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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1 TEST S-28-2 (STEAM GENERATOR TUBE RUPTURE TEST)

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October 1977

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-28-2

(STEAM GENERATOR TUBE RUPTURE TEST SERIES)

Approved:

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TEST S-28-2

(STEAM GENERATOR TUBE RUPTURE TEST SERIES)

by

**Morris L. Patton
Kenneth E. Sackett**

EG&G IDAHO, INC.

October 1977

**PREPARED FOR THE
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AND
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. EY-76-C-07-1570**

ABSTRACT

Recorded test data are presented for Test S-28-2 of the Semiscale Mod-1 steam generator tube rupture test series. These tests are among several Semiscale Mod-1 experiments conducted to investigate the thermal and hydraulic phenomena accompanying a hypothesized loss-of-coolant accident in a pressurized water reactor (PWR) system.

Test S-28-2 was conducted from initial conditions of 15 936 kPa and 558 K to investigate the response of the Semiscale Mod-1 system to a depressurization and reflood transient following a simulated double-ended offset shear of the broken loop cold leg piping. During the test, cooling water was injected into the cold leg of the intact and broken loops to simulate emergency core coolant injection in a PWR. For Test S-28-2, accumulator injection into the intact loop hot leg was provided to simulate the rupture of six steam generator tubes.

The purpose of this report is to make available the uninterpreted data from Test S-28-2 for future data analysis and test reporting activities. The data, presented in the form of graphs in engineering units, have been analyzed only to the extent necessary to ensure that they are reasonable and consistent.

SUMMARY

Test S-28-2 was performed as part of the Semiscale Mod-1 portion of the Semiscale Program conducted by EG&G Idaho, Inc. for the United States Government. This test is part of the steam generator tube rupture test series (Test Series 28) performed to investigate the response of the Mod-1 system to the rupture of steam generator tubes during a hypothesized loss-of-coolant accident (LOCA). The test objective specific to Test S-28-2 was to define a lower limit on the range of steam generator tube ruptures over which high peak cladding temperatures can occur. Hardware configuration and test parameters were selected to yield a system response that simulates the response of a pressurized water reactor during a hypothesized LOCA with subsequent refill and reflood.

Test S-28-2 utilized the Semiscale Mod-1 system equipped with a pressure vessel with a 40-rod electrically heated core; an intact loop with pump, steam generator, and pressurizer; a broken loop with simulated pump, simulated steam generator, and rupture assemblies; and a pressure suppression system with header, pressure suppression tank, and heated steam supply system. High and low pressure coolant injection pumps and a coolant injection accumulator were provided for each system loop. An additional injection accumulator was provided for the intact loop hot leg. Intact loop hot leg injection flow rate was set to simulate the rupture of six steam generator tubes. In addition, for Test S-28-2, four heater rods were intentionally unpowered to simulate the effects of control rod guide tubes and the power in three heater rods was increased to produce a slightly peaked power profile.

The test was conducted from initial conditions of 15 936 kPa and 558 K (at the intact loop cold leg vessel inlet) with a simulated full size (200%) double-ended offset shear of the cold leg broken loop piping at an initial core power level of 1418 kW and an initial core inlet flow rate 9.84 l/s. The instantaneous offset shear of the broken loop cold leg piping was simulated by simultaneous (within 10 ms) actuation of the rupture assemblies. After initiation of blowdown, power to the heated core was reduced to simulate the predicted heat flux response of nuclear fuel rods during a LOCA. Blowdown was accompanied by simulated emergency core coolant injected into the cold legs of the intact and broken loops and followed by injection into the intact loop hot leg to simulate steam generator tube ruptures.

Test S-28-2 was generally conducted as specified. Conditions which did not conform to the specified test configuration were considered acceptable for analysis purposes within the test objectives. The instrumentation used generally functioned as intended. Of 230 measurements taken, 229 produced usable data.

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-28-2

(STEAM GENERATOR TUBE RUPTURE TEST)

I. INTRODUCTION

The Semiscale Mod-1 experiments represent the current phase of the Semiscale Program conducted by EG&G Idaho, Inc. for the United States Government. The program, which is sponsored by the Nuclear Regulatory Commission through the Energy Research and Development Administration, is part of the overall program designed to investigate the response of a pressurized water reactor system to a hypothesized loss-of-coolant accident (LOCA). The underlying objectives of the Semiscale Program are to quantify the physical processes controlling system behavior during a LOCA and to provide an experimental data base for assessing reactor safety evaluation models. The Semiscale Mod-1 Program has the further objective of providing support to other experimental programs in the form of instrumentation assessment, optimization of test series, selection of test parameters, and evaluation of test results.

