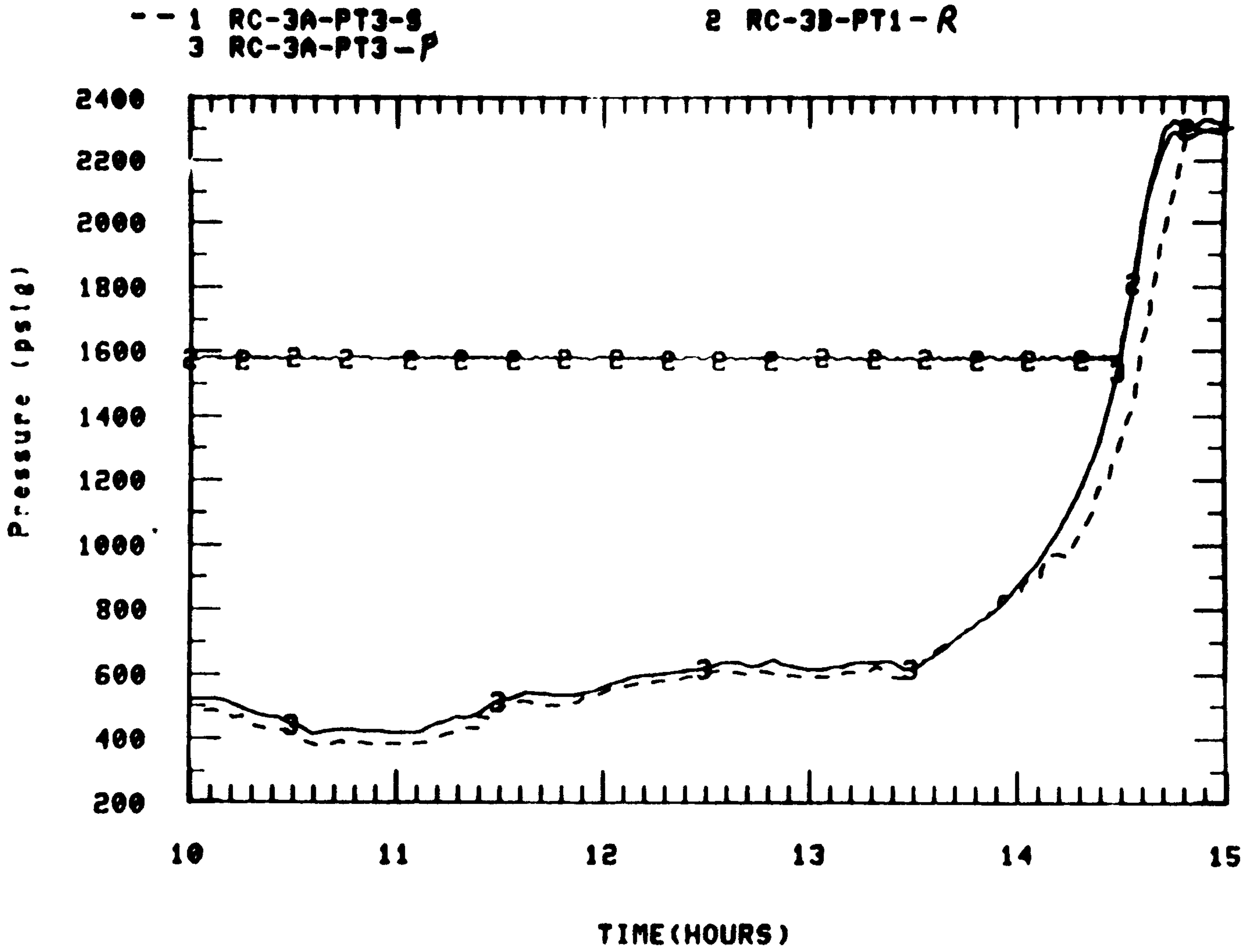
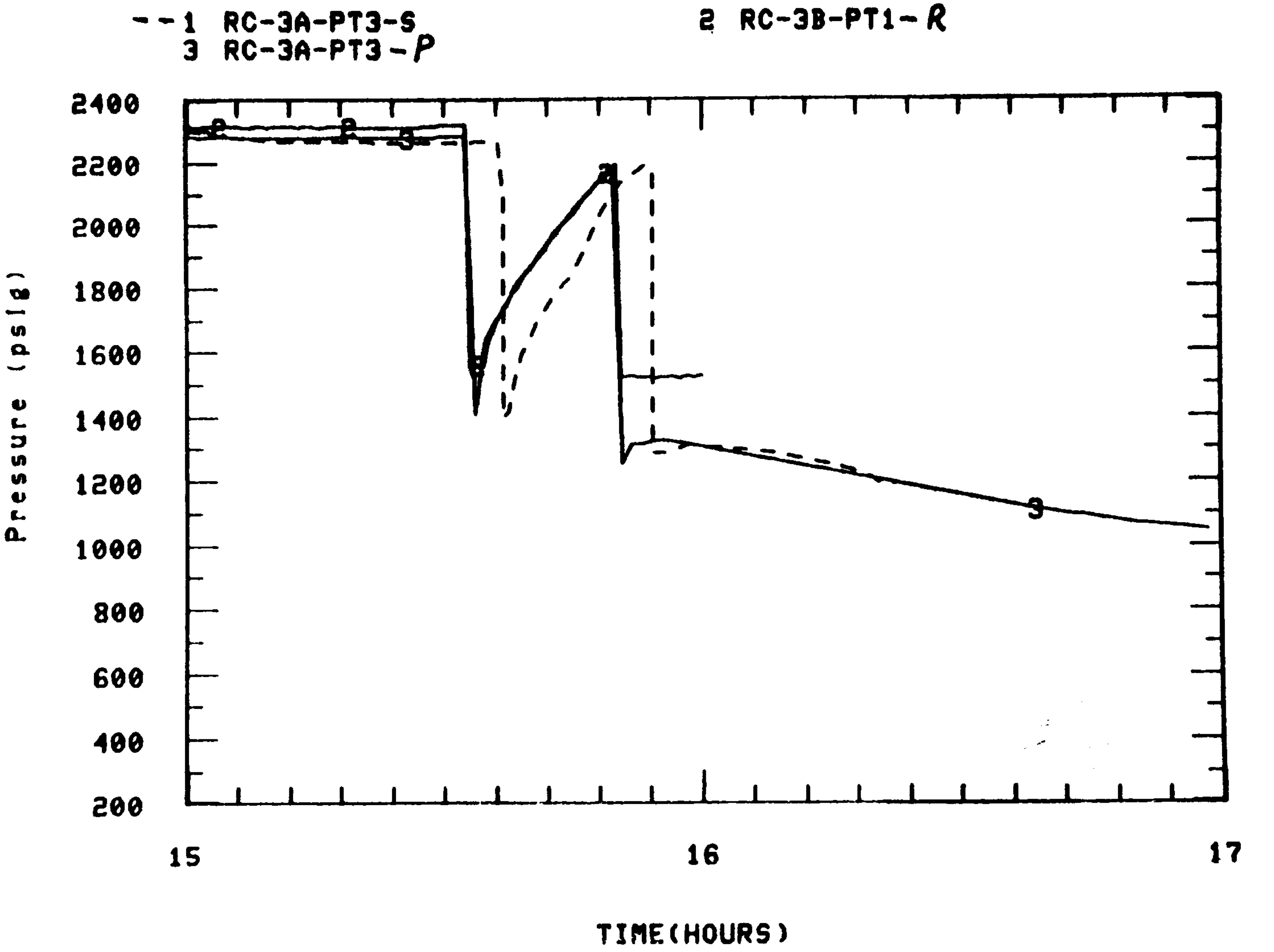


Fig. 11. Comparison of A-loop wide range pressure recorded on the strip chart No. 59 and the B-loop narrow range pressure on the reactimeter



DATA FROM SC-059

Fig. 12. Comparison of A-loop wide range pressures recorded on strip chart and utility printer with the B-loop narrow range pressure on the reactimeter



DATA FROM SC-059

Fig. 13. Comparison of A-loop wide range pressures recorded on strip chart and utility printer with the B-loop narrow range pressure on the reactimeter

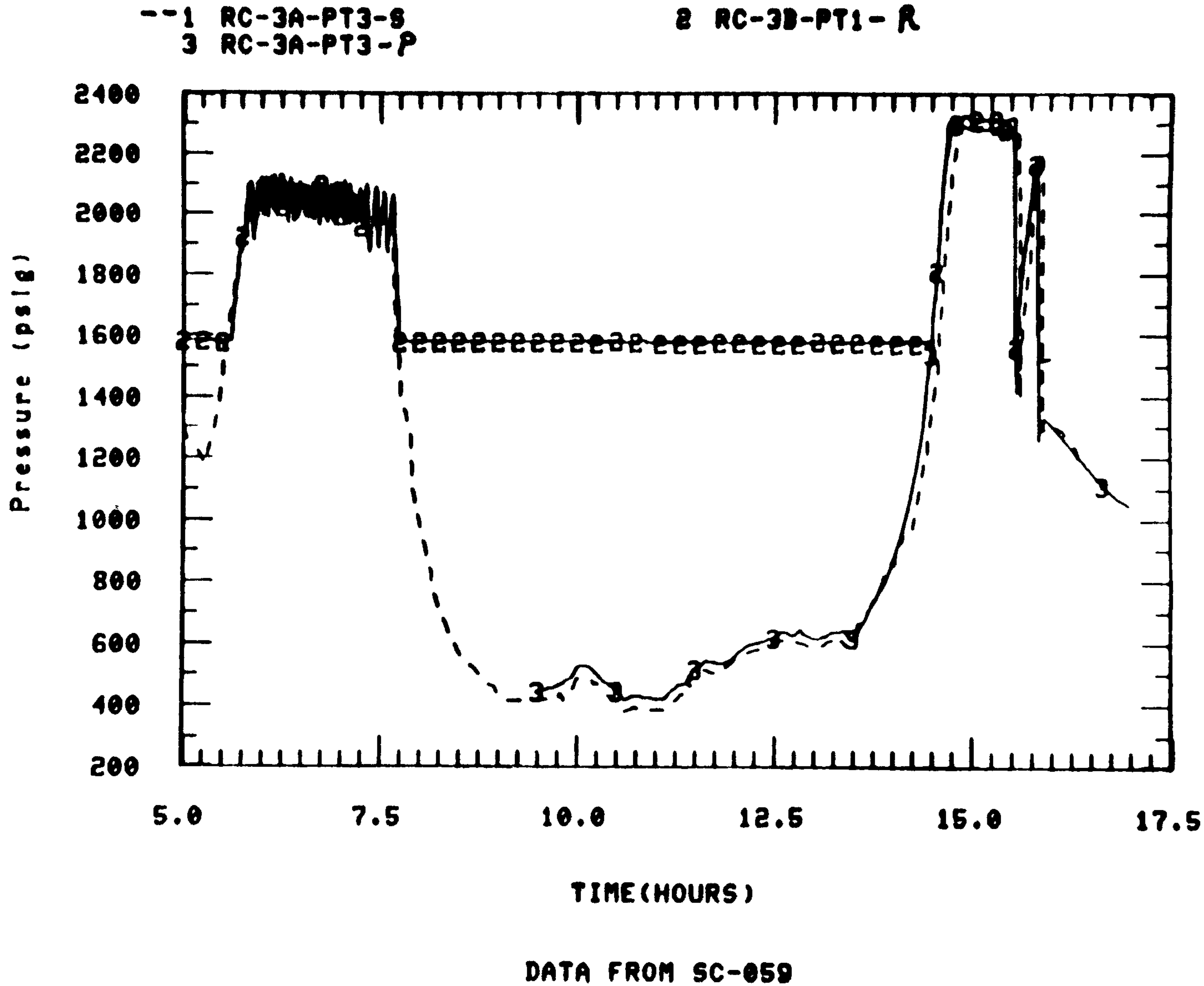


Fig. 14. Comparison of A-loop wide range pressures recorded on strip chart and utility printer with the B-loop narrow range pressure on the reactimeter

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: April 15, 1987

To: Distribution

From: J. L. Anderson JLA

Subject: DATA QUALIFICATION - REACTOR BUILDING PRESSURE - JA-4-87

The reactor building (containment) pressure was recorded during the accident on two different strip chart recorders. Each recorder was a two-pen Taylor recorder, model 830J, with input from two different Foxboro pressure transmitters. One transmitter on each recorder had a wide range of 0-100 psig, and the other transmitter had a narrow range of -5 - 15 psig. The measurement to be qualified is BS-PT-4388-N-S, recorded on recorder SC-056, from the -5 - 15 psig narrow range transmitter, SN 3259652. This measurement was within its measurement range during the accident, with the exception of the pressure spike during the hydrogen burn. The only useful information from the wide range transmitter (0-100 psig) BS-PT-4388-W-S (SN 3259653) is the magnitude of the pressure spike. Therefore this data will only be qualified at that single value. [Note that the only records of instrument calibration and loop setup are from March 1977.] The narrow range pressure measurement on the other strip chart recorder (SC-055) BS-PR-1412-N-S was not recorded prior to the pressure spike due to failure of the pen to properly ink. Comparison between the two recorded narrow range measurements can to performed following the pressure spike. This was done to help in obtaining an estimate of the data uncertainty. The output from the wide range pressure transmitter BS-PT-1412-W-S was also routed to the plant computer, channel 97. However, there is no indication that any data from this measurement was recorded during the accident.

Data uncertainty estimates for the narrow and wide range measurements recorded on SC-056 are provided in Tables 1 and 2. The total uncertainty estimates are $\pm$ 0.32 psig for the narrow range measurement, and $\pm$ 2.15 psig for the wide range estimate. The magnitude of the pressure spike which occurred at the hydrogen burn was 28.7 $\pm$ 2.2 psig, from the wide range pressure measurement, BS-PT-4388-W-S. This compares quite closely to the other recorded wide range pressure, within the digitization uncertainty.

I recommend that a composite channel be created from the narrow range data and the single data point for the pressure spike from the wide range channel, with a measurement identification of BS-PT-4388-S, and that this data be entered into the data base as qualified data. The recommended data is show in Figure 1 for the 0-300 min. time span, and in Figure 2 for the 0-1000 min. time span.

jla

Attachment:
As Stated

Distribution:
R. W. Brower
D. W. Golden
R. D. McCormick
Y. Nomura

cc: J. M. Broughton
J. L. Anderson File
Central File
DIRC File

TABLE 1

REACTOR BUILDING NARROW RANGE PRESSURE
[BS-PR-4388-N-S]
UNCERTAINTY ANALYSIS

UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[1] % of Range Span	Absolute (psig)
Transmitter (Foxboro)[2] Accuracy[3]	± 0.50 %	± 0.075
Electronics (Tolerance)[4]	± 2.0 %	± 0.300
Recorder (Strip Chart)		
Set-up[5]	± 0.50 %	± 0.075
Digitization[6]	± 0.33 %	± 0.050
TOTAL UNCERTAINTY[7]	± 2.15 %	± 0.32 psig

----
1 Uncertainty estimates are based upon individual uncertainties footnoted below.
2 The transmitter range for this mesasurement is -5 - 15 psig, which is used for the range span to obtain the absolute uncertainty estimates.
3 From the Foxboro transmitter manual.
4 From the instrument loop test calibration sheet for tolerance in the setup of the electronics of the measurement.
5 Estimated from comparison of independent measurements recorded on the two strip charts.
6 Estimated from the recorder line width.
7 The total uncertainty estimate is obtained by combining the individual uncertainty components using the Root-Sum-Square method.

TABLE 2

REACTOR BUILDING WIDE RANGE PRESSURE
[BS-PR-4388-W-S]
UNCERTAINTY ANALYSIS

UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[8] % of Range Span	Absolute (psig)
Transmitter (Foxboro)[9]		
Accuracy[10]	± 0.50 %	± 0.50
Electronics (Tolerance)[11]	± 2.0 %	± 2.00
Recorder (Strip Chart)		
Set-up [12]	± 0.50 %	± 0.50
Digitization [13]	± 0.33 %	± 0.33
TOTAL UNCERTAINTY[14]	± 2.15 %	± 2.15 psig

---

8 Uncertainty estimates are based upon individual uncertainties footnoted below.
9 The transmitter range for this mesasurement is 0 - 100 psig, which is used for the range span to obtain the absolute uncertainty estimates.
10 From the Foxboro transmitter manual.
11 From the instrument loop test calibration sheet for tolerance in the setup of the electronics of the measurement.
12 Estimated from comparison of independent measurements recorded on the two strip charts.
13 Estimated from the recorder line width.
14 The total uncertainty estimate is obtained by combining the individual uncertainty components using the Root-Sum-Square method.

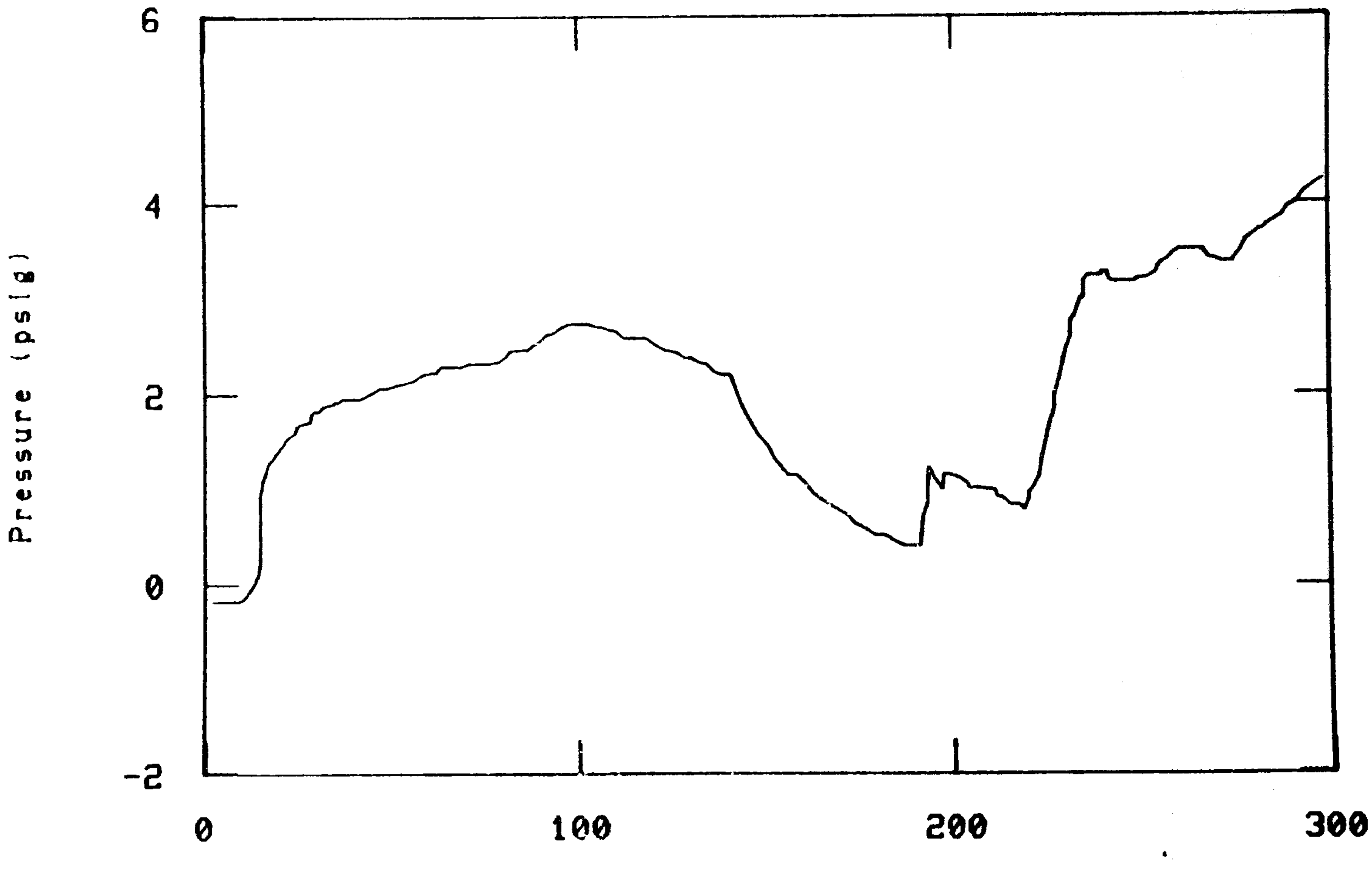


FIG. 1. CØNTAINMENT BUILDING PRESSURE
BS-PT-4388-S

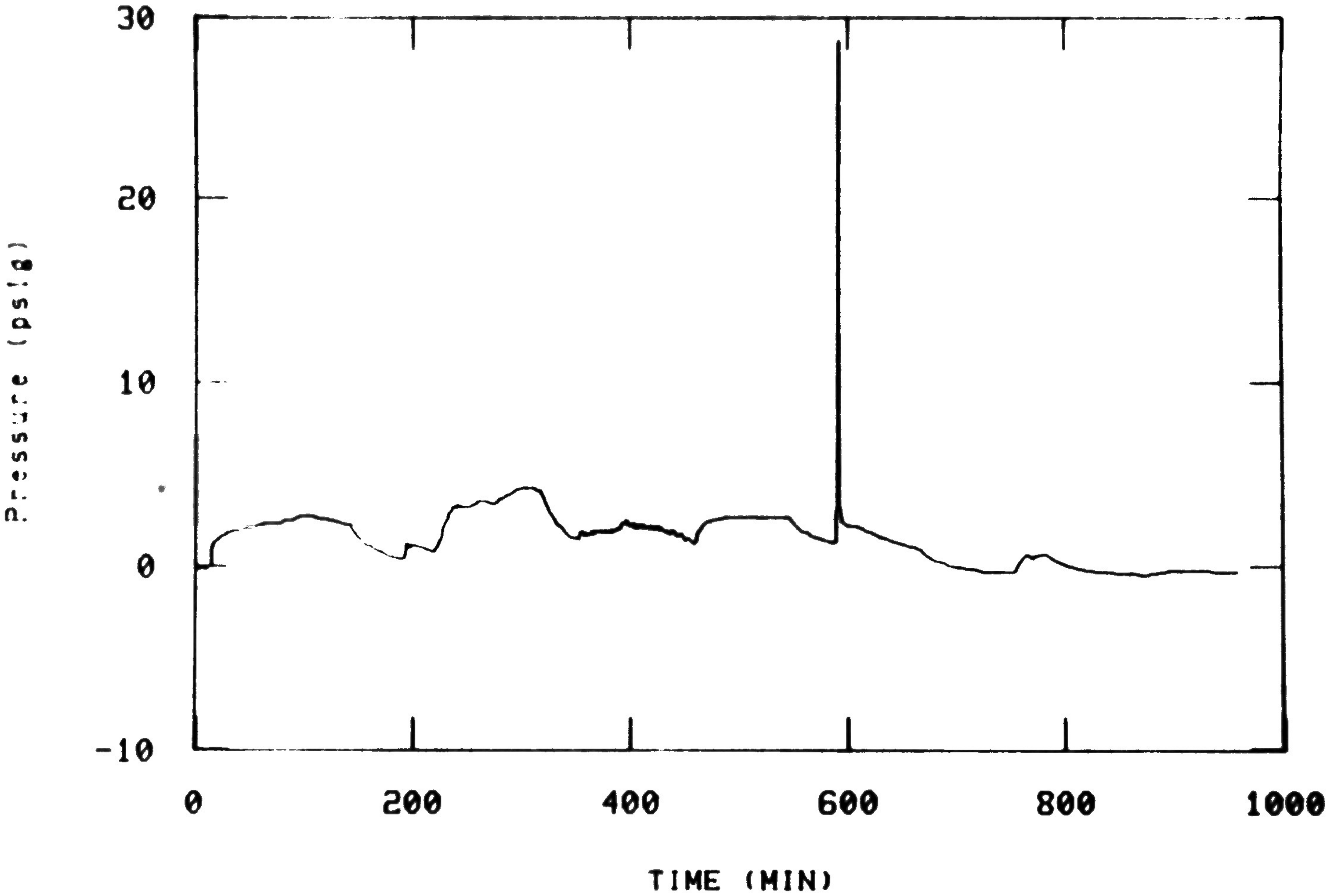


FIG. 2. CØNTAINMENT BUILDING PRESSURE
BS-PT-4388-S

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: March 2, 1987

To: Distribution

From: J. L. Anderson JLA

Subject: DATA QUALIFICATION - TURBINE HEADER PRESSURE - JA-2-87

Ref: J. L. Anderson ltr to D. W. Golden, JA-18-86, Data Qualification - Secondary Pressures, September 11, 1986

I have reviewed the turbine header pressure data recorded on the reactimeter system [SP-10A-PT1-R]. This measurement was located in the 1A steam line (A-loop steam generator), downstream of the main steam isolation valve [MS-V7A] and upstream of the A-loop steam chest (in which the turbine steam stop valves were located). Since there is no indication that the main steam isolation valves in the A-loop were closed during the first day of the accident, there should be good comparison between the turbine header pressure and the main steam pressure measured in the reactor building and recorded on the reactimeter. These two measurements are compared in the attached Figure 1 for the first 300 minutes of the accident. With the exception of the 15-50 min. period there is very good comparison. By 150 min. the secondary pressure had dropped below the lower range of the turbine header pressure, where is remained for the remainder of the first day. Note that the turbine header pressure dropped down to 500 psig, which is 100 psig below the stated minimum range for the measurement. This behavior was also observed for the narrow range primary pressure recorded on the reactimeter. In addition, this measurement exhibited behavior of an abrupt drop in pressure when the 1A RCP was bumped at 930 min., which was also similiar to the behavior of the main steam pressure measurements [SP-6A&B-PT1-R]. No explanation is available for this behavior.