Test S-28-2 was conducted June 9, 1977 in the Semiscale Mod-1 system as part of the steam generator tube rupture test series (Test Series 28). This series was designed to obtain thermal-hydraulic response data from blowdown, refill, and reflood transients in a simulated nuclear reactor with a heated core to study system response during a LOCA with steam generator tube ruptures. The test objective specific to Test S-28-2 was to define a lower limit on the range of steam generator tube ruptures over which high peak cladding temperatures can occur.

The purpose of this report is to present the test data in an uninterpreted but readily usable form for use by the nuclear community in advance of detailed analysis and interpretation. Section II briefly describes the system configuration, procedures, initial test conditions, and events that are applicable to Test S-28-2; Section III presents the data graphs and provides comments and supporting information necessary for interpretation of the data. A description of the overall Semiscale Program and test series, a more detailed description of the Semiscale Mod-1 system, and a description of the measurement and data processing techniques and uncertainties can be found in Reference 1. Appendix A also provides additional information on the data acquisition system capabilities.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TEST S-28-2

The following system configuration, procedures, initial test conditions, and events are specific to Test S-28-2 as indicated.

1. SYSTEM CONFIGURATION AND TEST PROCEDURES

The Semiscale Mod-1 system used for this test consisted of a pressure vessel with internals, including a 40-rod core with 36 electrically heated rods; an intact loop with steam generator, pump, and pressurizer; a broken loop with simulated steam generator, simulated pump, and two rupture assemblies; coolant injection accumulators for the cold legs of the intact and broken loops, and a heated accumulator for the intact loop hot leg; high and low pressure injection pumps for each of the system loops; and a pressure suppression system with a suppression tank, header, and heated steam supply system. For Test S-28-2, the volume of the lower plenum was reduced to $0.014\ 980\ \text{m}^3$ by the addition of a metal filler piece. Semiscale Mod-1 experimental system configuration information is described further in Reference 1. Figures 1 and 2 show the system configuration for Test S-28-2.

For Test S-28-2, 33 rods of the 40-rod electrically heated core were operated at a peak power density of approximately $37.7\ \text{kW/m}$, three rods (Rods D-4, E-4, and E-5) were operated at a peak power density of $39.7\ \text{kW/m}$ to yield a slightly peaked power profile, and four rods (Rods C-3, D-5, F-3, and F-6) were unpowered to simulate the effect of control rod guide tubes. The resulting total core power was approximately $1418\ \text{kW}$.

In preparation for the test, the accumulators for the intact and broken loop cold legs were filled with treated demineralized water, drained to the specified initial levels, and pressurized with nitrogen to $4223\ \text{kPa}$. The accumulator for the intact loop hot leg was filled with treated demineralized water, drained to the specified initial level, heated to $541\ \text{K}$, and pressurized to $7584\ \text{kPa}$. The system was filled with treated demineralized water and vented at strategic points to ensure a liquid full system. Prior to warmup the system was pressurized to check for leakage, system instrumentation was checked, and transducer readings were initialized. Warmup to initial test conditions was accomplished with the heaters in the vessel core. Heatup of the broken loop piping was accomplished with bypass lines which served to allow circulation through the broken loop. During warmup, the purification and sampling systems were valved into the primary system to maintain water chemistry requirements and to provide a water sample at system conditions for subsequent analysis. At 55.6-K -temperature intervals during warmup, detector readings were sampled to allow the integrity of the measurement instrumentation and the operability of the data acquisition system to be checked.

Fig. 1 Semiscale Mod-1 system for cold leg break configuration -- isometric.

INEL-B-3073

Fig. 2 Semiscale Mod-1 system for cold leg break configuration -- schematic.

Prior to the initial core power level being established, the pressure suppression system was pressurized to 241 kPa with saturated steam from the steam supply system. After the core power was increased to 1418 kW, initial test conditions were held for 521 s to establish equilibrium in the system. At the end of this period all auxiliary systems including the bypass lines were isolated to prevent blowdown through those systems.

The system was successfully subjected to a simulated double-ended cold leg break through two rupture assemblies and two blowdown nozzles, each having a break area of 0.000 243 m². Pressure to operate the rupture assemblies and initiate blowdown was taken from an accumulator system filled with water and pressurized to 15 513 kPa with gaseous nitrogen. Immediately (within 0.02 s) after initiation of blowdown, the lines to the accumulator were again isolated. The effluent was ejected from the primary system into the pressure suppression system which was vented to maintain a constant pressure of 241 kPa. At blowdown, power to the primary coolant circulation pump was reduced and the pump was allowed to coast down to a speed of 1475 rpm which was maintained for the duration of the test. During the blowdown transient, power to the electrically heated core was automatically controlled to simulate the thermal response of nuclear heated fuel rods.

For Test S-28-2, the coolant injection systems were arranged to discharge into both system loops at the cold leg injection points (Spool 14 and Spool 42). The high pressure coolant injection pumps were started immediately after initiation of blowdown (0 s) and continued to the end of the test (640 s). Low pressure coolant injection was initiated 28 s after blowdown at a system pressure of 1034 kPa and continued until test termination (640 s). Coolant injection from the intact loop accumulator (CI-T-1) started 17 s after blowdown, and nitrogen discharge began 64 s after rupture and was terminated 88 s after blowdown. The broken loop accumulator (CI-T-2) began injection 4 s after blowdown, nitrogen discharge began 28 s after rupture, and was terminated 67 s after blowdown. The steam generator rupture system accumulator (CI-T-3) began injection at 40 s at a system pressure of 680 kPa and continued to test termination.

2. INITIAL TEST CONDITIONS AND SEQUENCE OF EVENTS

Conditions in the Semiscale Mod-1 system at initiation of blowdown are given in Tables I and II; the primary system water chemistry prior to blowdown is given in Table III; and the sequence of events relative to rupture is given in Table IV.

TABLE I
CONDITIONS AT BLOWDOWN INITIATION

	Test S-28-2	
	Measured ^[a]	Specified
Core power (MW)	1.418	1.43 $\pm$ 0.01
Intact loop cold leg fluid temperature (K)	558	557.6 $\pm$ 1
Hot leg to cold leg temperature differential (K)	36	36.7 $\pm$ 0.5
Pressurizer pressure (kPa)	15 936	15 603 $\pm$ 172
Pressurizer liquid mass (kg) ^[b]	10.6	9.07
Steam generator feedwater temperature (K)	495	497 $\pm$ 17
Steam generator liquid level (from bottom of tube sheet) (cm)	292	294.6 $\pm$ 5
Broken loop fluid temperature (pump-side) (K)	592	589 to 594
Broken loop fluid temperature (vessel-side) (K)	558	Not Specified
Intact loop cold leg flow (L/s)	9.84	[c]
Pressure suppression tank water level (cm)	121	121 $\pm$ 1
Pressure suppression tank pressure (kPa)	228	241.3 $\pm$ 6.9
Pressure suppression tank water temperature (K)	290	<297

[a] Measured initial conditions are taken from digital scan read just prior to blowdown. Those measured conditions which did not meet the specified initial conditions were considered acceptable for analysis purposes within the test objectives.

[b] Pressurizer liquid mass including surge line.

[c] Flow is not specified, since it must be adjusted to achieve the required differential temperature across the core.

TABLE II
PRIMARY COOLANT TEMPERATURE DISTRIBUTION PRIOR TO RUPTURE^[a]

	<u>Test S-28-2</u>	
	<u>Detector</u>	<u>Temperature (K)</u>
Vessel lower plenum (upper portion above filler block)	TFV-LP-7	560
Intact loop hot leg (near vessel)	RBU-2	594
Intact loop cold leg (near pump inlet)	TFU-10	560
Intact loop cold leg (near vessel)	RBU-14A	558
Broken loop cold leg (near nozzle)	TFB-23	558
Broken loop hot leg (near vessel)	TFB-30	592
Broken loop cold leg (near nozzle)	TFB-42	589

[a] Data taken from digital scan 0.5 s before blowdown.

TABLE III
WATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

	<u>Test S-28-2</u>
pH	10.80
Conductivity ($\mu\text{mho/cm}$)	158.0
Lithium ($\mu\text{m}\ell$)	4.2
Chlorides (ppm)	<0.1
Fluorides ($\mu\text{m}\ell$) ^[b]	<0.4
Oxygen (cc/ ℓ)	0.2
total gas (cc/ ℓ)	115.5
Suspended solids ($\mu\text{m}\ell$)	24.6

[a] Water sample taken at a system pressure of approximately 15 603 kPa and a system temperature of approximately 555 K (cold leg).