The -10 to 90 min. time period is expanded in Figure 2, in which the turbine header pressure is as much as 20 psi lower than the main steam pressure, a possible indication of steam flow through the steam line (note that the turbine bypass line is upstream of the isolation valve). This is similiar to the difference between these measurements prior to the turbine trip.

My review of this data does not indicate any failure of the measurement during the first 300 min. of the accident. I therefore recommend that this measurement be assigned a data qualification category of QUALIFIED for the first 150 min. of the accident (within the valid measurement range), with an amplitude uncertainty of ± 8.2 psig and a timing uncertainy of ± 3 seconds. The amplitude uncertainty value is documented in the attached Table 1. Estimates for uncertainties from the main steam pressure measurements are used since we do not have detailed information on the turbine header pressure measurement. This procedure should provide reasonable uncertainty estimates.

jla

Attachment:
As Stated

Distribution
R. W. Brower
D. W. Golden
R. D. McCormick
Y. Nomura

cc: J. M. Broughton
J. L. Anderson File
Central File
DIRC File

TABLE 1

TURBINE HEADER PRESSURE [SP-10A-PT1-R] - UNCERTAINTY ANALYSIS

UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[1] % of Range Span	UNCERTAINTY ESTIMATE[1] Absolute (psig)
Transmitter (Foxboro)[2]		
Accuracy[3]	± 0.50 %	± 3.0
Temperature Sensitivity[4]	± 1% / 65°F	± 6.0
Electronics (Tolerance)[5]	± 0.79 %	± 4.7
Recorder (Reactimeter)	± 0.11 %	± 0.7
TOTAL UNCERTAINTY[6]	± 1.37 %	± 8.2 psig

----

1 Uncertainty estimates are based upon the uncertainty analysis for the secondary pressures presented in the referenced letter.

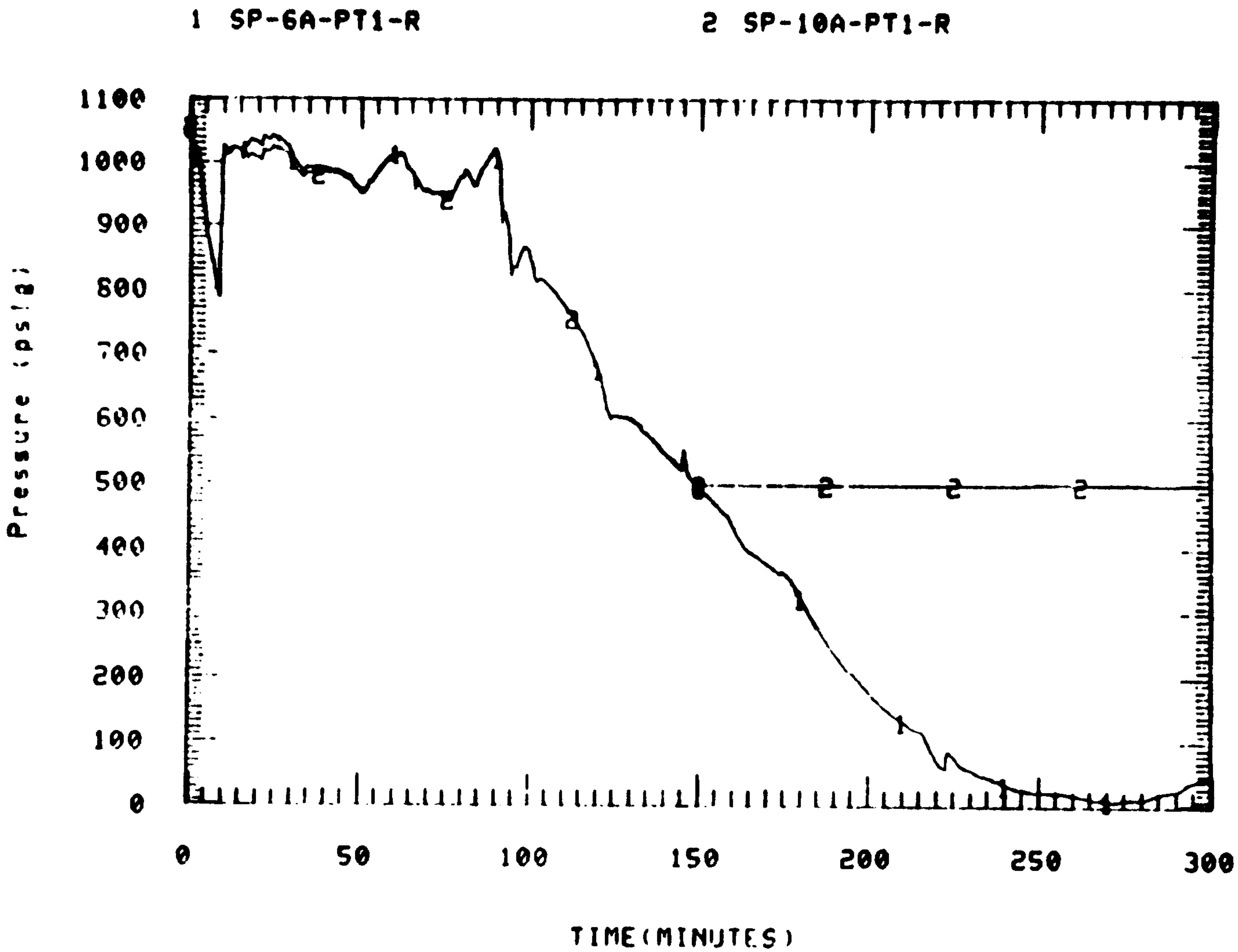
2 The transmitter range for this mesasurement is 600-1200 psig, which is used for the range span to obtain the absolute uncertainty estimates.

3 From the Foxboro transmitter manual.

4 A maximum temperature increase at the transmitter of 65°F is assumed based upon the observed reactor building temperture increase.

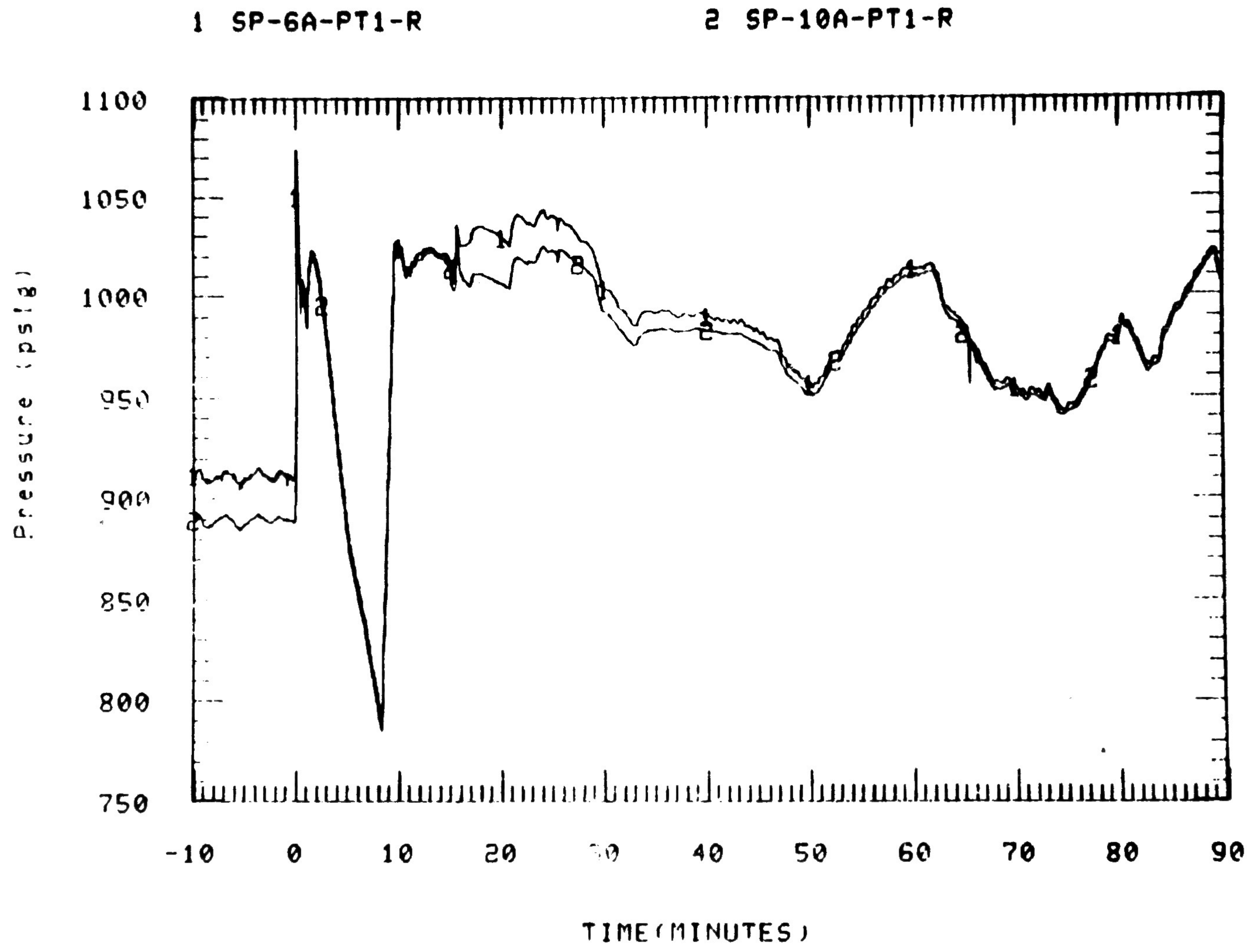
5 From the referenced document for tolerance in the setup of the electronics of the SP-6A-PT1-R measurement.

6 The total uncertainty estimate is obtained by combining the individual uncertainty components using the Root-Sum-Square method.



COMPARISON OF OTSG
STEAM AND TURBINE HEADER PRESSURES

Fig. 1



COMPARISON OF OTSG
STEAM AND TURBINE HEADER PRESSURES

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: September 11, 1986

To: D. W. Golden

From: J. L. Anderson JLA

Subject: DATA QUALIFICATION - SECONDARY PRESSURES - JA-18-86

Attached is a final copy of the data qualification document for the secondary system pressures. The secondary pressures were assigned a qualification classification of QUALIFIED with an uncertainty of ± 16 psi by the Data Integrity Review Committee (DIRC) during the August 19, 1986 meeting.

jla

Attachment:
As Stated

cc: J. M. Broughton
R. W. Brower
P. J. Grant
H. E. Knauts
P. Kuan
R. C. McCormick
Y. Nomura
A. Takizawa
E. L. Tolman
J. L. Anderson File
DIRC File
Central File

STEAM GENERATOR SECONDARY PRESSURES

DATA QUALIFICATION DOCUMENT

J. L. Anderson

September 1986

STEAM GENERATOR SECONDARY PRESSURES DATA QUALIFICATION DOCUMENT

1. INTRODUCTION

One of the primary parameters needed for thermal-hydraulic analysis of the TMI-2 accident is the secondary pressures in each of the two once through steam generators (OTSG's). In addition, knowledge of the secondary pressures is required as boundary conditions for the standard problem package. Luckily these pressures were recorded during the accident and are available for use in analysis and as boundary conditions. This report documents the data qualifications and uncertainty analysis of these recorded secondary pressures.

2. MEASUREMENT DESCRIPTION AND DATA SOURCES

Each of the two OTSG's had two steam lines connecting the secondary sides to the turbines in the turbine building. Connected to each of the four steam lines (in the reactor building) was a Foxboro model E11GM-SAF1 bourdon tube/electronic force balance gage pressure transmitter (output of 10-50 mADC) with a measurement range of 0-1200 psig. The sense lines penetrated the steam lines at an elevation of approximately 331 feet above sea level, upstream of the main steam isolation valves and the turbine bypass valves. The other end of the sense lines were connected to the pressure transmitters, located in the reactor building basement at an elevation of 287'8" (the transmitters were mounted in rack 426, location 30N-48W). The low pressure side of the gage pressure transmitters were open to the reactor building atmosphere, and thus responded to changes in the reactor building pressure. No adjustments were made to the recorded pressures due to the changing reactor building pressure since the maximum reactor building pressure was less than 5 psi (except for the very brief pressure spike due to the hydrogen burn).

There are three basic sources of recorded secondary pressures. The most complete data source is the data recorded on the reactimeter at a sample every three seconds. The output from one of the pressure transmitters in each steam generator was recorded on the reactimeter. This is considered to be the best source of data for the secondary pressures. The output from one of the pressure transmitters in each steam generator (probably the second transmitter) was input to the plant computer. At selected times the transmitter outputs was printed on the utility printer. Data is available from -15 to +15 minutes of the reactor trip (the Memory Trip Review) and once an hour on the hourly logs for both steam generators. Data is also available for the A-loop steam generator on the operator group trend C from 570-1000 minutes at a output rate of once every 2 minutes. Transmitter output from both steam generators was also recorded on strip charts, however, this data is not considered to be as reliable as the other data sources and has not been digitized.

A measurement block diagram for the secondary pressures is shown in Figure 1. Output from each of the pressure transmitters in each steam generator goes through a manual switch before going to the plant computer or the reactimeter. The position of this switch was not recorded. As a result it is unknown which of the two transmitters in each steam generator was recorded.

3. DATA PRESENTATION

The data recorded on the reactimeter is compared to the data recorded on the utility printer for the A-loop secondary pressure (SP-6A-PT1/PT2) in Figures 2-5. In Figure 2 the memory trip review data is compared to the reactimeter data. The two measurements compare quite well. The data from the two sources is compared in Figure 3 for the first 1000 minutes, with good comparison until the A-loop pump was restarted at 932 minutes. This figure is expanded in Figure 4 for the first 500 minutes, and in Figure 5 for the 500-1000 minute period. Until the A-loop pump (RC-P-1A) was restarted, the maximum difference between the two recordings was about 14.5 psi. Following the restart of RC-P-1A, the two measurements differed by more than 100 psi (the measurement identified as SP-6A-PT1-R decreased to a -50 psi). This indicates that the two recordings were for the two different pressure transmitters. In addition, is appears that the pressure transmitter recorded on the reactimeter failed as a result of the pressure spike in the secondary side, which resulted from the increased heat transfer when the pump was restarted.

The B-loop secondary pressures recorded on the reactimeter and the utility printer are compared in Figures 6 & 7. For the time period prior to the reactor trip there was an approximate 14 psi difference between the two recorded measurements. This could be an indication that two different pressure transmitter outputs were being recorded, or that the front end electronics for the reactimeter caused this difference.

The secondary pressures of the two steam generators at the times given as initial conditions in the international standard problem are tabulated in Table 2.

4. UNCERTAINTY ANALYSIS

The uncertainties associated with each component of the secondary pressures are summarized in Table 1. Individual uncertainties are combined using the root-sum-square method given in references 1 & 2. The result is an uncertainty in the reactimeter recorded measurements of approximately ±16 psi.

5. DATA QUALIFICATION

The secondary pressure data recorded on the reactimeter system was reviewed by the Data Integrity Review Committee (DIRC) during its August 19, 1986 meeting and assigned a qualification classification of QUALIFIED with an uncertainty of ±16 psi, and a FAILED classification after 932 min.

6. REFERENCES

1. R. D. McCormick, Data Qualification and Uncertainty Analysis, attachment to letter RDMc-4-86, "Final Data Analysis Plan", to J. M. Broughton, dated June 2, 1986.

2. Measurement Uncertainty for Fluid Flow in Closed Conduits, ANSI/ASME, MFC-2M-1983.

3. Foxboro Company, Installation/Operation/Maintenance for Model E11GH Pressure Transmitter, 20-220, Jan. 1969.

TABLE 1 OTSG SECONDARY PRESSURES - UNCERTAINTY ANALYSIS

DATA SOURCE[a]	UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[b] % of Range Span	Absolute (psig)
REACTIMETER[c] SP-6A-PT1-R (Range = 0-1200)	Transmitter (Foxboro)[d]		
	Accuracy	± 0.50%	± 6.0
	Temperature Sensitivity[n]	± 1.0%/65°F	± 11.1
	Stability	± 0.25% FS	± 3.0
	Electronics (Tolerance)[e] [$=\sqrt{(.25\%^2+.75\%^2)}$]	± 0.79%	± 9.5
	Recorder[f]	± 0.11%	± 1.3
	TOTAL UNCERTAINTY[g]		± 16.1
UTILITY PRINTER[h] SP-6A-PT2-P (Range = 0-1200 psig)	Transmitter (Foxboro)[d]		
	Accuracy	± 0.50%	± 6.0
	Temperature Sensitivity	1.0%/65°F	± 11.1
	Electronics (Tolerance)[e]	± 0.50%	± 6.0
	Recorder (Computer)[i]	± 0.11%	± 1.3
	TOTAL UNCERTAINTY		± 14.0

a. Data sources used for comparison purposes are the reactimeter and plant computer data recorded on the utility printer.

b. The uncertainty estimates given were obtained from various sources, which are listed in the following footnotes. The uncertainty estimates are given for the 95% confidence level, and are all considered to be Bias estimates due to the total lack of any statistically significant data.

c. The secondary pressure recorded on the Reactimeter (SP-3A-PT1-R) is considered to be the most accurate data source, and is used as the primary data source.

d. The source of uncertainty estimates for the pressure transmitter is the Foxboro transmitter manual, Reference 3.

TABLE 1. (continued)

e. The acceptable tolerance limits stated in the instrumentation calibration sheets and the surveillance procedure data sheets are used as the uncertainty estimates for the signal conditioning electronics.

f. The uncertainties associated with recording on the reactimeter are assumed to be the same as for recording on the plant computer. No uncertainty information on the reactimeter is available. This includes manuals, drawings, model number, and serial number of the unit installed by B&W during the accident.

g. Individual uncertainty components are combined using the Root-Sum-Square method outlined in References 1 & 2.

h. Available utility printer secondary pressure data is from the Memory Trip Review (± 15 minutes of reactor trip) and the operator group trend C data (starting at 570 minutes).

i. The uncertainty estimate for the data recorded on the computer (via the utility printer) is based on the individual uncertainty components of the analog-to-digital convertor given in the Bailey 855 Computer manual, section 8.3.

TABLE 2

OTSG SECONDARY INITIAL CONDITIONS FOR STANDARD PROBLEM

Parameter	Time (min.)	A-loop	B-loop
Pressure (MPa)	0[a]	6.38 ±0.11 (σ=.015)	6.24 ±0.11 (σ=.011)
	100	5.96 ±	1.27 ±
	174	2.58 ±	1.07 ±
	225	0.49 ±	2.62 ±

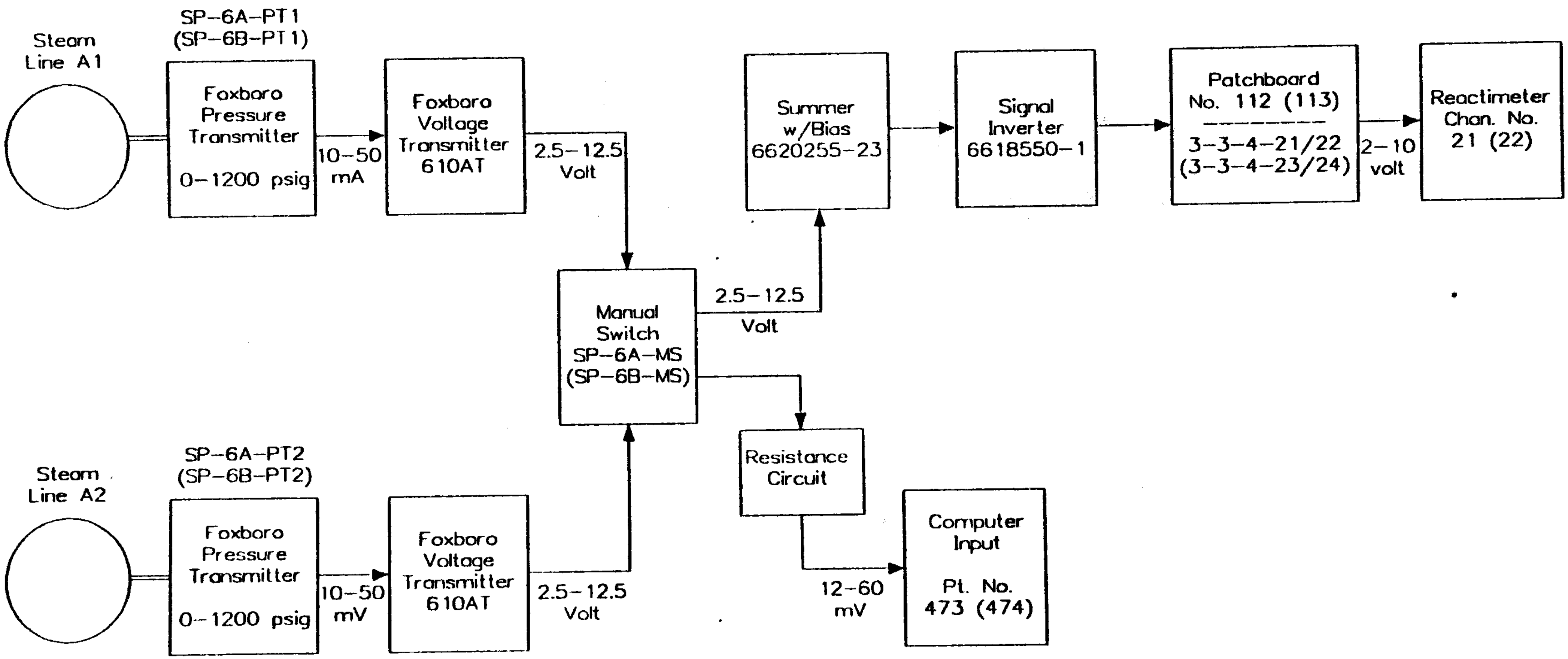
a. σ is the standard deviation of the initial condition data from -10 to -0.1 minutes.