[b] Present analytical methods prevent accurate determination of fluorides at concentrations of less than 0.4 ppm.

TABLE IV
SEQUENCE OF EVENTS DURING TEST S-28-2^[a]

<u>Event</u>	<u>Time Relative to Rupture (s)</u>
Core power level established	-521
Bypass lines valved out of system	-2.5
Blowdown initiated	0
Pump power reduced	0
High pressure injection system pumps started ^[b]	0
ECC accumulators valved in ^[b]	0
Steam generator feedwater and discharge valves closed	1
Core power decay transient started	2.87
Low pressure injection system pumps started ^[b]	27.7
Core power tripped off ^[c]	640

[a] A time-controlled sequencer was used to control critical events during the test.

[b] Injection from ECC accumulators and high and low pressure injection system pumps does not start until system pressure drops below accumulator or pump pressure, respectively.

[c] Core power tripped manually at termination of test.

III. DATA PRESENTATION

The data from Semiscale Mod-1 Test S-28-2 are presented with brief comment. Processing analysis has been performed only to the extent necessary to obtain appropriate engineering units and to ensure that the data are reasonable and consistent. In all cases, in converting transducer output to engineering units, a homogeneous fluid was assumed. Further interpretation and analysis should consider that sudden decompression processes such as those occurring during blowdown may have subjected the measurement devices to nonhomogeneous fluid conditions.

The performance of the system during Test S-28-2 was monitored by 230 detectors. The data obtained were recorded on both digital and analog data acquisition systems. The digital system was used to process the data presented in this report. The analog system was used to provide better resolution capability (needed as input to various data analysis codes). The long term data (-32 to 640 s) presented in this report were recorded at an effective sample rate of 1.369 points per second. Long term plots are given for -20 to 350 s rather than for the full 640 s recording time to provide better resolution. Short term data (-6 to 42 s) were recorded at an effective sample rate of 19.17 points per second.

The data are presented, in some instances, in the form of composite graphs to facilitate comparison of the values of given variables at several locations. The scales selected for the graphs do not reflect the obtainable resolution of the data. (The data processing techniques are described further in Appendix A and Reference 1.)

Figures 3 through 8 and Table V provide supporting information for interpretation of the data graphs shown in Figures 9 through 370 and provide relative locations of all detectors used during Test S-28-2. Table V groups the measurements according to measurement type; identifies the specific measurement location and the range of the detector and actual recording range of the data acquisition system; provides brief comments regarding the data; and references the measurements and comments to the corresponding figure. Figures 9 through 370 present all the blowdown and reflood data obtained. Time zero on the graphs is the time of rupture initiation. Appendix A provides information explaining the data acquisition system capabilities. Appendix B provides information explaining posttest data processing for data conversion into engineering units and data adjustments. Presented in Appendix C is an analysis of selected data which provide a guide to the uncertainty associated with data measurements in the Semiscale Mod-1 system.

Fig. 3 Semiscale Mod-1 system and instrumentation for cold leg break configuration -- isometric.

Fig. 4 Semiscale Mod-1 system and instrumentation for cold leg break configuration -- schematic.

Fig. 5 Semiscale Mod-1 pressure vessel -- cross section showing instrumentation.

Distance from
cold leg ϕ (cm)

Distance from
cold leg ϕ (cm)

INEL-A-4307

Fig. 6 Semiscale Mod-1 pressure vessel -- isometric showing instrumentation.

INEL-A-4306

Fig. 7 Semiscale Mod-1 pressure vessel -- penetrations and instrumentation.

INEL-A-4308

Fig. 8 Semiscale Mod-1 heated core -- plan view.