FIGURE 1

Measurement Block Diagram

Steam Generator Steam Pressures

SP–6A–PT1/PT2 (SP–6B–PT1/PT2)



Reference: Bailey Dwg 8038499D

* Items in parentheses are for the B-loop OTSG

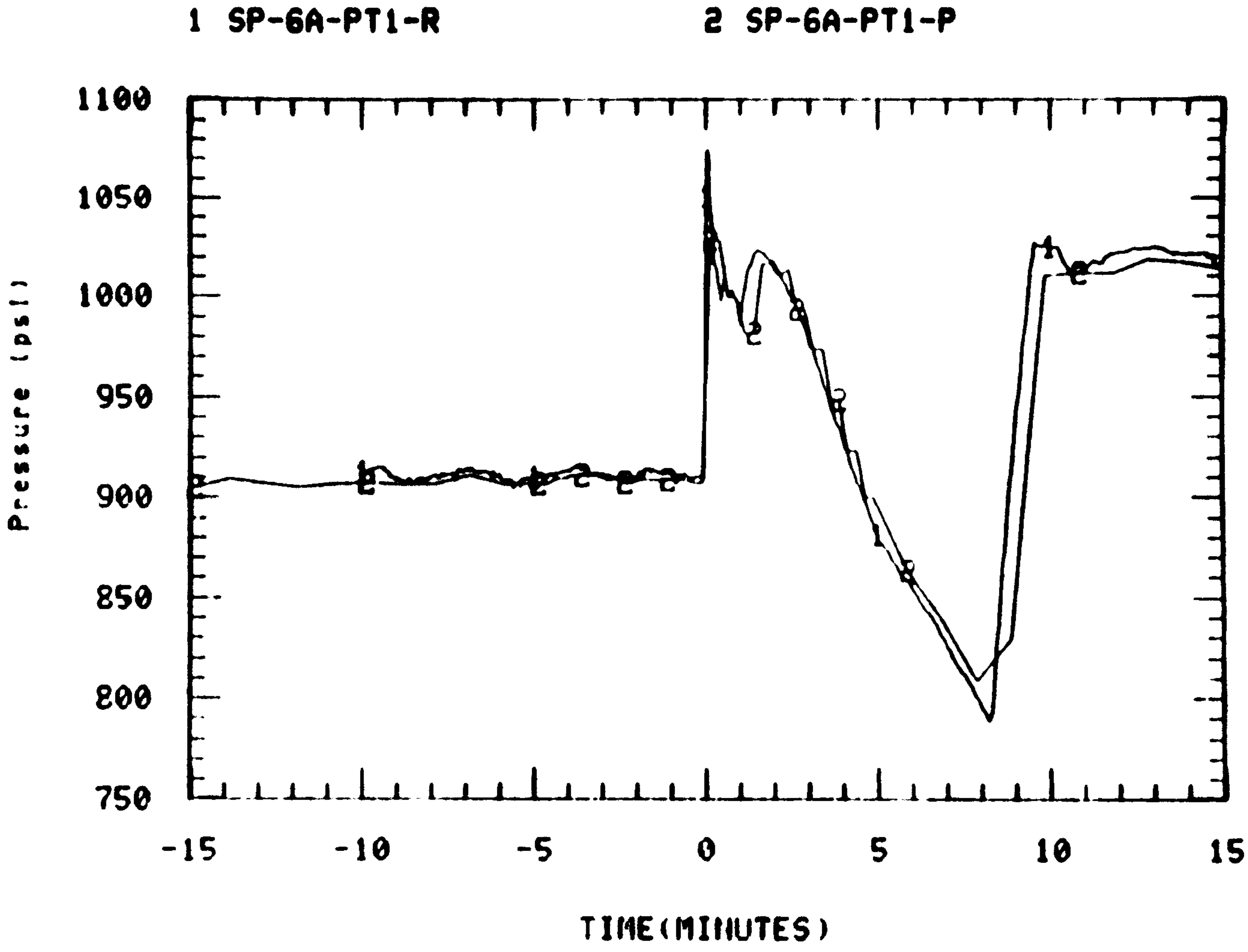


FIG. 2 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

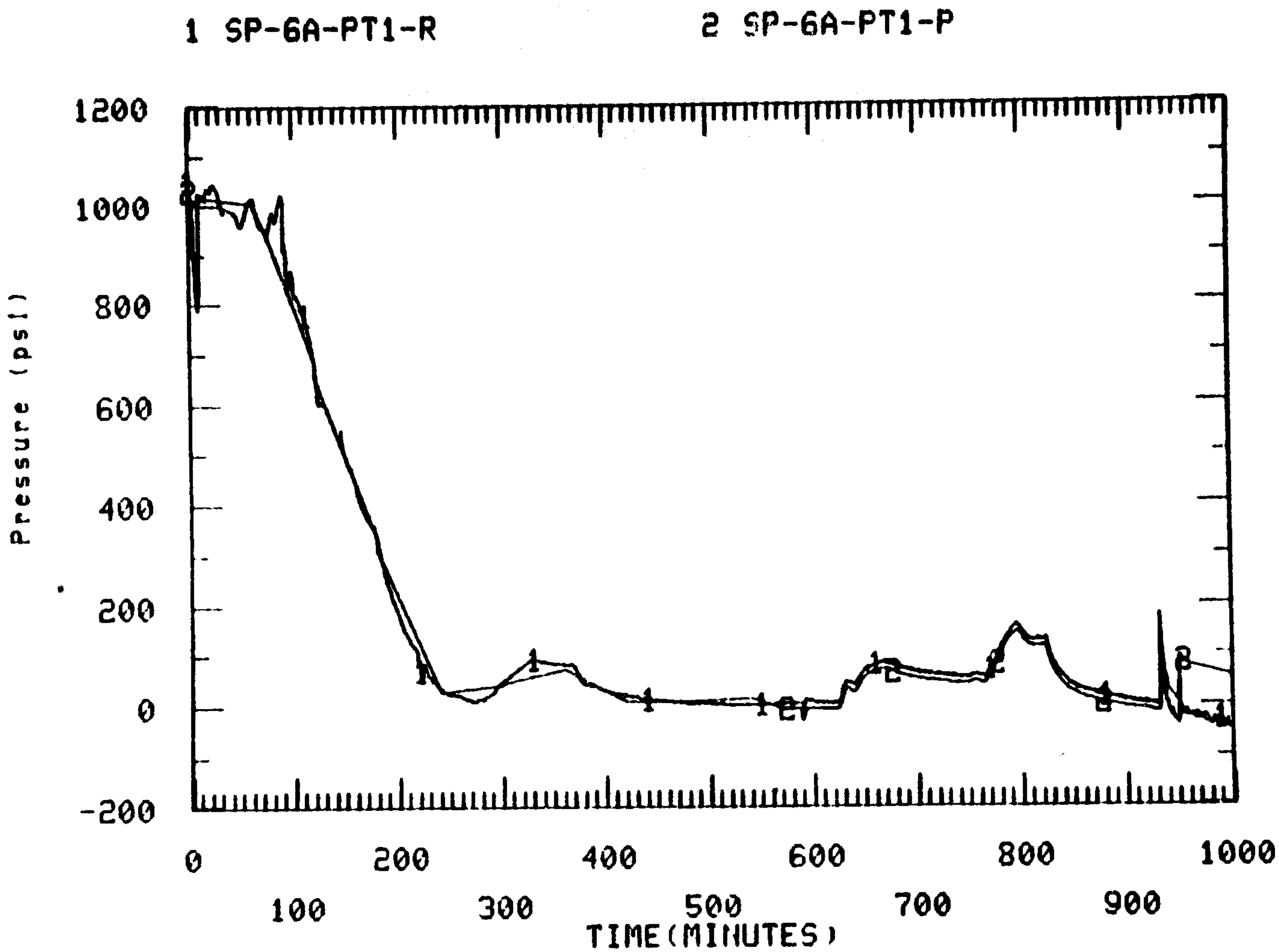


FIG. 3 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

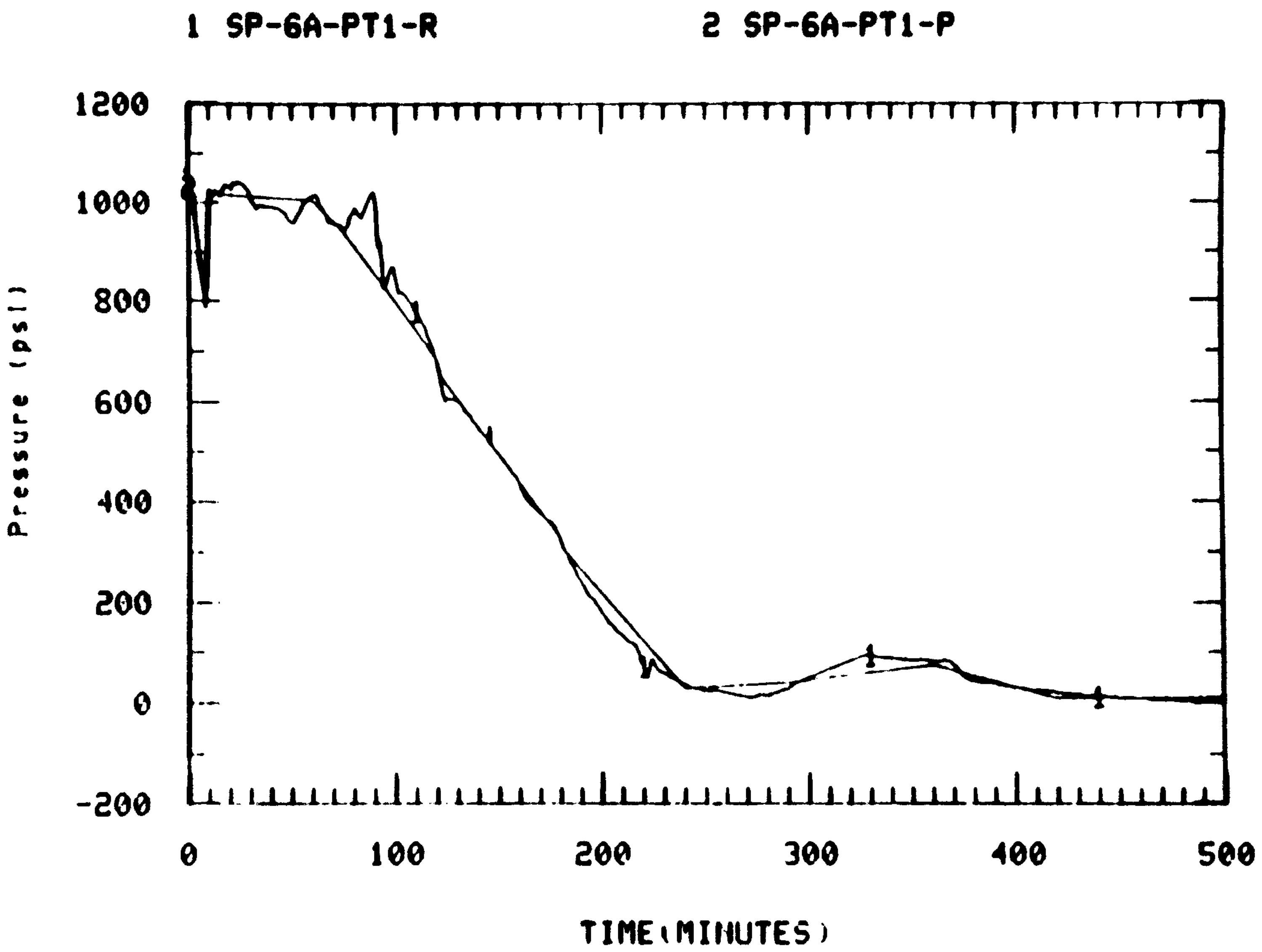


FIG. 4 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

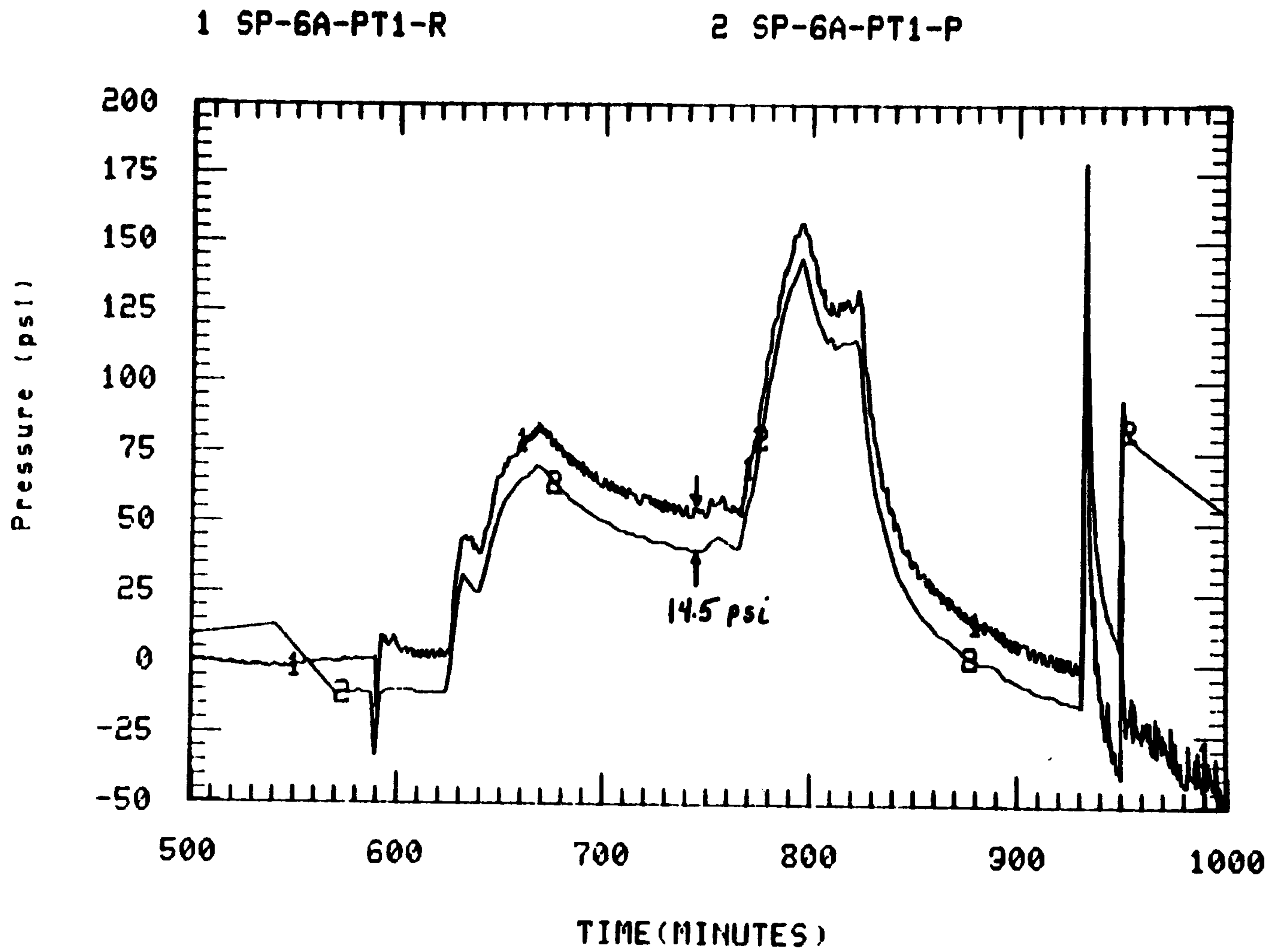


FIG. 5 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

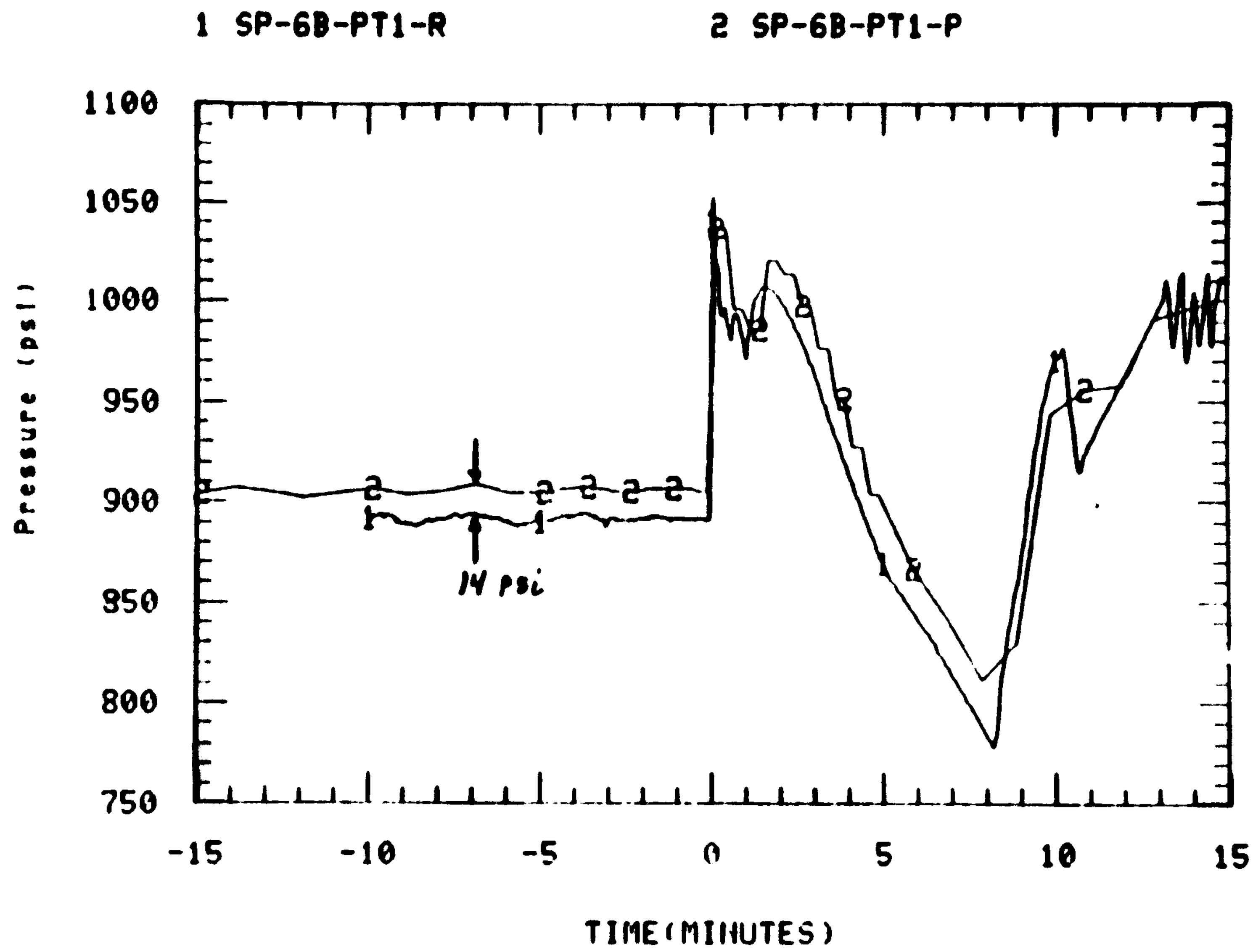


FIG. 6 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

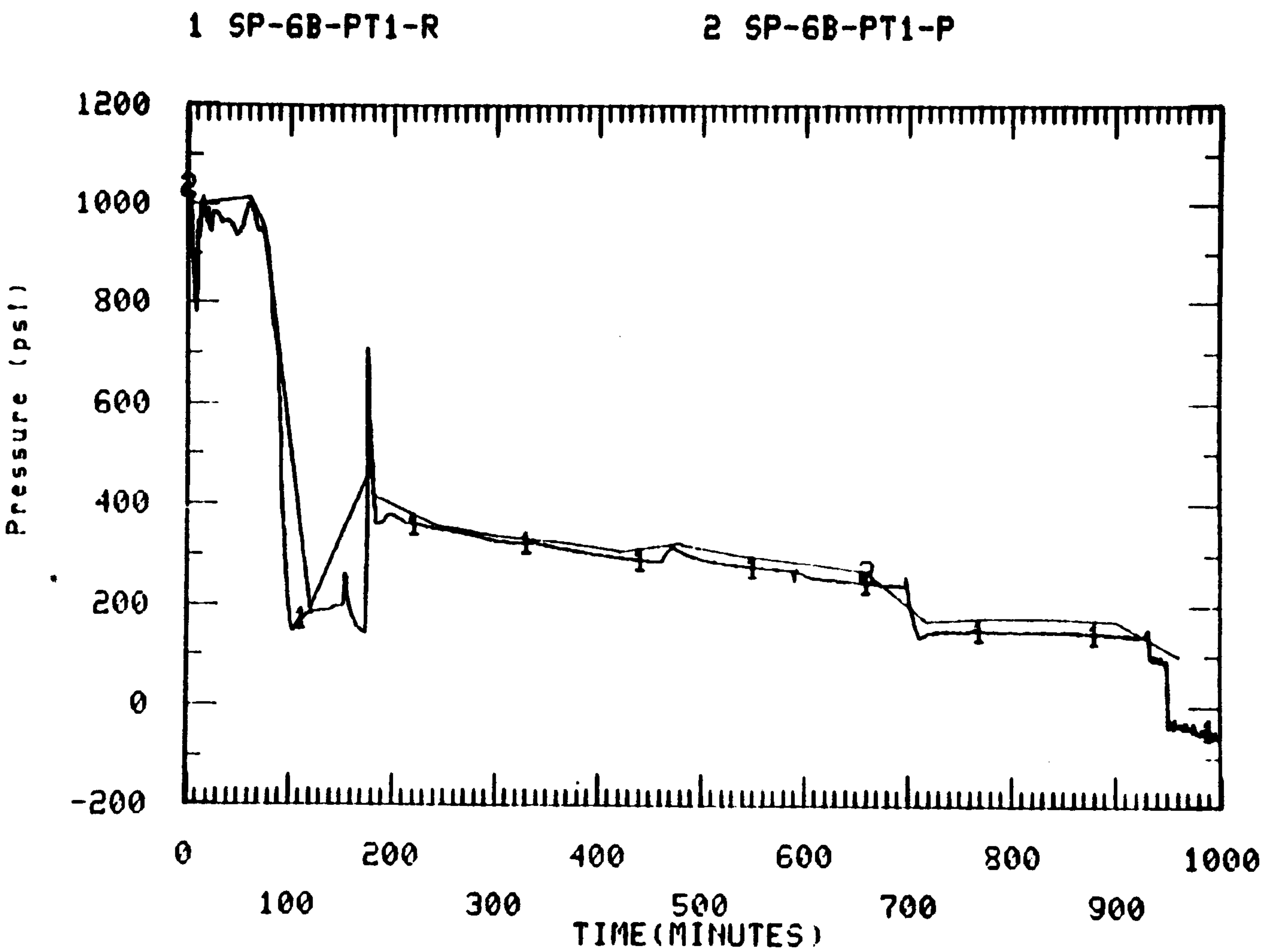


FIG. 7 COMPARISON OF UTILITY PRINTER AND REACTIMETER SECONDARY PRESSURE DATA

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: February 27, 1987

To: Distribution

From: J. L. Anderson JLA

Subject: DATA QUALIFICATION - RCDT TEMPERATURE AND PRESSURE - JA-1-87

I have reviewed the recorded data from the Reactor Coolant Drain Tank (RCDT) temperature and pressure measurements. The pressure data was recorded on the reactimeter system, and appears to be valid for the first 932 minutes of the accident, at which time the measurement output goes negative (see attached Figure 1). This response indicates failure of the measurement at this time (the mechanism is unknown; however, this is simultaneous with the bumping of the 1A reactor coolant pump prior to its restart). It should be noted that the rupture disc on the RCDT failed just prior to 15 minutes into the accident, severely limiting the usefulness of the pressure data. This response is shown in Figure 2. Failure of the rupture disc should not have effected the quality of the recorded pressure data. Therefore I recommend a data classification of QUALIFIED for the measurement WDL-PT-1202-R, with an uncertainty of ± 3.9 psi in magnitude and a timing uncertainty of ± 3 seconds. The uncertainty value is documented in the attached Table 1.

The RCDT temperature [WDL-TE-1200-P] was recorded on the utility printer once every 2 minutes starting at 570 minutes (a computer scan rate of once every 30 seconds was used for this measurement). This data is shown in Figure 3, and an uncertainty analysis is provided in Table 2. Documentation of the exact location of the measurement in the RCDT has not been located. There is no indications that the measurement was performing improperly. Therefore I recommend that this measurement be assigned a measurement classification of QUALIFIED, with an amplitude uncertainty of ± 1.7°F, and a timing uncertainty of +0/-30 seconds.

jla

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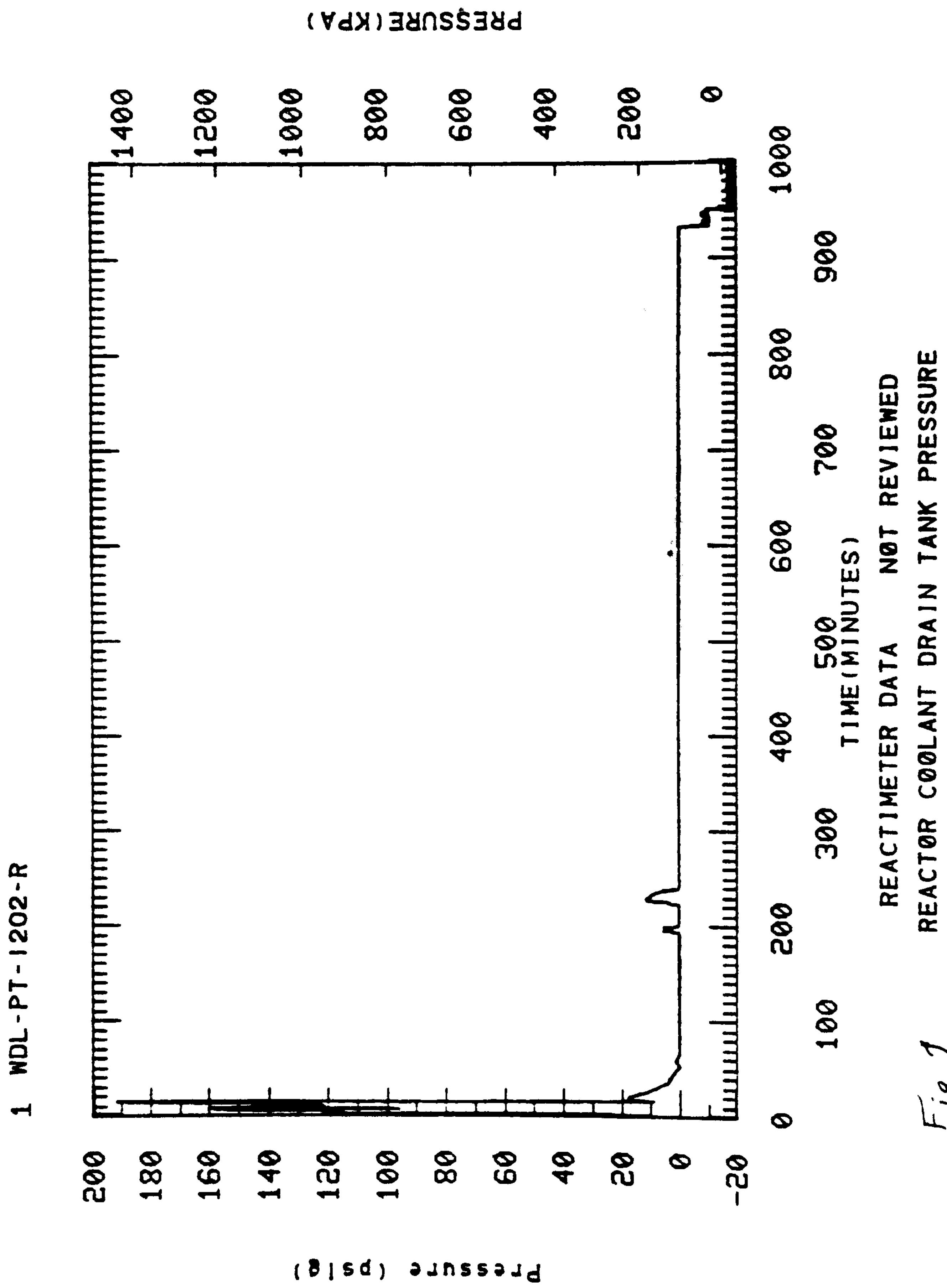
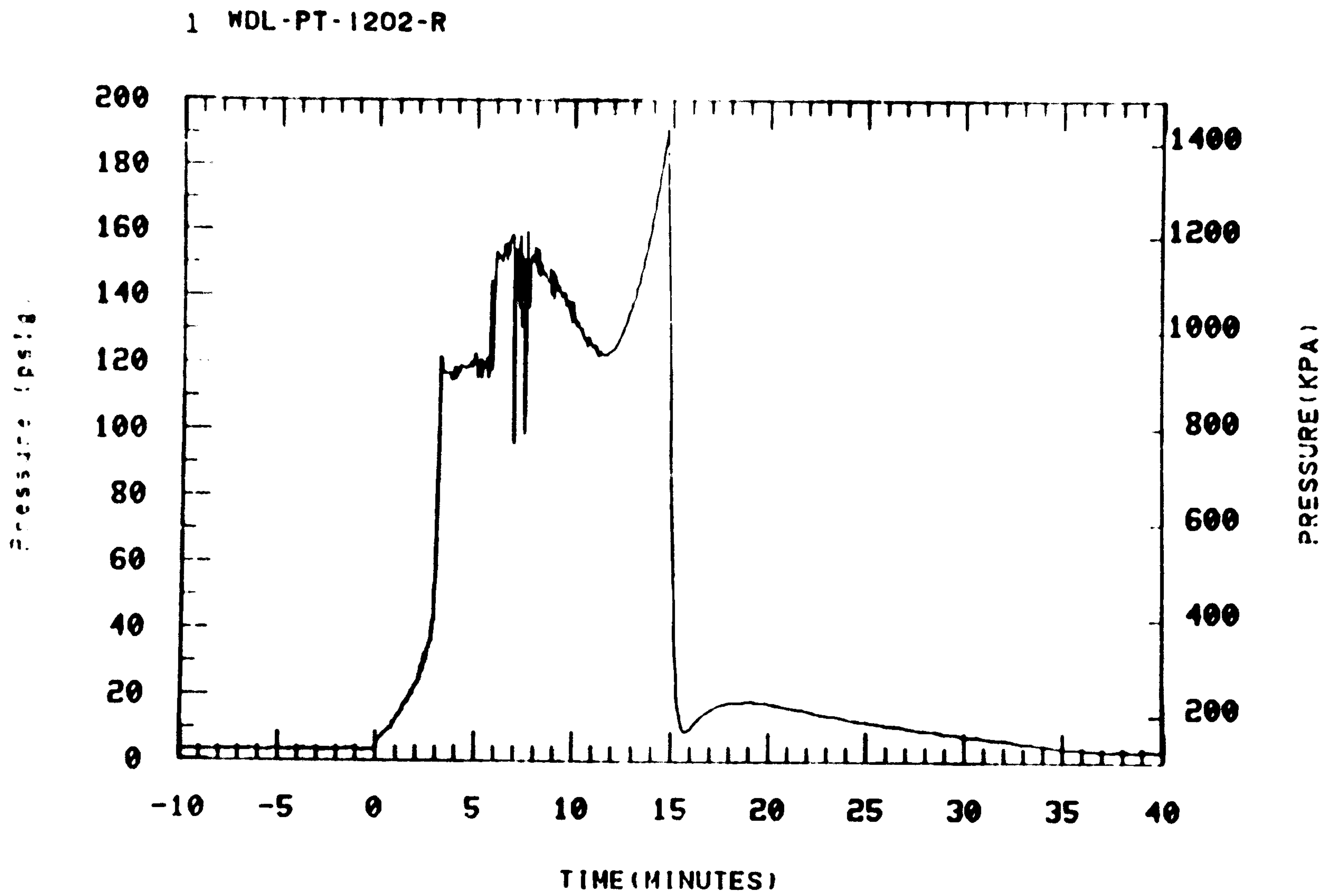

WDL-PT-1202-R
PRESSURE(KPA)
Pressure (psig)
TIME(MINUTES)
REACTIMETER DATA NOT REVIEWED
REACTOR COOLANT DRAIN TANK PRESSURE

Fig 1.



REACTIMETER DATA NØT REVIEWED

Fig 2 REACTØR CØØLANT DRAIN TANK PRESSURE

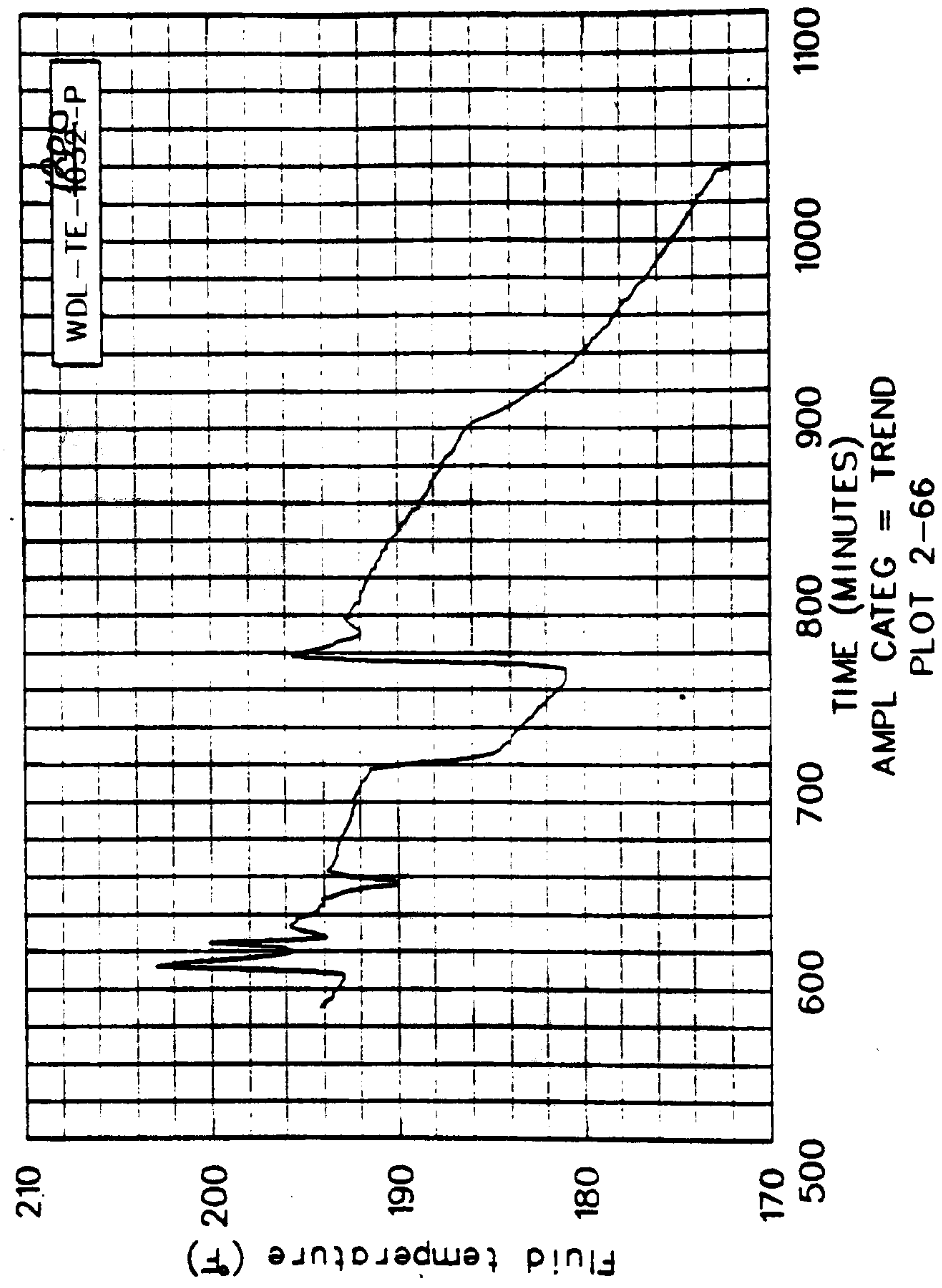


Fig. 3 Data from WDL-TE-1200-P

TABLE 1

REACTOR COOLANT DRAIN TANK PRESSURE
[WDL-PT-1202-R]
UNCERTAINTY ANALYSIS

UNCERTAINTY COMPONENT	UNCERTAINTY ESTIMATE[a] % of Range Span	Absolute (psig)
Transmitter [b]		
Accuracy	± 0.50%	± 1.3
Temperature Sensitivity[c]	± 1.0%/65°F	± 2.5
Drift [d]	± 0.50%	± 1.3
Observed Noise		± 2.0
Electronics (Tolerance)[e]	± 0.50%	± 1.3
Recorder (Reactimeter)[f]	± 0.11%	± 0.3
TOTAL UNCERTAINTY[g]	±1.33%	± 3.9 psi

a. The uncertainty estimates given were obtained from various sources, which are listed in the following footnotes. The uncertainty estimates are given for the 95% confidence level, and ar all considered to be Bias estimates due to the lack of statistically significant data.

b. The RCDT pressure was measured using a Foxboro pressure transmitter (model E11GM-HSAD2, style B) with a measurement range of 0-250 psig. The output from this transmitter was recorded on the Reactimeter once every 3 seconds with a measurement identification of WDL-PT-1202-R. The source of uncertainty estimates for the pressure transmitter is the Foxboro transmitter manual (Installation/Operation/Maintenance for Model E11GH Pressure Transmitter, Jan. 1969).

c. A maximum temperature increase of 65°F is assumed for the location where the transmitter was mounted.

d. An uncertainty due to drift in the transmitter of 0.5% is assumed based upon engineering judgement.

e. The acceptable tolerance limits stated in the instrumentation calibration sheets and the surveillance procedure data sheets are used as the uncertainty estimates for the signal conditioning electronics.

f. The uncertainties associated with recording on the reactimeter are assumed to be the same as for recording on the plant computer. No uncertainty information on the reactimeter is available.

g. Individual uncertainty components are combined using the Root-Sum-Square method.

TABLE 2

RCDT TEMPERATURE - [WDL-TE-1200-P]
UNCERTAINTY ANALYSIS

ITEM	ERROR	COMMENT
RTD element[1]	.05%	Of span (0-250^{0}F)
Calibration[2]		
RTD and Bridge	.15%	Temperature conversion to resistance and mV.
Signal Converter[3]	.1%	Resistance span to mV
Converter[4]		
Accuracy	.15%	
Linearity	.15%	
RTD drift[5]	.45%	Per year
Electronic drift[6]	1.0^{0}F	
Recorder (Computer)[7]	.1%	
TOTAL UNCERTAINTY[8]	1.68^{0}F	

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[1]Taken from the Bailey Meter Company Specification sheet.
[2]Taken from the Bailey Meter Company Specification sheet.
[3]From TMI instrument calibration sheet. This is a percent of span tolerance. Resistance is input to bridge and mV is output.
[4]Bailey Meter Company product instruction sheet E92-1906 for signal converter.
[5]From Rosemount Engineering Company product data sheets. Specification of < .25+C drift per year for a platinum RTD element.
[6]Estimate is based upon engineering judgement to account for drift in electronic system.
[7]Based upon uncertainty components of the analog-to-digital convertor given in the Bailey 855 Computer manual, section 8.3.
[8]Total uncertainty is obtained using the Root-Sum-Square method for combining the individual uncertainty components.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: March 5, 1987

To: D. W. Golden

From: R. D. McCormick RDM

Subject: QUALIFICATION OF CONTAINMENT AIR TEMPERATURE DATA - RDMc-5-87

The air temperature measurement data for the drain tank region (AH-TE-5011-M) and the letdown cooler region (AH-TE-5012-M) were reviewed. The information base for the review was the Reference 1 and 2 documents. The data were recorded on multipoint recorder AH-Y-MTR-5017 also referred to as Recorder No. 1. The recorder was calibrated in November 1977 and again in March 1982. At this later time a maximum error of 1°F was measured in the recorder. According to the specifications on the RTD, there was a possible error of approximately 1°F in the accuracy of the RTD. The stability of the RTD was 0.2% of maximum temperature or 0.95°F. It was estimated that the maximum temperature in the containment exceeded 1000°F (according to references). The time uncertainty of data was ± 90 seconds and data were printed every 6 minutes. The time constant was estimated to be 41 ± 24 seconds in air. In 1982 there was a resistance reading error equivalent to 10°F in RTDs. This was believed to be due to corrosion and surface contamination after the accident.

It is estimated that the RTDs were working okay during the accident but they could not measure temperatures of the hydrogen burn because of the slow sample rate. I think the data should be qualified for all time except at temperature peaks. After the hydrogen burn I increased the error because of the high exposure temperatures. Table I and II give details of the data qualification and uncertainty analysis.

TABLE I

SUMMARY OF DATA QUALIFICATION

Item	Time (Hours)	Category	Uncertainty (± °F)
Letdown cooler AH-TE-5011-M	Up to 13:46	Qualified	2.7
	13:52	Trend	--
	13:58 and after	Qualified	3.3
RC drain tank AH-TE-5012-M	Up to 04:41	Qualified	2.7
	04:47 and 04:53	Trend	--
	04:59 to 13:47	Qualified	2.7
	13:53 and 13:59	Trend	--
	14:05 and on	Qualified	3.3

TABLE II

UNCERTAINTY ANALYSIS

RTD Air Temperatures

AH-TE-5011-M - Letdown Cooler Temperature
AH-TE-5012-M - RC Drain Tank Temperature

Item	(±) Error	Comment
RTD[a] Accuracy	.95°F	At 100°C deviation from nominal R vs T cruve
Stability[b]	.46°F	Before H_2 burn
	2°F	After H_2 burn
Recorder[c]	1°F	In 1981
Temperature[d]	1°F	
Digitizing error[e]	2°F	

Before hyrogen burn ± 2.7°F.

After hydrogen burn ± 3.3°F.

Time uncertainty ± 1.5 minutes.

NOTE:

(a) Taken from Rosemount Inc. Product Data Sheet 2178 on the series 78 platinum RTD.

(b) Stability listed as 0.2% of exposed temperature hydrogen burn resulted in temperature greater than 1000°F from GEND-INF-030.

(c) Recorder error was measured in 1982 (EG&G Report ED-E3-82-017) and previously in 1977.

(d) The RTD's used a three wire system which would allow some error due to temperature changes in the facility affecting the resistance of the lead wires. A 140°F change in temperature would yield approximately .1% of span change output.

(e) Estimated error of 1% for interpretation and reading. UI students projected the 16 mm image onto some kind of digitizing table.

References

(1) ED-E3-82-017, June 1982
"Current Status and Accident Data Presentation of Containment Air Temperature Resistant Temperature Sensors," James W. Mock.

(2) GEND-INF-030, April 1983
"Analysis of Air Temperature Measurements from the Three Mile Island Unit 2 Reactor Building," Michael O. Fryer.

jlm

cc: J. L. Anderson
J. M. Broughton
R. W. Brower
Y. Nomura
R. D. McCormick File
Central File
DIRC File

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: Distribution

From: R. D. McCormick RDM

Subject: DIRC RESULTS ON TEMPERATURE MEASUREMENTS - RDMc-1-87

A Data Integrity Review Committee (DIRC) meeting was held on January 27, 1987, to review the subject temperature measurement uncertainty analysis and verify their quality categories. The details of the uncertainty analyses are contained in the attached Tables 2 to 6. Table 1 below summarizes the results of the DIRC meeting. The data were all considered QUALIFIED for the times shown and NOT REVIEWED for all other times.

The pressurizer surge line temperature was estimated to be trend data primarily because it came from a strap-on thermocouple.

Measurement	± Uncertainty	Time Qualified
RC-4A-TE1-R	1.14°F	All time
RC-4B-TE1-R	1.14°F	All time
SP-4A-TE	2.1°F	Prior to 0 time
SP-4B-TE	2.1°F	Prior to 0 time
SP-5A-TE-P	1.71°F	Prior to 0 time
FW-TE-1131-P	1.78°F	Prior to 0 time
RC-5A-TE2-R	1.91°F	All time
RC-5B-TE2-R	3.73°F	All time
RC-9-TE-P	None	Trend for all time

jlm

Attachments:
As Stated

Distribution
J. L. Anderson
J. M. Broughton
R. W. Brower
D. W. Golden
H. E. Knauts
R. D. McCormick File
Central File

TABLE 2

RC HOT LEG TEMPERATURES

Uncertainty Analysis
RTD Range 520 to 620°F
RC4A-TE-1-R and RC-4B-TE1-R

Item	Error	Comment
RTD element[a]	.05%	Span
Calibration[b] (RTD and Bridge)	.15%	Temp to resistance and mv
Calibration[c]	.1%	Res span to mv
Converter[d]	.15%	Accuracy span
	.15%	Linearity span
RTD drift[e]	.45%	Per year
Electronic draft[f]	1.0°F	
Reactimeter[g]	.1%	Span

$U_n = [B^2 + S^2]^{1/2} = \pm 1.137°F$

a&b - These were taken from the Bailey Meter Company Spec found on microfische.

c - From Instrument Calibration Sheet at TMI. This is a percent of span tolerance. Resistance is input to bridge and mv is readout.

d - Bailey Meter Company Product Instruction E92-1906 for signal converter

e - From Rosemount Engineering Company product data sheets. Says <.25°C drift per year in platinum RTD element.

f - Estimate based on engineering judgment to account for drift in electronic system.

g - Based on calculation using TMI data on computer system.

TABLE 3

STEAM TEMPERATURE

Uncertainty Analysis
for RTD Range 100 to 650°F
SP-4A-TE-P and SP-4B-TE-P
Hourly Log

Item	(±)Error	Comment
RDT element[a]	.05%	Span of 550°F
Calibration[b] (RTD and Bridge)	.15%	
Calibration[c] (Bridge)	.1%	Span
Converter[d]	.15% .15%	Span Span
RTD drift[e]	.45°F	
Electronic drift[f]	1.0°F	
Computer[g]	.1%	Span
Read out[h]	.5°F	
Radiation loss[i]	1.0°F	

U_n = 2.22°F - .5°F = 2.72°F

a-g - Same as Table 2.

h - Read out of hourly log is rounded off to 1°F. This error is added to uncertainty directly (no RSS).

i - Estimated radiation loss based on engineering judgment.

TABLE 4

FEEDWATER TEMPERATURE

Uncertainty in RDT Range 0 to 500°F
SP-5A-TE1-R and FW-TE-1131-P

Item	(±)Error	Comment
RTD element	.25°F	
Calibration (RTD and Bridge)	.15°F	
Calibration (Bridge)	.5°F	
Converter	.75°F .75°F	
RTD drift	.45°F	
Electronic drift	1°F	
Reactimeter/computer	.5°F	
Hourly log readout	.5°F	Do not RSS this error.

SP-5A-TE1-R on reactimeter

$$U_n = \pm 1.71°F$$

FW-TE-1131-P (on hourly log)

$$U_n = 1.71 + .5 = 2.21°F$$

NOTE: The 0.5°F is added directly to the uncertainty not RSS.

TABLE 5

Uncertainty in RC Cold Leg Temperature
RC-5A-TE2-R   Range 50 to 650°F

Item	(±) Error	Comment
RTD element	0.3°F	Span 600°F
Calibration (RTD and Bridge)	0.15°F	
Calibration (Bridge)	0.6°F	
Converter	1.273°F	
RTD drift	0.45°F	
Electronic drift	1.0°F	
Reactimeter	0.6°F	

Uncertainty = ± 1.91°F

TABLE 6

Uncertainty in RC Cold Leg Temperatures
RC-5B-TE2-R Range 50 to 650°F

Item	(±) Error	Comment
RTD element	0.3°F	Span 600°F
Calibration (RTD and Bridge)	0.15°F	
Calibration (Bridge)	0.6°F	
Converter	1.273°F	
RTD drift	0.45°F	
Electronic drift	1.0°F	
Reactimeter	0.6°F	
Offset[a]	3.2°F	

Uncertainty = ± 3.73°F

a) The offset was due to the mismatch between RC-5A-TE2-R temperature and the hot leg and saturation temperatures during the first approximate 75 minutes of the accident. This is an anomaly which has not been explained.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: DIRC File

From: R. D. McCormick

Subject: PRESSURIZER TEMPERATURE AND OTSG TEMPERATURE UNCERTAINTIES - RDMc-11-87 - Revision

This letter gives the uncertainty analyses for the OTSG downcomer and upper downcomer (SP-12A(B)-TE and SP-3A(B)-TE), the pressurizer (RC-2-TE1-P) and the pressurizer surge line (RC-9-TE) temperature measurements. The surge line temperature is measured by a Chromel-Constantan thermocouple while the other three are measured by RTDs in thermal wells. The surge line thermocouple is of the strap-on type and is believed to go directly to the plant computer, not going through a reference junction or signal conditioning.

Analysis of the RC-9-TE measurement indicated that it should have had an uncertainty of less than 10°F if the device were operating properly. It is concluded from comparing the analysis with observed measurement errors that the device was not operating properly.

jlm

Attachments:
As Stated

cc: J. L. Anderson
R. W. Brower
D. W. Golden
R. D. McCormick File
Central File

TABLE 1

UNCERTAINTY ANALYSIS
SP-3A-TE1/2-P
DOWNCOMER TEMPERATURE ON PLANT COMPUTER
RANGE 0 TO 600°

Item	(±) Error	Comment
RDT Element[a]	0.3°F	Span
Calibration[b] RTD and Bridge	1.0°F	°F to ohms
Calibration[c]	0.6°F	Ohms to mv
Converter[d]	0.9°F 0.9°F	Accuracy Linearity
RTD Drift[e]	0.45°F	Per year
Electronic Drift[f]	1.0°F	
Readout and[g] Computer	0.85°F	Span

Uncertainty = ± 2.2°F

a&b - These were taken from the Bailey Meter Company Spec found on microfische.

c - From Instrument Calibration Sheet at TMI. This a percent of span tolerance. Resistance is input to bridge and mv is readout.

d - Bailey Meter Company Product Instruction E92-1906 for signal converter.

e - From Rosemount Engineering Company product data sheets. Says <.25°C drift per year in platinum RTD element.

f - Estimate based on engineering judgment to account for drift in electronic system.

g - Based on calculation using TMI data on computer system and a ± 0.1°F resolution in print out.

TABLE 2

UNCERTAINTY ANALYSIS
SP-12A(B)-TE-1-P AND SP-12A(B)-TE-2-P
OTSG UPPER DOWNCOMER TEMPERATURE
RANGE 70 TO 570°F

Item	(±) Error	Comment

There is no information on this element. It is assumed, therefore, that it is identical to SP-3 (upper downcomer) system.

Uncertainty = ±2.2°F

TABLE 3

UNCERTAINTY ANALYSIS
PRESSURIZER SURGE LINE TEMPERATURE
RC-9 - TE-P
RANGE 0 TO 700°F
CHROMEL CONSTANTAN TC

Item	(±) Error	Comment
TC Wire[a]	3°F	
Extension Wire[a]	3°F	
Plant Computer[b]	0.6°F	
Signal Conditioning[c]	5.0°F	Estimate
Calibration[d]	1.0°F	
Installation[e]	6°F	
Wire Cold Work[f]	3°F	Estimate

Uncertainty = ± 9.5°F

a - Omega Engineering, Inc. Handbook 1985 edition specifications on wire.

b - This is the accepted value for the plant computer system.

c - This is an estimate based on the fact that no reference junctions are used and signal is sent directly to the computer. There is also error in computer simulation of the mv versus temperature curve.

d - Taken from TMI-2 instrument calibration sheets.

e - This is an estimate based on engineering judgment.

f - Estimated effect of cold working wire during installation.

TABLE 4

UNCERTAINTY ANALYSIS
PRESSURIZER TEMPERATURE

RC-2-TE1/2-P RANGE 0 TO 700°F

Item	± (Error)	Comment
RDT element[a]	1.0°F	
Calibration[b] RTD and Bridge	1.0°F	
Calibration[c]	0.7°F	
Converter[d]	1.5°F	
RTD Drift[e]	0.45°F	
Electronic Drift[f]	1°F	
Computer[g]	0.7°F	

Uncertainty = ± 2.5°F

a&b - These were taken from the Bailey Meter Company Spec found on microfische.

c - From Instrument Calibration Sheet at TMI. This is a percent of span tolerance. Resistance is input to bridge and mv is readout.

d - Bailey Meter Company Product Instructions E92-1906 for signal converter.

e - From Rosemount Engineering Company product data sheets. Says <.25°C drift per year in platinum RTD element.

f - Estimate based on engineering judgment to account for drift in electronic system.

g - Based on calculation using TMI data on computer system and a ± 0.1°F resolution in print out.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: DIRC File

From: R. D. McCormick RDM

Subject: DIRC MEETING APRIL 22, 1987 - RDMc-12-87 - Revision

A DIRC meeting was convened with R. D. McCormick, J. L. Anderson in attendance. D. W. Golden reviewed the DIRC recommendations. Items discussed were:

a. TE-HL-A and TE-HL-B. These data sets had been previously categorized. Letter RDMc-9-87 was submitted as documentation of previous decisions.

b. SP-2A-TE-(1 to 5)-P and SP-2B-TE-(1 to 5)-P. These OTSG shell temperatures had been reviewed in the last DIRC meeting but further investigation of the method of thermocouple attachment had been requested. Letter RDMc-10-87 reports on this investigation. These measurements are considered qualified with uncertainty of ± 8.1^{o}F and -30 to 0 seconds.

c. SP-12A(B)-TE, SP-3A(B)-TE, and RC-2-TE1-P. These measurements have been declared qualified with accordance of letter RDMc-11-87. SP-3A-TE1/2-P and SP-3B-TE1/2-P have uncertainties of ± 2.2^{o}F and -30 to 0 seconds. SP-12A-TE1-P, SP-12B-TE1-P, SP-12A-TE2-P, and SP-12B-TE2-P have uncertainties of ± 2.2^{o}F and -30 to 0 seconds. RC-2-TE1/2-P has an uncertainty of ± 2.5^{o}F and -30 to 0 seconds. RC-9-TE-P is declared Trend data with a qualified time of -30 to 0 sec.

d. BS-PT-4388-S. This is a composite data set. This data set was declared qualified according to information in letter JA-4-87. The uncertainty of all the data except the pressure spike is ± 0.32 psig and ± 2.2 psig at the pressure spike. The time base uncertainty is ± 1.2 minutes.

e. All reactimeter data has a time uncertainty of - 3 to +3 seconds.

f. All hourly log data has an uncertainty of ± 1.0 minutes.

g. RC-15A-TE1-M. These data are in error and the new digitized data set should be substituted. RC-15B-TE2-M should be put onto the system. These are both Trend data.

jlm

cc: J. L. Anderson
R. W. Brower
D. W. Golden
R. D. McCormick
C. L. Olaveson
R. D. McCormick File
Central File

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 11, 1987

To: D. W. Golden

From: R. D. McCormick

Subject: TMI-2 CORE THERMAL POWER INITIAL CONDITION - RDMc-17-86 - Revision

The core thermal power of TMI-2 immediately prior to the accident was 2696 ± 39 MW. The value was obtained from a calculation using the OTSG parameters, estimated system heat losses, and the RCP contribution. The attachment to this letter contains the details of the power calculation and uncertainty analysis.

jlm

Attachment:
As Stated

cc: J. L. Anderson
R. W. Brower
H. E. Knauts
P. Kuan
E. L. Tolman
Y. Nomura
R. D. McCormick File
Central File

CORE POWER CALCULATION

The calculation of reactor core thermal power is traditionally done using the secondary side parameters rather than the primary. TMI-2 used an operating procedure[1] for calculating core thermal power which contained some contribution from the primary side power. At or near 100% reactor power, however, values calculated using this procedure were virtually identical to those using only the secondary side parameters (within 0.05% in our case). Therefore, only the secondary side calculation will be shown here for simplicity. Energy losses and RCP pump contributions from the TMI-2 operating procedure[1] were used for these calculations.

The equation used to calculate core power was:

$$P = [W_{AF}(H_{AS} - H_{AF}) + W_{BF}(H_{BS} - H_{BF}) + W_{LD}(H_{BC} - H_{MU}) + C] \times 2.93 \times 10^{-7} - PE \qquad (1)$$

where

P = thermal core power (MW)

W_{AF} & W_{BF} = feedwater flowrate (lb/hr)

H_{AS} & H_{BS} = steam enthalpy (Btu/lb)

H_{AF} & H_{BF} = feedwater enthalpy (Btu/lb)

W_{LD} = letdown flowrate (lb/hr)

H_{BC} = loop B cold leg enthalpy (Btu/lb)

H_{MU} = makeup enthalpy (Btu/lb)

C = miscellaneous losses and credits

PE = RC pump power input.

CORE POWER UNCERTAINTY

The basic calculation of core thermal power after combining the two loop parameters is $p = \dot{m}\ \Delta h + c$ where c combines the system losses and gains. Since the two main feedwater loops are nearly equal in power extracted from the system, virtually no error is introduced by calculating uncertainty using this abbreviated equation. The uncertainty in percent is calculated by the root-sum-squared technique.

Parameter	Error (%)	Comment
Total feedwater mass flowrate	1.31	From OTSG analysis
Feedwater enthalpy	0.48	
Steam enthalpy	0.2	
Energy gain or loss	0.38	Estimate based on a 50% uncertainty in "C" value

Uncertainty = 1.46%

Details of the calculation are shown in the appendix. The uncertainty in the OTSG feedwater mass flowrate was taken from the OTSG uncertainty analysis. The uncertainty in enthalpies were calculated from the steam table values taken at the initial operating conditions and using the uncertainties established for the temperatures and pressures. The uncertainty in the "C" was estimated by assuming there was a 50% uncertainty. The "C" value contained all the gains and losses for the system including the letdown flow loss and the gain from the RC pumps.

REFERENCES

1. Three Mile Island Nuclear Station Unit No. 2 Operating Procedure 2103-1.10, Revision 3, April 5, 1978, Heat Balance Calculations.

APPENDIX

This appendix gives initial condition parameters used to calculate the core thermal power.

Table 1 lists the initial condition values used in the core power calculation. It also indicates through notes where the data or assumptions came from.

TABLE 1

Parameter	Symbol	Value	Origin
Feedwater, Flowrate			
Loop A	W_{AF}	5.74×10^6 lb/hr	1
Loop B	W_{BF}	5.68×10^6 lb/hr	1
Enthalpy Steam			
Loop A	H_{AS}	1253.6 Btu/lb	2
Loop B	H_{BS}	1255.6 Btu/lb	2
Enthalpy Feedwater			
Loop A	H_{AF}	446 Btu/lb	3
Loop B	H_{BF}	442.87 Btu/lb	4
Letdown Flowrate	W_{LD}	3.25×10^4 lb/hr	5
Enthalpy, Cold Leg	H_{BC}	556.19 Btu/lb	6
Enthalpy, Makeup	H_{MU}	93.58 Btu/lb	7
Misc Credit & Losses	C	1.14×10^6 Btu/hr	7
RC Pump Power	PE	16 MW	7

NOTE:

1. Flowmeter SP-8A-FT and SP-8B-FT recorded on the reactimeter.
2. Steam tables using pressure SP-6A-PT and SP-6B-PT from the reactimeter and temperature from computer hourly log.
3. Steam tables using pressure from hourly log and temperature from SP-5A-TE1 recorded on the reactimeter.
4. Steam tables using pressure from computer hourly log and Loop B temperature (~~SP-5B-TE~~) from the hourly log.
   FW-TE-131-A
5. Calculated by subtracting leakage from the makeup flowrate. Makeup flowrate was 70 gpm and leakage was estimated at 5 gpm. A multiplier of 500 was used to convert gpm to lb/hr taken from the reference one operating procedure.
6. Steam table using cold leg B temperatures (RC-5B-TE2) and pressure (RC-3B-PT) both from reactimeter.
7. Values taken from operating procedure of Reference 1.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: DIRC File

From: R. D. McCormick

Subject: QUALIFICATION OF PRIMARY COOLANT TEMPERATURES ON THE HOURLY LOG - RDMc-7-87 - Revision

The hourly log contains four cold leg temperatures and two hot leg temperatures all of which are narrow band data. I have checked these six temperatures against the reactimeter and found good agreement. An uncertainty analysis was then performed using the previous analysis for reactimeter data as a basis. The analyses are generic in that all the cold leg temperatures on the hourly log have the same uncertainty, and the two hot leg temperatures have the same uncertainties. The analyses are contained on the following two tables.

jlm

Attachment:
As Stated

cc: J. L. Anderson
R. W. Brower
D. W. Golden
R. D. McCormick File
Central File

ATTACHMENT
June 10, 1987
RDMc-7-87

TABLE I

RC HOT LEG TEMPERATURES

Uncertainty Analysis
RTD Range 520 to 620°F
RC4A-TE-1-P and RC-4B-TE1-P

Item	(±)Error	Comment
RTD element[a]	.05%	Span
Calibration[b] (RTD and Bridge)	.15%	Temp to resistance and mv
Calibration[c]	.1%	Res span to mv
Converter[d]	.15%	Accuracy span
	.15%	Linearity span
RTD drift[e]	.45%	Per year
Electronic draft[f]	1.0°F	
Print out[g]	.5°F	

$U_n = 1.13 + .5 = \pm 1.63°F$

a&b - These were taken from the Bailey Meter Company Spec found on microfische.

c - From Instrument Calibration Sheet at TMI. This is a percent of span tolerance. Resistance is input to bridge and mv is readout.

d - Bailey Meter Company Product Instruction E92-1906 for signal converter.

e - From Rosemount Engineering Company product data sheets. Says <.25°C drift per year in platinum RTD element.

f - Estimate based on engineering judgment to account for drift in electronic system.

g - Hourly log print out contains only integer numbers.

TABLE II

Uncertainty in RC Cold Leg Temperature
RC-5B-TE1-P
RC-5A-TE1-P   Range 50 to 650°F

Item	(±) Error	Comment
RTD element	0.3°F	
Calibration (RTD and Bridge)	0.15°F	
Calibration (Bridge)	0.6°F	
Converter	1.273°F	
RTD drift	0.45°F	
Electronic drift	1.0°F	
Print out	0.5°F	Hourly log

Uncertainty = 1.82 + .5 = ± 2.32°F

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: April 7, 1987

To: DIRC File

From: R. D. McCormick RDM

Subject: OTSG SHELL TEMPERATURE UNCERTAINTY - RDMc-10-87

The OTSG shell temperature measurement has been analyzed to determine its uncertainty. The transducers were Chromel-Constantan sheathed thermocuoples which were welded to metal tabs which were in turn welded to the OTSG shell outer surface. Since the OTSG is insulated there should be only a small measurment error due to radiation and conduction losses. The electrical signal went directly to the plant computer, not going to a reference junction or to a signal conditioner.

jlm

Attachment:
Table on Uncertainty Analysis

cc: J. L. Anderson
R. W. Brower
D. W. Golden
R. D. McCormick File
Central File

ATTACHMENT
RDMc-10-87
April 3, 1987

UNCERTAINTY ANALYSIS

SP-2A-TE1 TO TE5
SP-2B-TE1 TO TE5
Range 70 TO 600°F
OTSG Shell Temperature
Chromel-Constantan Thermocouple

Item	(±) Error	Comment
TC Wire[a]	3°F	
Extension Wire[a]	3°F	
Plant Computer	0.6°F	Accepted value
Signal Conditioning[b]	5°F	Estimate
Calibration[c]	3°F	
Installation	2°F	Estimate
Wire Cold Work[d]	3°F	

$U_n = \pm 8.1°F$

[a] Omega Engineering, Inc. Handbook, 1985 Edition and TMI-2 instrument calibration sheets.

[b] This is an estimate. The extension wire goes to the computer where all signal conditoning is done. Errors could be due to lack of a reference junction and to simulation of mv versus temperature curve.

[c] From TMI-2 Instrument Calibration Sheets tolerance of error.

[d] This is an engineering estimate of errors possible due to cold working of the TC and extension wire during installation.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 10, 1987

To: DIRC File

From: R. D. McCormick

Subject: HOT LEG TEMPERATURES TO 1000 MINUTES - RDMc-9-87 - Revision

The hot leg temperature data files TE-HL-A and TE-HL-B are composites which are made up from reactimeter and stripchart data. The reactimeter channels had a temperature range from 520°F to 620°F. During the time that the hot leg temperatures exceeded these limits, temperature data were taken from stripchart MP-010 (YM-TR-1922). The stripchart data files are RC-15A-TE1-M (pin 6) and RC-15B-TE1-M (pin 5). The attached Tables 1 and 2 list the times and corresponding data sources for the two composite data files. The quality categories of the hot leg reactimeter and stripchart data have been determined and reported in letter RDMc-7-86; i.e., the reactimeter data are "qualified" and the stripchart data "trend". The stripchart data as recorded was adjusted for errors found in amplitude and time. Table 3 gives details of the adjustments made to the stripchart data. The composite data on the TMI-2 data base was truncated at 300 minutes.

A new file has been made up of MP-010 pin 8 data. All data from MP-010 is "trend".

jlm

Attachments:
As Stated

cc: J. L. Anderson
R. W. Brower
D. W. Golden
Y. Nomura
R. D. McCormick File
Central File

ATTACHMENT
June 10, 1987
RDMc-9-87

TABLE 1

COMPOSITE A-LOOP HOT LEG TEMPERATURE

TE-HL-A

Time (min)	Data Source
-15.0 to 130.50	RC-4A-TE1-R
132.6 to 135.1	RC-15A-TE1-M
135.75 to 141.85	RC-4A-TE1-R
142.3 to 624.5	RC-15A-TE1-M
626.20 to 635.55	RC-4A-TE1-R
639.40 to 806.30	RC-4A-TE1-R
807.6	RC-15A-TE1-M
807.05 to 932.60	RC-4A-TE1-R
935.3 to 950	RC-15A-TE1-M

TABLE 2

COMPOSITE B-LOOP HOT LEG TEMPERATURE

TE-HL-B

Time (min)	Data Source
-15.0 to 121.4	RC-4B-TE1-R
123.15 to 149.2	RC-4B-TE1-R
149.5 to 949.9	RC-15B-TE1-M
950.25	RC-4B-TE1-R
952 to 1000	RC-15B-TE1-M

TABLE 3

CORRECTIONS MADE TO STRIPCHART DATA

Data Source	Amplitude Adjustment	Time Base Adjustment
RC-15A-TE1-M	-11.0°F	x 0.9642
RC-15B-TE1-M	+7°F	x 0.9642
RC-15B-TE2-M	-15°F	x 0.9642

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: July 18, 1986

To: Distribution

From: R. D. McCormick RDM

Subject: REVIEW OF DATA FOR STANDARD PROBLEM - RDMc-9-86

A Data Integrity Review Committee meeting is being held at 8:00 a.m. on Thursday, July 24 in Room 122, TSA. This meeting is a continuation of the one on July 16 where the agenda was not completed.

jlm

Distribution
J. L. Anderson
R. W. Brower
L. D. Goodrich
H. E. Knauts
R. D. McCormick
Y. Nomura
R. D. McCormick File
Central File

INTEROFFICE CORRESPONDENCE

Date: August 28, 1986

To: Distribution

From: D. W. Golden

Subject: PRESSURIZER SPRAY VALVE OPERATION - DWG-5-86

The reactimeter and other data for the pressurizer spray valve operation times has been reviewed. Prior to the turbine trip the spray valve was in manual control as part of the effort to control boron concentration. After the turbine trip the spray valve was placed in automatic control (approximately .13 minutes). At 0.2 minutes ± 0.05 minutes the reactimeter data indicates that the spray valve was ordered to close. Figure 1 shows the reactimeter actuation indication for the spray valve and primary system pressure calibrated 0.05 minutes). At 0.2 minutes primary pressure has decreased to the spray valve close set point of 2155 psig. Therefore, it is concluded that at 0.2 minutes the reactimeter correctly indicated the actuation signal sent to the spray valve.

Between 0.6 and 11 minutes the reactimeter indicates cycling of the spray valve actuation signal, Figure 2. The primary system pressure, Figure 3, does not suggest that the spray valve would actuate during this time period. Review of the Sequence of Events (SOE) data base does not indicate the operators placed the spray valve in manual control and cycled it. A comparison of the turbine trip, reactor trip and spray valve actuation signals as recorded by the reactimeter are shown in Figure 4. This figure shows a coincidence of the use to 10 volts at 0.6 minutes and the drop at 0.8 minutes. This trend continues throughout the first 11 minutes and this behavior disappears after 11 minutes. It is likely that another contact closer signal which was indeed cycling during the first 11 minutes was crosstalking with these channels. The most likely candidates for this are MS-25A and MS-25B, air operated control valves. However, the data to verify this is not in hand. The reactimeter patch panel log does not provide any information on/off signals and the only data we have for on/off signals during the accident are for the above three measurements.

Although there is uncertainty, it is within engineering judgment to conclude that there were no actuation signals sent to the spray valve from 0.6 to 11 minutes.

At 174 minutes the SOE indicates that the operators took manual control of the spray valve and opened it to stem the rapid primary system pressure rise. The reactimeter data at 175 minutes verifies the actuation signal. The review of the SOE and reactimeter data (Figure 5) indicates the operators did attempt to operate the spray in the manual mode at various time to 1000 minutes.

A summary of the actuation signal times is provided in Table 1. The basic uncertainty in these data is the sampling rate of 0.05 minutes. After 0.2 minutes there is an additional uncertainty associated with decimating the file to an effective sample rate of 0.4 minutes to read the file. Therefore, between 0 and 0.2 minutes the total uncertainty is ± 0.5 minutes. After 0.2 minutes the total uncertainty is $\pm \sqrt{.05^2 + 44^2} \simeq \pm 0.4$ minutes.

jlm

Attachments:
As Stated

Distribution
J. L. Anderson
R. W. Brower
L. D. Goodrich
H. E. Knauts
R. D. McCormick
Y. Nomura
A. Takizawa

cc: J. M. Broughton
D. W. Golden
Central File

TABLE 1

SPRAY VALVE OPERATION TIMES

Time (min)	Position
0.0	OPEN
0.20	CLOSED
175.0	OPENED
193.4	CLOSED
225.2	OPENED
261.4	CLOSED
478.2	OPENED
547.0	CLOSED
604.6	OPENED
725.4	CLOSED
1110.2	OPENED
1111.0	CLOSED
1131.0	OPENED
1132.6	CLOSED
1152.6	OPENED
1153.4	CLOSED
1195.8	OPENED
1196.6	CLOSED

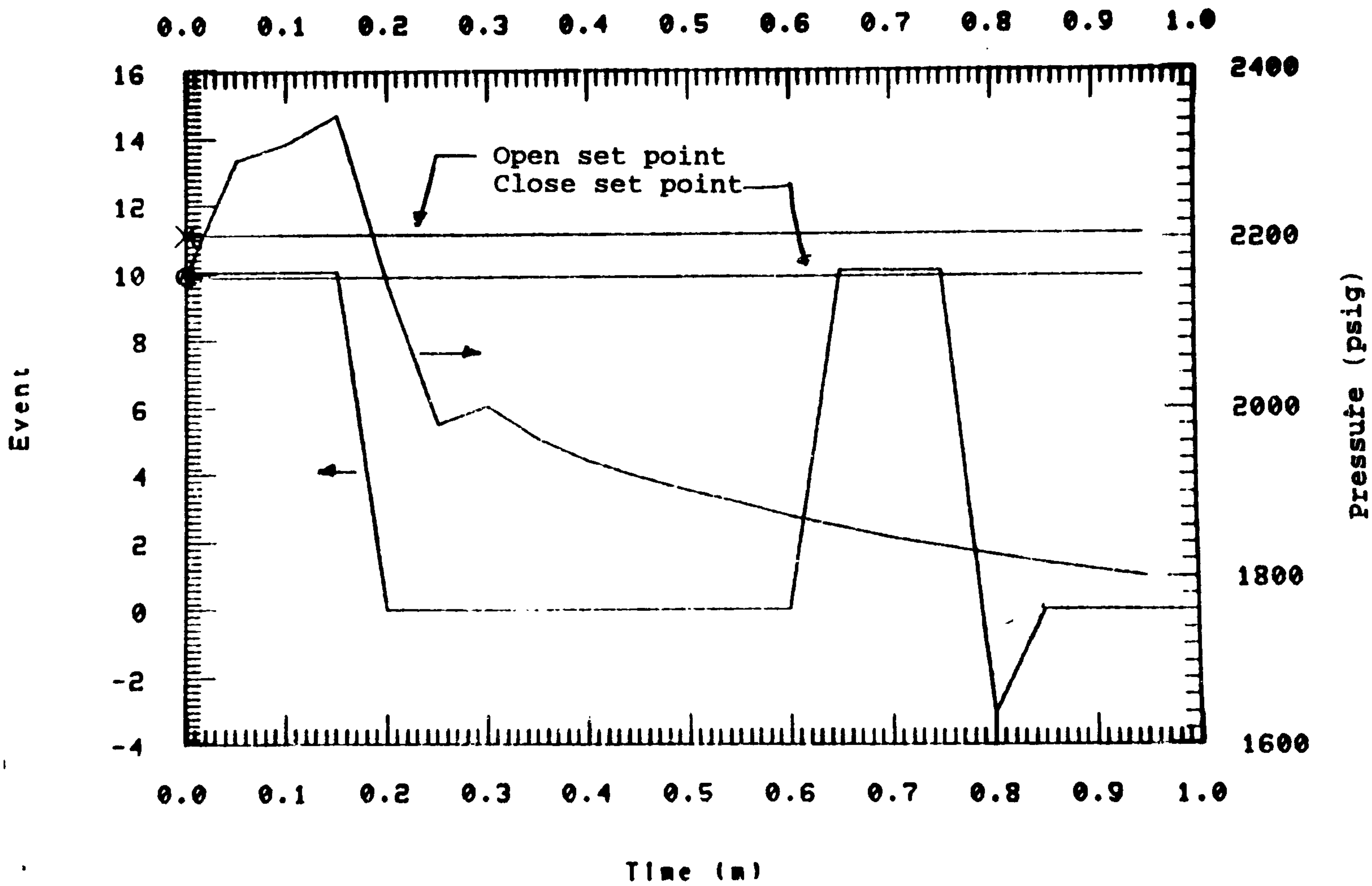

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
16 14 12 10 8 6 4 2 0 -2 -4
2400 2200 2000 1800 1600
Open set point
Close set point
Event
Pressure (psig)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Time (m)

Figure 1.

1 RC-VI-R

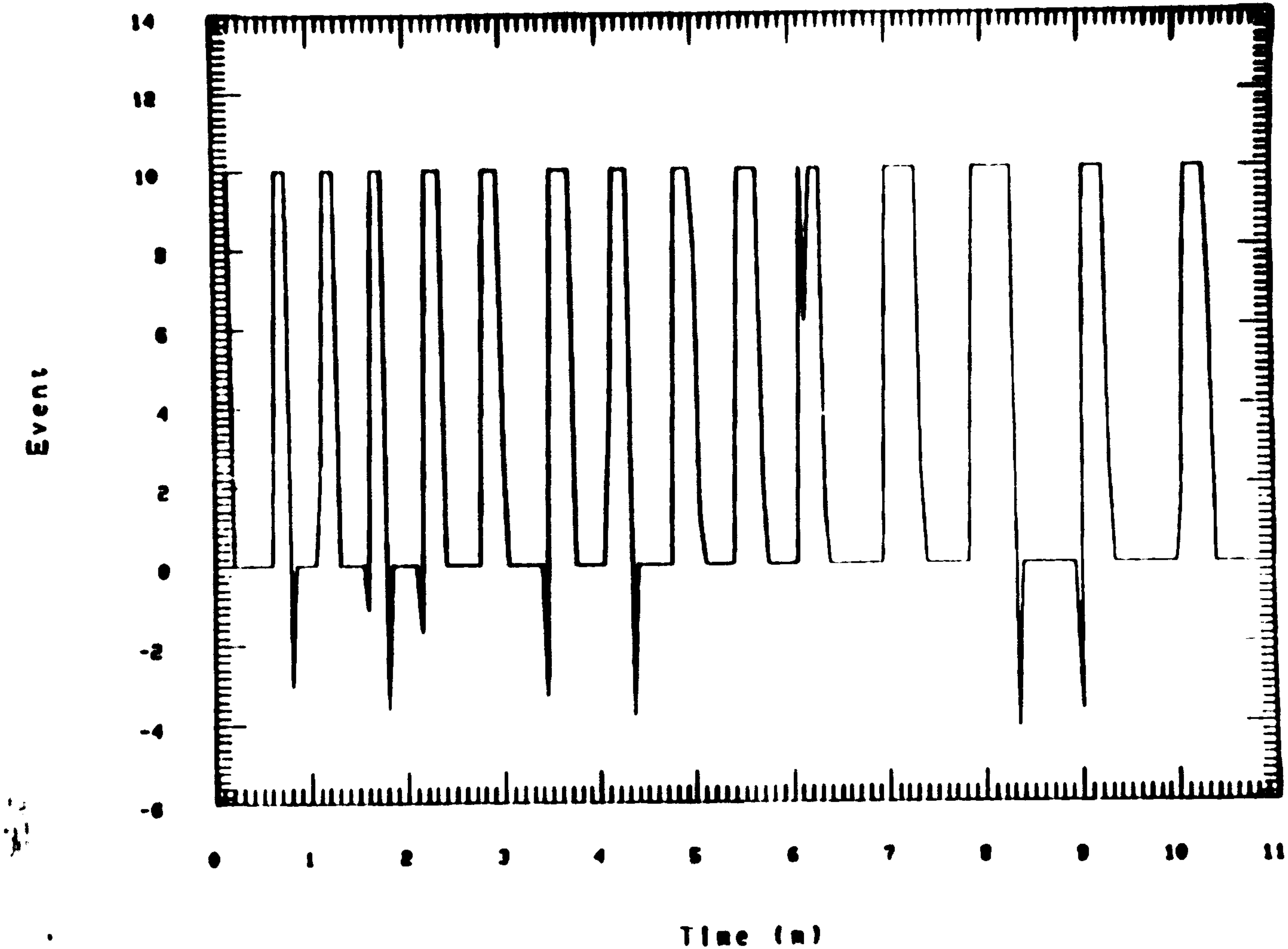
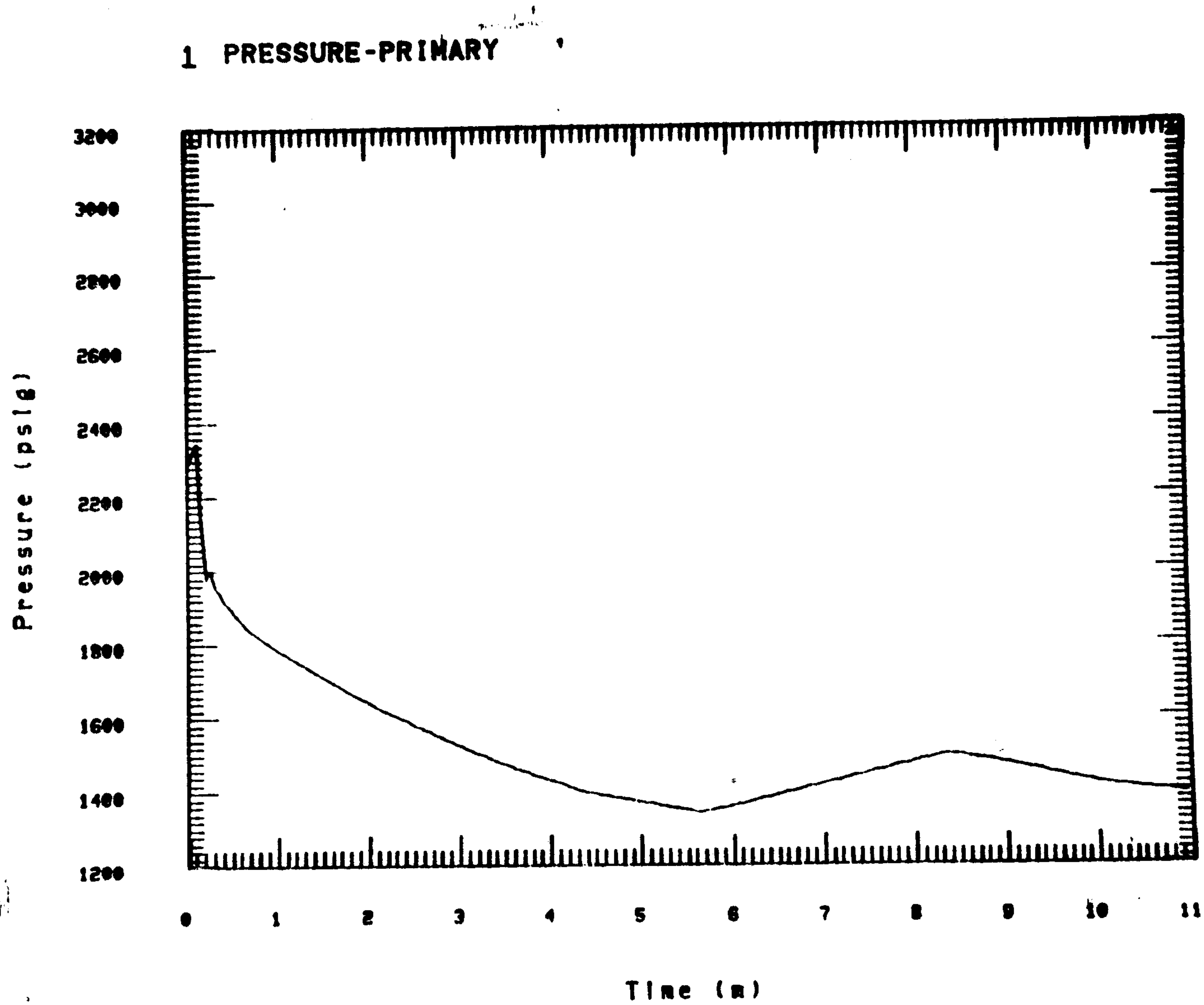


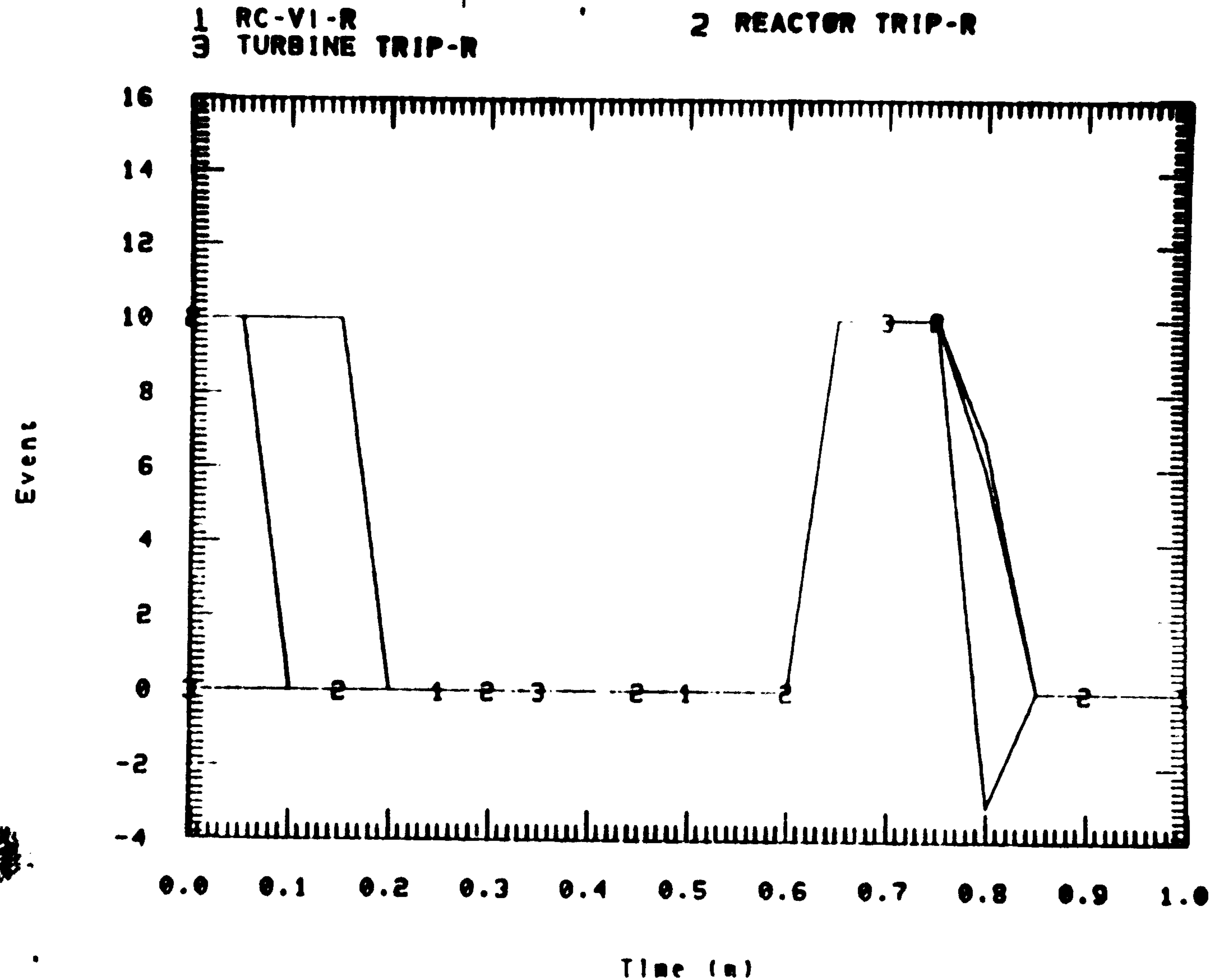
Figure 2.

E-149



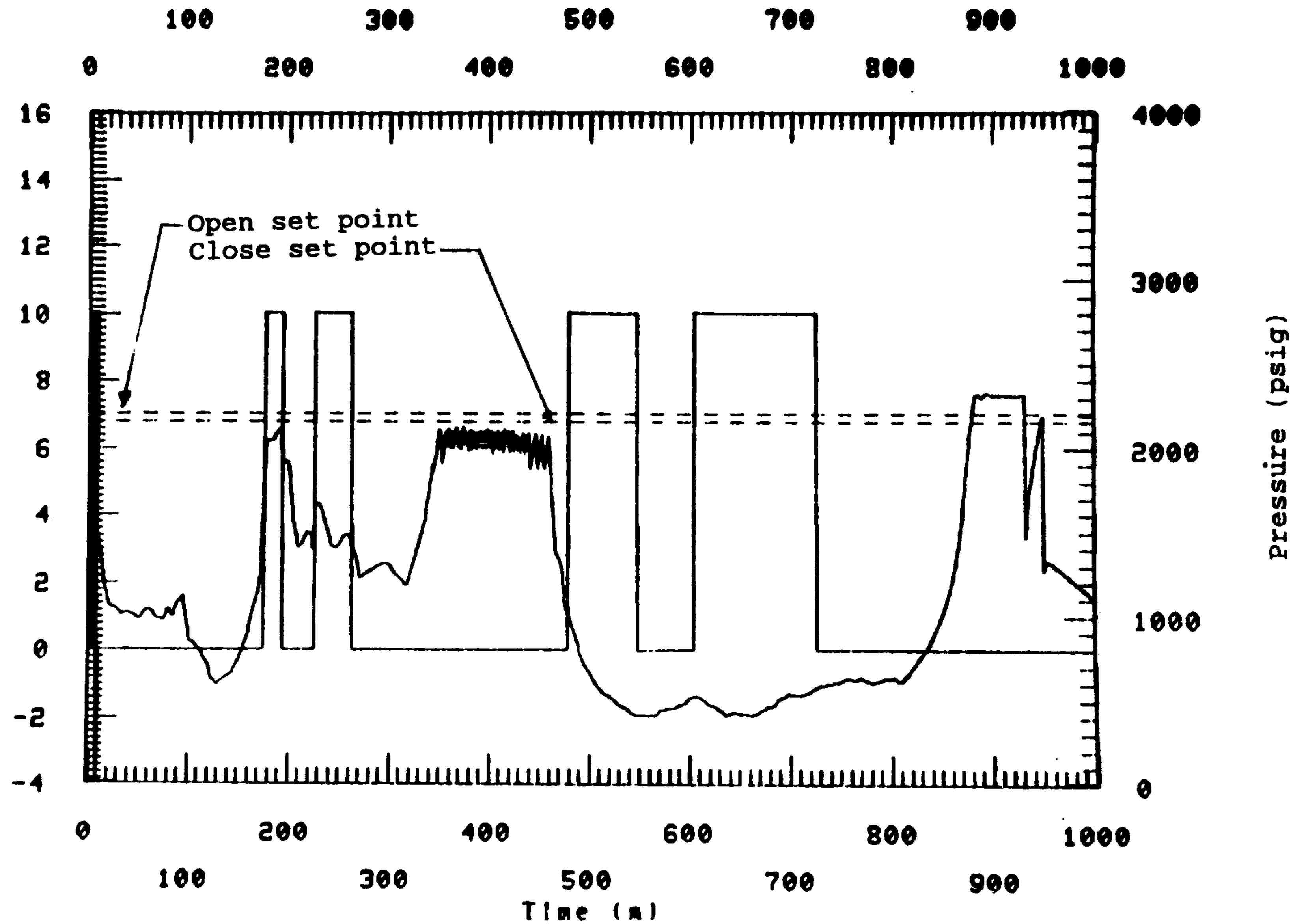
Primary pressure

Figure 3.



NOT REVIEWED

Figure 4.



NØT REVIEWED

Figure 5.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: September 5, 1986

To: Distribution

From: D. W. Golden

Subject: PORV/PROV BLOCK VALVE OPERATION TIMES FINAL QUALIFICATION DOCUMENT - DWG-7/86

Attached is the final qualification document for the operation times of the PORV/PORV block valve. Based on the DIRC meeting of August 20, 1986, these data are considered qualified to the level of uncertainty indicated.

jlm

Attachment:
As Stated

Distribution
J. L. Anderson
R. W. Brower
L. D. Goodrich
H. E. Knauts
R. D. McCormick
Y. Nomura
A. Takizawa

cc: J. M. Broughton
D. W. Golden
Central File

OPERATION OF THE PORV AND PORV BLOCK VALVE

1 PORV OPENING TIME

The time at which the PORV first opened is indicated by the primary pressure. between the time of turbine trip and scram there are are only two data samples on the reactimeter (0.05 and 0.10 minutes). at 0.05 minutes the slope of the increasing primary pressure decreases, Figure 1. This can be taken as the point at which the PORV opened. At this time the primary pressure is measured to be 37.5 psi above the PORV nominal set point (2255 psig). Thus it is quite possible that the PORV opened earlier than .05 minutes. However, from the data one cannot infer an opening time to a scale finer than the reactimeter sampling rate (0.05 minutes). Thus the uncertainty in the opening time is ±0.05 minutes.

2 Block valve operating times

The first closure of the PORV block valve is generally taken to have occurred at 139 minutes. Evidence of closure is not indicated by either the primary or secondary systems thermal hydraulic data. The indications of block valve closure is the reactor building pressure. Figure 2 shows the reactor coolant drain tank pressure (WDL-PT-1202-R) from the reactimeter and the digitized reactor building pressure (BS-PR-4388-N-S). Reactor building pressure has been pinned to the to the drain tank rupture disk failure. The stated block valve closure time of 139 minutes is supported by the sharp drop in reactor building pressure between 138.2 and 139.7 minutes. The sample rate for digitizing the reactor building pressure was 1.5 minutes. therefore the uncertainty in timing is taken to be ±1.5 minutes.

Operation of the PORV block valve for the remainder of the transient can be taken from EGG-TMI-7100. These times, through 318 minutes are given in Table 1. Although these times are based on reactimeter data there is an additional uncertainty associated with round off in the table. The round off uncertainty is ±0.5 minutes for those cases cases reported to the nearest minute. the total uncertainty for these cases based on rss is ±0.5 minutes.

Table 1. PORV block valve operation

time (min)	Operation
139 ±0.5	closed
191.6 ±0.05	opened
194.8 ±0.05	closed
197.9 ±0.05	opened
198.4 ±0.05	closed
220 ±0.5	opened
260 ±0.5	closed
276 ±0.5	opened
318 ±0.5	closed

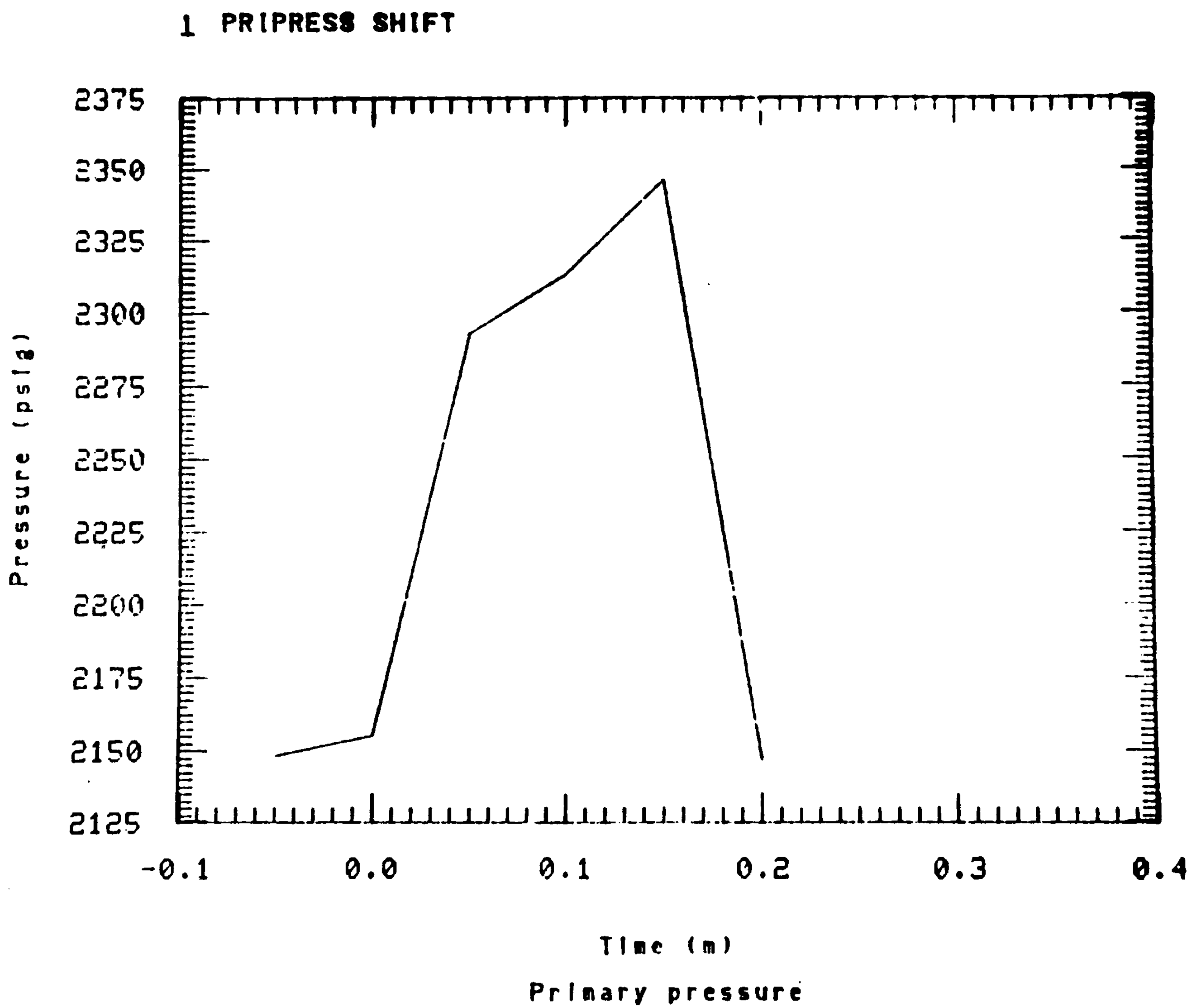
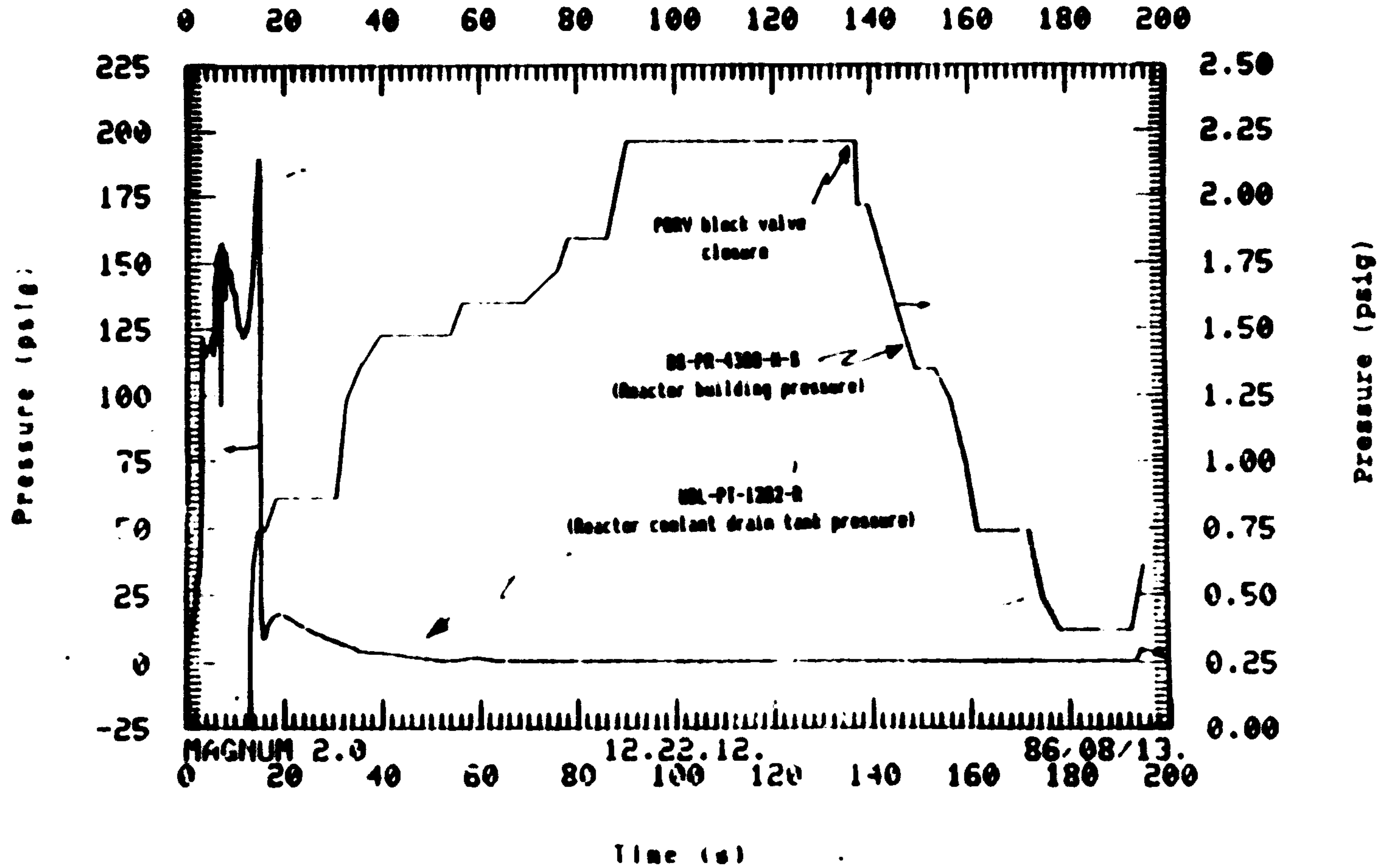


Figure 1. Primary system pressure shifted 0.05 seconds.



NOT REVIEWED

Figure 2. PORV block valve closure inferred from reactor building pressure.

3/19

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
AFW-SG-A	Auxiliary Feedwater Secondary Injection Rate. Based upon secondary mass inventory -Steam Generator A	Steam Generator A	EST TREND	0 - 135 lbm/s	
AFW-SG-B	Auxiliary Feedwater Secondary Injection Rate. Based upon secondary mass inventory -Steam Generator B	Steam Generator B	EST TREND	0 - 135 lbm/s	
AH-TE-5011-M	Ambient Temperature, Letdown Cooler Area	Reactor Building	QUAL/TREND	0 - 200 F	2.7 or 3.3 F
AH-TE-5012-M	Ambient Temperature, Drain Tank Area	Reactor Building	QUAL/TREND	0 - 200 F	2.7 or 3.3 F
BS-PR-4388-N-S	Reactor Building Pressure - Narrow Range	Reactor Building	QUALIFIED	-5 - 10 psig	0.32 psig
BS-PR-4388-W-S	Reactor Building Pressure - Wide Range	Reactor Building	QUALIFIED	0 - 100 psig	2.15 psig
BS-PT-4388-S	Reactor Building Composite Air Pressure	Reactor Building	QUALIFIED	-5 - 100 psig	.32&2.15psig
DC-R-3399-M	Decay Heat Closed A Loop Radiation Monitor	Decay Heat	TREND	10 - 10E+6 CPM	
DC-R-3400-M	Decay Heat Closed B Loop Radiation Monitor	Decay Heat	TREND	10 - 10E+6 CPM	
FW-TE-1131-P	Feedwater Heater B Outlet Temperature	Feedwater B	QUALIFIED	0 - 800 F	2.2 deg F
FW-TE-1134-P	Feedwater Heater A Outlet Temperature	Feedwater A	QUALIFIED	0 - 800 F	2.2 deg F
HP-R-207-M	Intermediate Cooling Pump Area Radiation Monitor - in the Auxiliary Building	Aux Building	TREND	0.1 - 10E+4 mR/Hr	
HP-R-219-G-M	Station Vent Radiation Monitor - Gas	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-222-G-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Upstream of Filter - Gas	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-222-I-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Upstream of Filter - Iodine	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-222-P-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Upstream of Filter - Particulate	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-225-G-M	Reactor Building Purge Air Exhaust, Duct A, Radiation Monitor - Gas	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-225-I-M	Reactor Building Purge Air Exhaust, Duct A, Radiation Monitor - Iodine	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-225-P-M	Reactor Building Purge Air Exhaust, Duct A, Radiation Monitor - Particulate	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-226-G-M	Reactor Building Purge Air Exhaust, Duct B, Radiation Monitor - Gas	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-226-I-M	Reactor Building Purge Air Exhaust, Duct B, Radiation Monitor - Iodine	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-226-P-M	Reactor Building Purge Air Exhaust, Duct B, Radiation Monitor - Particulate	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-228-G-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Downstream of Filter - Gas	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-228-I-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Downstream of Filter - Iodine	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-228-P-M	Auxiliary Building Purge Air Exhaust Radiation Monitor, Downstream of Filter - Particulate	Aux Building	TREND	10 - 10E+6 CPM	
HP-R-229-G-M	Hydrogen Purge Radiation Monitor - Gas	Reactor Building	TREND	10 - 10E+6 CPM	
HP-R-3236-M	Reactor Building Purge Unit Area Radiation Monitor	Reactor Building	TREND	0.1 - 10E+4 mR/Hr	
HP-R-3238-M	Auxiliary Building Exhaust Unit Area Radiation Monitor	Aux Building	TREND	0.1 - 10E+4 mR/Hr	
HP-R-3240-M	Fuel Handling Exhaust Unit Area Radiation Monitor	Fuel Handling Building	TREND	0.1 - 10E+4 mR/Hr	

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
HPI-MUP1	HPI/Makeup Estimate Based on Expected Results, from a mass balance analysis of the Primary System	Makeup/Letdown	EST TREND	0 - 140 lbm/s	
IC-R-1091-M	Intermediate Coolant Letdown, Cooler B Radiation Monitor	RC	TREND	10 - 10E+6 CPM	
IC-R-1092-M	Intermediate Coolant Letdown, Cooler A Radiation Monitor	RC	TREND	10 - 10E+6 CPM	
IC-R-1093-M	Intermediate Coolant Letdown, Inlet Radiation Monitor	RC	TREND	10 - 10e+6 CPM	
LETDOWN FLOW	Letdown Cooler Volumetric Flowrate	Makeup/Letdown	QUALIFIED	0 - 45 lbm/s	24.6% Read.
MS-TE-103-M	Steam Generator B2 Outlet Temperature	Steam Generator B	TREND	0 - 400 F	
MS-TE-109-M	Steam Generator A2 Outlet Temperature	Steam Generator A	TREND	0 - 400 F	
MU-R-720H-M	Primary Coolant Letdown HI Radiation Monitor	Makeup/Letdown	TREND	10 - 10E+6 CPM	
MU-R-720L-M	Primary Coolant Letdown LO Radiation Monitor	Makeup/Letdown	TREND	10 - 10E+6 CPM	
MU-TE-739-M	Letdown Cooler 1A Outlet Temperature	Makeup/Letdown	QUALIFIED	0 - 400 F	10% Reading
MU-TE-740-M	Letdown Cooler 1B Outlet Temperature	Makeup/Letdown	QUALIFIED	0 - 400 F	10% Reading
NI-ND-1-P	Source Range Power Level	RV	QUALIFIED	0.1 - 10E+6 CPS	
NI-ND-1-S	Source Range Power Level	RV	QUALIFIED	0.1 - 10E+6 CPS	
NI-ND-2-P	Source Range Power Level	RV	QUALIFIED	0.1 - 10E+6 CPS	
NI-ND-3-S	Intermediate Range Power Level	RV	TREND	10E-11 - 10E-3 Amps	
NI-ND-4-S	Intermediate Range Power Level	RV	TREND	10E+11 - 10E+3 Amps	
PCP1A	Primary Coolant Pump 1A (Start/Stop Times), Binary Function	RC-A	TREND	OFF/ON	
PCP1B	Primary Coolant Pump 1B (Start/Stop Times), Binary Function	RC-B	TREND	OFF/ON	
PCP2A	Primary Coolant Pump 2A (Start/Stop Times), Binary Function	RC-A	TREND	OFF/ON	
PCP2B	Primary Coolant Pump 2B (Start/Stop Times), Binary Function	RC-B	TREND	OFF/ON	
PORV FLOW RATE	Discharge Flow Rate Through the Pressurizer PORV - Calculated Parameter	Pressurizer	QUALIFIED	0 - 240 lbm/s	20% Reading
PRESS.-PRIMARY	Reactor Coolant Composite Pressure	RC	QUALIFIED	0 - 2500 psig	40 psi (MAX)
PRESSURE UNC	Primary System Pressure Uncertainty, Discontinuous Function	RC			
RC-1-LT1-L-R	Pressurizer Level	Pressurizer	QUALIFIED	0 - 400 in/H2O	24 in
RC-14A-FT-CALC	Calculated Loop A Mass Flow Rate	RC-A	QUALIFIED	0 - 90 MPPH	see Unc. chn
RC-14A-FT-UNC-L	Lower Uncertainty of Function RC-14A-FT-CALC				
RC-14A-FT-UNC-U	Upper Uncertainty of Function RC-14A-FT-CALC				
RC-14B-FT-CALC	Calculated Loop B Mass Flow Rate	RC-B	QUALIFIED	0 - 90 MPPH	see Unc. chn
RC-14B-FT-UNC-L	Lower Uncertainty of Function RC-14B-FT-CALC				
RC-14B-FT-UNC-U	Upper Uncertainty of Function RC-14B-FT-CALC				
RC-15A-TE1-M	Hot Leg Temperature - Loop A : Wide Range (Elev. 355'2")	RC-A	TREND	0 - 800 F	
RC-15A-TE3-M	Cold Leg Temperature - Pump 2A Inlet : Wide Range (Elev. 310'2")	RC-A	TREND	0 - 800 F	

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
RC-15B-TE1-M	Hot Leg Temperature - Loop B : Wide Range	RC-B	TREND	0 - 800 F	
RC-15B-TE2-M	Cold Leg Temperature - Pump 1B Inlet : Wide Range	RC-B	TREND	0 - 800 F	
RC-15B-TE3-M	Cold Leg Temperature - Pump 2B Inlet : Wide Range (Elev. 310'2")	RC-B	TREND	0 - 800 F	
RC-2-TE1/2-P	Pressurizer Temperature	Pressurizer	QUALIFIED	0 - 700 F	2.5 deg F
RC-3A-PT3-P	Reactor Coolant Pressure - Loop A : Wide Range	RC-A	QUALIFIED	0 - 2500 psig	29 psi
RC-3A-PT3-S	Reactor Coolant Pressure - Loop A : Wide Range	RC-A	QUALIFIED	0 - 2500 psig	39.7 psi
RC-3B-PT1-R	Reactor Coolant Pressure - Loop B : Narrow Range	RC-B	QUALIFIED	1700 - 2500 psig	10.9 psi
RC-4A-TE1-R	Hot Leg Temperature - Loop A : Narrow Range (Elev. 352'8")	RC-A	QUALIFIED	520 - 620 F	1.14 deg F
RC-4A-TE1/4-P	Hot Leg Temperature - Loop A : Narrow Range	RC-A	QUALIFIED	520 - 620 F	1.63 deg F
RC-4B-TE1-R	Hot Leg Temperature - Loop B : Narrow Range (Elev. 352'8")	RC-B	QUALIFIED	520 - 620 F	1.14 deg F
RC-4B-TE1/4-P	Hot Leg Temperature - Loop B : Narrow Range	RC-B	QUALIFIED	520 - 620 F	1.63 deg F
RC-5A-TE1-P	Cold Leg Temperature - Pump 1A Inlet : Narrow Range (Elev. 310'2")	RC-A	QUALIFIED	520 - 620 F	2.32 deg F
RC-5A-TE2-R	Cold Leg Temperature - Pump 1A Inlet : Wide Range	RC-A	QUALIFIED	50 - 650 F	1.91 deg F
RC-5B-TE1-P	Cold Leg Temperature - Pump 1B Inlet : Narrow Range (Elev. 310'2")	RC-B	QUALIFIED	520 - 620 F	2.32 deg F
RC-5B-TE2-R	Cold Leg Temperature - Pump 1B Inlet : Wide Range	RC-B	QUALIFIED	50 - 650 F	1.91 deg F
RC-9-TE-P	Pressurizer Surge Line Temperature	Pressurizer	TREND	0 - 700 F	
RC-V1-R	Pressurizer Spray Valve Position, Binary Function, ICBC name is Spray Valve	Pressurizer	QUALIFIED	Open - Closed	N. A.
RC-V2	Pressurizer Block Valve Position (Open/Closed), Binary Function, ICBC name is Block Valve	RC	QUALIFIED	Open - Closed	N. A.
SF-R-3402-M	Spent Fuel Cooling Area Radiation Monitor	Spent Fuel	TREND	10 - 10E+6 CPM	
SG-A-LEVEL	Steam Generator A - Composite Level	Steam Generator A	QUALIFIED	5.9 - 394 in	9 in
SG-B-LEVEL	Steam Generator B - Composite Level	Steam Generator B	QUALIFIED	5.9 - 394 in	9 in
SP-10A-PT1-R	Turbine Header Pressure - Loop A	Steam Generator A	QUALIFIED	600 - 1200 psig	8.2 psi
SP-12A-TE1-P	Steam Generator A - Upper Downcomer Temperature	Steam Generator A	QUALIFIED	70 - 570 F	2.2 deg F
SP-12A-TE2-P	Steam Generator A - Upper Downcomer Temperature	Steam Generator A	QUALIFIED	70 - 570 F	2.2 deg F
SP-12B-TE1-P	Steam Generator B - Upper Downcomer Temperature	Steam Generator B	QUALIFIED	70 - 570 F	2.2 deg F
SP-12B-TE2-P	Steam Generator B - Upper Downcomer Temperature	Steam Generator B	QUALIFIED	70 - 570 F	2.2 deg F
SP-2A-TE1-P	Steam Generator A - Shell Temperature	Steam Generator A	QUALIFIED	70 - 600 F	8.1 deg F
SP-2A-TE2-P	Steam Generator A - Shell Temperature	Steam Generator A	QUALIFIED	70 - 600 F	8.1 deg F
SP-2A-TE3-P	Steam Generator A - Shell Temperature	Steam Generator A	QUALIFIED	70 - 600 F	8.1 deg F
SP-2A-TE4-P	Steam Generator A - Shell Temperature	Steam Generator A	QUALIFIED	70 - 600 F	8.1 deg F
SP-2A-TE5-P	Steam Generator A - Shell Temperature	Steam Generator A	QUALIFIED	70 - 600 F	8.1 deg F
SP-2B-TE1-P	Steam Generator B - Shell Temperature	Steam Generator B	QUALIFIED	70 - 600 F	8.1 deg F
SP-2B-TE2-P	Steam Generator B - Shell Temperature	Steam Generator B	QUALIFIED	70 - 600 F	8.1 deg F
SP-2B-TE3-P	Steam Generator B - Shell Temperature	Steam Generator B	QUALIFIED	70 - 600 F	8.1 deg F
SP-2B-TE4-P	Steam Generator B - Shell Temperature	Steam Generator B	QUALIFIED	70 - 600 F	8.1 deg F
SP-2B-TE5-P	Steam Generator B - Shell Temperature	Steam Generator B	QUALIFIED	70 - 600 F	8.1 deg F
SP-3A-TE1/2-P	Steam Generator A - Downcomer Temperature	Steam Generator A	QUALIFIED	0 - 600 F	2.2 deg F
SP-3B-TE1/2-P	Steam Generator B - Downcomer Temperature	Steam Generator B	QUALIFIED	0 - 600 F	2.2 deg F
SP-4A-TE-P	Steam Generator A - Main Steam Temperature	Steam Generator A	QUALIFIED	100 - 650 F	2.1 deg F
SP-4B-TE-P	Steam Generator B - Main Steam Temperature	Steam Generator B	QUALIFIED	100 - 650 F	2.1 deg F
SP-5A-TE1/2-R	Feedwater Temperature	Feedwater	QUALIFIED	0 - 500 F	1.78 deg F

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
SP-6A-PT1-P	Steam Generator A - Steam Pressure in Steam Line A1 or A2	Steam Generator A	QUALIFIED	0 - 1200 psig	14.0 psi
SP-6A-PT1-R	Steam Generator A - Steam Pressure	Steam Generator A	QUALIFIED	0 - 1200 psig	16.1 psi
SP-6B-PT1-R	Steam Generator B - Steam Pressure	Steam Generator B	QUALIFIED	0 - 1200 psig	16.1 psi
SP-8A-FI-R	Main Feedwater Flow Rate - Loop A Steam Generator	Feedwater A	QUALIFIED	0 - 6.5 MPPH	.106 Mlb/hr
SP-8B-FI-R	Main Feedwater Flow Rate - Loop B Steam Generator	Feedwater B	QUALIFIED	0 - 6.5 MPPH	.106 Mlb/hr
TE-HL-A	Reactor Coolant Composite Hot Leg Temperature Loop A	RC-A	QUAL/TREND	0 - 800 F	1.14 deg F
TE-HL-B	Reactor Coolant Composite Hot Leg Temperature - Loop B	RC-B	QUAL/TREND	0 - 800 F	1.14 deg F
TSAT PRIMARY	Reactor Coolant Saturation Temperature - Calculated from composite primary pressure, PRESS.-PRIMARY	RC	QUALIFIED	212 - 670 F	4.8 deg F
TSAT-SG-A	Saturation Temperature Calculated from Secondary Pressure (SP-6A-PT1-R), Steam Generator A	Steam Generator A	QUALIFIED	212 - 567 F	5.5 deg F
TSAT-SG-B	Saturation Temperature Calculated from Secondary Pressure (SP-6B-PT1-R), Steam Generator B	Steam Generator B	QUALIFIED	212 - 567 F	5.5 deg F
WDL-PT-1202-R	Reactor Coolant Drain Tank (RCDT) Pressure	Pressurizer	QUALIFIED	0 - 250 psig	3.9 psi
WDL-R-1311-M	Plant Effluent Radiation Monitor, Unit 2	Discharge	TREND	10 - 10E+6 CPM	
WDL-TE-1200-P	Reactor Coolant Drain Tank (RCDT) Temperature	Pressurizer	QUALIFIED	0 - 250 F	1.7 deg F
WGD-R-1480-G-M	Waste Gas Discharge Duct Radiation Monitor - Gas	Waste Gas	TREND	10 - 10E+6 CPM	

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
AH-1923-TE-M	Outside Air Elevation Delta Temperature	Plant	NOT REVIEWED	-7 - 19 F	
AH-TE-5010-M	Ambient Temperature, Sump Area	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5013-M	Ambient Temperatue, Impingement Room	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5014-M	Ambient Temperature, Column R4	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5015-M	Temperature of Supply Air, Column R19, Outlet Plenum, East	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5020-M	Ambient Temperature, East, Outside Secondary Shield Wall at column R15	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5021-M	Ambient Temperature, West, Outside Secondary Shield Wall at column R7	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5022-M	Ambient Temperature, Column R16A	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5023-M	Ambient Temperature, Column R5	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5027-M	Temperature of the Supply Air, Column R1, Outlet Plenum, West	Reactor Building	NOT REVIEWED	0 - 200 F	
AH-TE-5088-M	Ambient Temperature, Between Columns R17A and R18A	Reactor Building	NOT REVIEWED	0 - 200 F	
BS-PR-1412-W-S	Reactor Building Pressure - Wide Range	Reactor Building	NOT REVIEWED	0 - 100 psig	
CRDM-3398-TE-M	Control Rod Drive Motor Temperature	RV	NOT REVIEWED	0 - 200 F	
DC-R-3401-M	Nuclear Service Closed Cooling Radiation Monitor	Decay Heat	NOT REVIEWED	10 - 10E+6 CPM	
EF-PT-1147-P	Emergency Feedwater Pump 2A Discharge Pressure	Feedwater	NOT REVIEWED		
EF-PT-1150-P	Emergency Feedwater Pump 2B Discharge Pressure	Feedwater	NOT REVIEWED		
EF-PT-826-P	Emergency Feedwater Pump 1 Discharge Pressure	Feedwater	NOT REVIEWED		
FC-WTP-XXX-S	Waste Transfer Pump Discharge Flow	Waste	NOT REVIEWED	0 - 100 GPM	
FW-P-1A-S	Main Feedwater Pump Speed & Governor Valve Position	Feedwater A	NOT REVIEWED	0 - 100% RPM	
FW-P-1B-S	Main Feedwater Pump Speed & Governor Valve Position	Feedwater B	NOT REVIEWED	0 - 100% RPM	
FW-P1A-VE-S	Main Feedwater Pump 1A Vibration/Eccentricity	Feedwater A	NOT REVIEWED	15 - 0 - 15 MILS	
FW-P1B-VE-S	Main Feedwater Pump 1B Vibration/Eccentricity	Feedwater B	NOT REVIEWED	15 - 0 15 MILS	
FW-TE-1131-M	Steam Generator B - Feedwater Temperature	Steam Generator B	NOT REVIEWED	0 - 800 F	
FW-TE-1133-P	Feedwater Pump 1B Discharge Temperature	Feedwater B	NOT REVIEWED		
FW-TE-1134-M	Steam Generator A - Feedwater Temperature	Steam Generator A	NOT REVIEWED	0 - 800 F	
FW-TE-1136-P	Feedwater Pump 1A Discharge Temperature	Feedwater A	NOT REVIEWED		
FX-ABE-XX-S	Auxiliary Building Ventilation Exhaust Flow Rate	Aux Building	NOT REVIEWED	0 - 90000 CFM	
FX-ABS-XX-S	Auxiliary Building Ventilation Supply Flow Rate	Aux Building	NOT REVIEWED	0 - 90000 CFM	
FX-CBE-XX-S	Control Building Ventilation Exhaust Air Flow Rate	Control Room	NOT REVIEWED	0 - 5000 CFM	
FX-CBS-XX-S	Control Building Ventilation Supply Air Flow Rate	Control Room	NOT REVIEWED	0 - 5000 CFM	
FX-FHBE-XX-S	Fuel Handling Building Ventilation Exhaust Air Flow Rate	Fuel Handling Building	NOT REVIEWED	30K - 60K CFM	
FX-FHBS-XX-S	Fuel Handling Building Ventilation Supply Air Flow Rate	Fuel Handling Building	NOT REVIEWED	30K - 60K CFM	
FX-RBE-XX-S	Reactor Building Ventilation Exhaust Air Flow Rate	Reactor Building	NOT REVIEWED	0 - 30000 CFM	
HP-R-201-M	Control Room Area Radiation Monitor	Control Room	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-202-M	Cable Room Area Radiation Monitor	Cable Room	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-204-M	Reactor Building Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-205-M	Reactor Coolant Evap Control Panel Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	

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MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
HP-R-206-M	Make-Up Tank Area Monitor	Makeup / HPI	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-209-M	Fuel Handling Bridge, North - Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-210-M	Fuel Handling Bridge, South - Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-211-M	Reactor Building Personnel Hatch Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-212-M	Reactor Building Equipment Hatch Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-213-M	Incore Instrument Panel Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-214-M	Reactor Building Dome Area Radiation Monitor	Reactor Building	NOT REVIEWED	10+3 - 10E+9 mR/Hr	
HP-R-215-M	Fuel Handling Bridge Area Radiation Monitor	Reactor Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-218-M	Waste Disposal Storage Area Radiation	Waste	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-219-I-M	Station Vent Radiation Monitor - Iodine	Aux Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-219-P-M	Station Vent Radiation Monitor - Particulate	Aux Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-220-G-M	Control Room Air Intake Radiation Monitor - Gas	Control Room	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-220-I-M	Control Room Air Intake Radiation Monitor - Iodine	Control Room	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-220-P-M	Control Room Air Intake Radiation Monitor - Particulate	Control Room	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221A-G-M	Fuel Handling Building Exhaust Air Radiation Monitor, Upstream of Filter - Gas	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221A-I-M	Fuel Handling Building Exhaust Air Radiation Monitor, Upstream of Filter - Iodine	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221A-P-M	Fuel Handling Building Exhaust Air Radiation Monitor, Upstream of Filter - Particulate	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221B-G-M	Fuel Handling Building Exhaust Air Radiation Monitor, Downstream of Filter - Gas	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221B-I-M	Fuel Handling Building Exhaust Air Radiation Monitor, Downstream of Filter - Iodine	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-221B-P-M	Fuel Handling Building Exhaust Air Radiation Monitor, Downstream of Filter - Particulate	Fuel Handling Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-227-G-M	Reactor Building Air Sample Radiation Monitor - Gas	Reactor Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-227-I-M	Reactor Building Air Sample Radiation Monitor - Iodine	Reactor Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-227-P-M	Reactor Building Air Sample Radiation Monitor - Particulate	Reactor Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-229-I-M	Hydrogen Purge Radiation Monitor - Iodine	Reactor Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-229-P-M	Hydrogen Purge Radiation Monitor - Particulate	Reactor Building	NOT REVIEWED	10 - 10E+6 CPM	
HP-R-231-M	Auxiliary Building Sump Tank Filter Room Area Radiation Monitor	Aux Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-232-M	Auxiliary Building Access Corridor Radiation Monitor	Aux Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
HP-R-233-M	Auxiliary Building Access Corridor Radiation Monitor	Aux Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	

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TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
HP-R-234-M	Auxiliary Building Access Corridor Radiation Monitor	Aux Building	NOT REVIEWED	0.1 - 10E+4 mR/Hr	
MS-PT-1099-P	HP Turbine 1 Steam Generator Side B Pressure	Steam Generator B	NOT REVIEWED	0 - 1500 psig	
MS-PT-1100-P	HP Turbine 1 Steam Generator Side A Pressure	Steam Generator A	NOT REVIEWED	0 - 1500 psig	
MS-PT-3898-P	Condensor C Cold Pressure	Condensors	NOT REVIEWED	0 - 30 in. Hg	
MS-PT-3899-P	Condensor H Hot Pressure	Condensor	NOT REVIEWED	0 - 30 in. Hg	
MS-TE-104-M	Steam Generator B1 Outlet Temperature	Steam Generator B	NOT REVIEWED	0 - 400 F	
MS-TE-110-M	Steam Generator A1 Outlet Temperature	Steam Generator A	NOT REVIEWED	0 - 800 F	
MU-14-LT-R	Make-Up Tank Level	Makeup/Letdown	NOT REVIEWED	0 - 100 in/H2O	
MU-14-LT-S	Make-Up Tank Level	Makeup/Letdown	NOT REVIEWED	0 - 100 in/H2O	
MU-TE-1581-M	Make-up Tank Temperature (RC Pump ?)	Makeup/Letdown	NOT REVIEWED	0 - 400 F	
MU-TE-741-M	Letdown Cooler Inlet Temperature	Makeup/Letdown	NOT RECORDED	0 - 400 F	
NI-ND-5-R	Power Range Level	RV	NOT REVIEWED	0 - 125 %	
NI-ND-5-S	Power Range Level	RV	NOT REVIEWED	0 - 125 %	
PC-COND-VC1-S	Condensor Vacuum	Steam Generators	NOT REVIEWED	0 - 30 in. HG	
RC-1-LT1-DP-P	Pressurizer Level - Differential Pressure	Pressurizer	NOT REVIEWED	0 - 400 inches	
RC-1-LT1-L-S	Pressurizer Level	Pressurizer	NOT REVIEWED	0 - 400 in/H2O	
RC-1-LT2-DP-P	Pressurizer Level - Differential Pressure	Pressurizer	NOT REVIEWED	0 - 400 inches	
RC-1-LT3-DP-P	Pressurizer Level - Differential Pressure	Pressurizer	NOT REVIEWED	0 - 400 inches	
RC-10-TE1-P	Temperature Downstream of PORV (RC-RV2)	Pressurizer	NOT REVIEWED	0 - 700 F	
RC-10-TE2-P	Temperature Downstream of Pressure Relief Valve RV1A	Pressurizer	NOT REVIEWED	0 - 700 F	
RC-10-TE3-P	Temperature Downstream of Pressure Relief Valve RV1B	Pressurizer	NOT REVIEWED	0 - 700 F	
RC-11-TE-P	Pressurizer Spray Line Temperature	Pressurizer	NOT REVIEWED	0 - 700 F	
RC-14A-FT-R	Reactor Coolant Flow Rate - Loop A	RC-A	NOT QUAL.	0 - 90 MPPH	
RC-14B-FT-R	Reactor Coolant Flow Rate - Loop B	RC-B	NOT QUAL.	0 - 90 MPPH	
RC-15A-TE2-M	Cold Leg Temperature - Pump 1A Inlet : Wide Range	RC-A	NOT RECORDED	0 - 800 F	
RC-22-PT-M	Reactor Coolant Pump Seal Cavity Pressure	RC	NOT REVIEWED	0 - 2500 psig	
RC-3A-PT1-P	Reacter Coolant Pressure - Loop A : Narrow Range	RC-A	NOT REVIEWED	1700 - 2500 psig	
RC-3A-PT1-S	Reactor Coolant Pressure - Loop A : Narrow Range	RC-A	NOT REVIEWED	1700 - 2500 psig	
RC-3B-PT1-P	Reactor Coolant Pressure - Loop B: Narrow Range	RC-B	NOT REVIEWED	1700 - 2500 psig	
RC-3B-PT1-S	Reactor Coolant Pressure - Loop B : Narrow Range	RC-B	NOT REVIEWED	1700 - 2500 psig	
RC-3B-PT3-P	Reactor Coolant Pressure - Loop B : Wide Range	RC-B	NOT REVIEWED	0 - 2500 psig	
RC-4A-TE1-S	Hot Leg Temperature - Loop A : Narrow Range	RC-A	NOT REVIEWED	520 - 620 F	
RC-5A-TE2/4-P	Cold Leg Temperature - Pump 1A/2A Inlet : Wide Range	RC-A	NOT REVIEWED	50 - 650 F	
REAC-TRIP-R	Reactor Trip	RV	NOT REVIEWED	Run - Trip	
SP-10A-PT1-P	Turbine Header Pressure - Loop A	Steam Generator A	NOT REVIEWED	600 - 1200 psig	
SP-1A-LT1-P	Steam Generator A - Full Range Level	Steam Generator A	NOT REVIEWED	0 - 600 inches	
SP-1A-LT2-R	Steam Generator A - Operating Level	Steam Generator A	NOT QUAL.	0 - 100 %	
SP-1A-LT2-S	Steam Generator A - Operating Level	Steam Generator A	NOT REVIEWED	0 - 100 %	
SP-1A-LT2-S	Steam Generator A - Operating Level	Steam Generator A	NOT REVIEWED	0 - 100 %	
SP-1A-LT4-R	Steam Generator A - Start-up Level	Steam Generator A	NOT QUAL.	0 - 200 inches	
SP-1B-LT1-P	Steam Generator B - Full Range Level	Steam Generator B	NOT REVIEWED	0 - 600 inches	

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TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
SP-1B-LT2-R	Steam Generator B - Operating Level	Steam Generator B	NOT QUAL.	0 - 100 %	
SP-1B-LT2-S	Steam Generator B - Operating Level	Steam Generator B	NOT REVIEWED	0 - 100 %	
SP-1B-LT2-S	Steam Generator B - Operating Level	Steam Generator B	NOT REVIEWED	0 - 100 %	
SP-1B-LT4-R	Steam Generator B - Start-up Level	Steam Generator B	NOT QUAL.	0 - 250 %	
SP-6A-PT1-S	Steam Generator A - Steam Pressure	Steam Generator A	NOT REVIEWED	600 - 1200 psig	
SP-6B-PT1-P	Steam Generator B - Steam Pressure	Steam Generator B	NOT REVIEWED	0 - 1200 psig	
SP-6B-PT1-S	Steam Generator B - Steam Pressure	Steam Generator B	NOT REVIEWED	600 - 1200 psig	
SP-8A-DPT-P	A loop SG Feedwater Flow DP	Feedwater A	NOT REVIEWED	0 - 1150 in. H2O	
SP-8A-FT-P	Main Feedwater Flow Rate - Loop A Steam Generator	Feedwater A	NOT REVIEWED	0 - 6.5 MPPH	
SP-8A-FT-S	Main Feedwater Flow Rate - Loop A Steam Generator	Steam Generator A	NOT REVIEWED	0 - 6.5 MPPH	
SP-8B-FT-P	Main Feedwater Flow Rate - Loop B Steam Generator	Feedwater B	NOT REVIEWED	0 - 6.5 MPPH	
SP-8B-FT-S	Main Feedwater Flow Rate - Loop B Steam Generator	Steam Generator B	NOT REVIEWED	0 - 6.5 MPPH	
SPND-C-10-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-C-6-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-E-7-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-E-9-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-13-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-13-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-13-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-3-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-3-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-F-3-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-11-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-11-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-11-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-5-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-5-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-G-5-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-H-8-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-H-8-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	

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MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
SPND-H-8-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-H-9-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-H-9-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-H-9-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-K-11-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-K-11-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-K-11-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-K-5-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-K-5-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-L-13-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-L-13-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-L-3-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-L-3-4-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-L-3-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-M-7-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-M-9-6-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-O-10-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SPND-O-6-2-M	Self-powered Neutron Detector, In-core	RV	NOT REVIEWED	-20 - 1500 Nanoamps	
SR-FR-1638-S	Cooling Tower Make-Up Water Flow Rate	Cooling Tower	NOT REVIEWED	0 - 160 GPM	
TC-RWWD-TX1-S	River Water Normal/Waste Discharge Differential Temperature	Discharge	NOT REVIEWED	Unknown	
TT-01H-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-02G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-02L-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-03F-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-03L-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-03M-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-04E-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-04N-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-05D-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	
TT-05G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 F	

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TT-05H-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-05K-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-05O-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-06C-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-06G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-06L-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-06O-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-06P-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-07B-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-07E-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-07F-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-07M-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-07R-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-08B-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-08F-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-08H-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-08N-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09C-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09E-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09H-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09M-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-09N-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-10C-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-10D-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-10M-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-10O-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-10R-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-11E-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-11G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-11K-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-11L-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-12F-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-12K-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-12O-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-13C-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-13F-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-13G-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-13H-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-13L-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-14D-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-14M-TC-P	In-Core Thermocouple	RV	NOT REVIEWED	0 - 700 Deg F	
TT-CONDC-TX1-S	Condensor C Inlet Temperature	Steam Generators	NOT REVIEWED	0 - 100 F	
TT-CONDH-TX1-S	Condensor H Inlet Temperature	Steam Generators	NOT REVIEWED	0 - 100 F	
TT-DHCA-TE1-M	Decay Heat Cooler A Outlet Temperature	Decay Heat	NOT REVIEWED	0 - 400 F	
TT-DHCB-TE1-M	Decay Heat Cooler B Outlet Temperature	Decay Heat	NOT REVIEWED	0 - 400 F	
TT-DHPA-TE1-M	Decay Heat Pump A Outlet Temperature	Decay Heat	NOT REVIEWED	0 - 400 F	
TT-DHPB-TE1-M	Decay Heat Pump B Outlet Temperature	Decay Heat	NOT REVIEWED	0 - 400 F	
TT-NDCT-TE1-M	Natural Draft Cooling Tower Temperature	Cooling Tower	NOT REVIEWED	0 - 400 F	

TABLE E-1

TMI-2 MEASUREMENTS DESCRIPTION LIST

MEASUREMENT IDENTIFICATION	MEASUREMENT DESCRIPTION	REACTOR SUB-SYSTEM	QUALIFICATION CATEGORY	MEASUREMENT RANGE	MEASUREMENT UNCERTAINTY
TT-RCAT-TXX-S	Reactor Coolant Average Temperature	RC	NOT REVIEWED	520 - 620 F	
TT-RWRS-TXX-M	Rad Waste Leakage Recovery System Temperatures	Waste	NOT REVIEWED	0 - 700 F	
TT-TURB-TX1-M	Turbine Generator Temperature	Turbine	NOT REVIEWED	0 - 200 F	
TT-TURB-TX2-M	Turbine Generator Temperature	Turbine	NOT REVIEWED	70 - 250 F	
TURB-TRIP-R	Turbine Trip	Turbine	NOT REVIEWED	Run-Trip	
VA-R-748-G-M	Condenser Vacuum Pump Discharge Radiation Monitor - Gas	Feedwater	NOT REVIEWED	10 - 10E+6 CPM	
VT-TURB-SW1-S	Main Turbine Governor Valve Position	Turbine	NOT REVIEWED	0 - 100 %	
WD-1A-S	Wind Direction	Plant	NOT REVIEWED	0 - 540 F	
WGD-R-1485-G-M	Waste Gas Decay Tank Discharge 1A Radiation Monitor - Gas	Waste Gas	NOT REVIEWED	10 - 10E+6 CPM	
WGD-R-1486-G-M	Waste Gas Decay Tank Discharge 1B Radiation Monitor - Gas	Waste Gas	NOT REVIEWED	10 - 10E+6 CPM	
WS-1A-S	Wind Speed	Plant	NOT REVIEWED	0 - 100 MPH	