TABLE V
DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-28-2

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
FLUID TEMPERATURE					
Chromel-Alumel thermocouples unless specified otherwise.					
<u>Intact Loop</u>					
TFU-1	Hot leg, Spool 1, 54 cm from vessel center.	0 to 1533 K	0 to 584 K	9, 10	
RBU-2	Hot leg, Spool 2, 117 cm from vessel center (platinum resistance bulb).	0 to 811 K	0 to 811 K	9, 10	
TFU-6	Hot leg, Spool 6, 290 cm from vessel center.			11, 12	
TFU-7	Cold leg, Spool 7, 624 cm from vessel center.			13, 14	
TFU-10	Cold leg, Spool 10, 367 cm from vessel center.			13, 14	
RBU-14A	Cold leg, Spool 14, 109 cm from vessel center, upstream of cold leg injection port (platinum resistance bulb).	0 to 811 K	0 to 811 K	15, 16	
TFU-14B	Cold leg, Spool 14, 99 cm from vessel center, downstream of cold leg injection port.			15, 16	
TFU-15	Cold leg, Spool 15, 54 cm from vessel center.			17, 18	
<u>Broken Loop</u>					
TFB-20	Cold leg, Spool 20, 52 cm from vessel center.	0 to 1533 K	0 to 820 K	19, 20	
TFR-23	Cold leg, Spool 23, 232 cm from vessel center, upstream of vessel-side nozzle.			19, 20	
TFB-30	Hot leg, Spool 30, 40 cm from vessel center.			21, 22	
TFB-37	Cold leg, Spool 37, 703 cm from vessel center along hot leg, discharge of simulated steam generator.			21, 22	
TFB-42	Cold leg, Spool 42, 1054 cm from vessel center along hot leg, upstream of pump-side nozzle.			21, 22	
<u>Inlet Annulus</u>					
	10 cm below cold leg centerline, 0.5 cm from vessel wall, Type J iron-constantan thermocouples.	0 to 1033 K	0 to 701 K		
TFV-ANN-4A	0°.			23, 24	
TFV-ANN-4M	180°.			23, 24	
<u>Downcomer Annulus</u>					
	Centered in annulus, Type J iron-constantan thermocouples.	0 to 1033 K	0 to 701 K		
TFV-ANN-35A	89 cm below cold leg centerline, 0°.			25, 26	
TFV-ANN-70A	178 cm below cold leg centerline, 0°.			25, 26	
TFV-ANN-115A	292 cm below cold leg centerline, 0°.			25, 26	
TFV-ANN-156A	396 cm below cold leg centerline, 0°.			25, 26	
<u>Upper Plenum</u>					
TFV-UP-13	In upper plenum, 34 cm above cold leg centerline at 180°.	0 to 1533 K	0 to 820 K	27, 28	
<u>Lower Plenum</u>					
	On fluid thermocouple rack, 2.54 cm from vessel center, 45°.	0 to 1533 K	0 to 820 K		
TFV-LP-2	5 cm above top of lower plenum filler block.			29, 30	
TFV-LP-4	10 cm above top of lower plenum filler block.			29, 30	
TFV-LP-7	18 cm above top of lower plenum filler block.			29, 30	
<u>Core</u>					
TFV-CORE-IN	In core flow mixer box, 381 cm below cold leg centerline (a part of FDV-CORE-IN).	0 to 1533 K	0 to 820 K	31, 32	Data acquisition system saturated intermittently between t=32 and t=60 s.

TABLE V. (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Core Grid Spacers					
<u>Grid Spacer 5</u>	140 cm below cold leg centerline, 54.6 cm above top of heated length.	0 to 1533 K	0 to 1579 K		
TFG-5CD-45	Thermocouple in space defined by Columns C and D, Rows 4 and 5.			33, 34	
<u>Grid Spacer 6</u>	193 cm below cold leg centerline, 1.3 cm above top of heated length.				
TFG-6CD-45	Thermocouple in space defined by Columns C and D, Rows 4 and 5.			35, 36	
<u>Grid Spacer 10</u>	363 cm below cold leg centerline at bottom of heated length.				
TFG-10AB-45	Thermocouple in space defined by Columns A and B, Rows 4 and 5.			37, 38	
ECC System		0 to 1533 K	0 to 584 K		
TFB-ECC-14	In ECC line leading to intact loop Spool 14.			20, 40	
TFB-ECC-42	In ECC line leading to broken loop Spool 42.			41, 42	
Steam Generator		0 to 1533 K	0 to 584 K		
TFU-SGFW	In feedwater line leading to steam generator.			43, 44	
TFU-SGSD	In steam dome, 329 cm above bottom of tube sheet.			45, 46	
TFU-SG1	Secondary side, 30 cm above bottom of tube sheet.			47, 48	
TFU-SG2	Secondary side, 61 cm above bottom of tube sheet.			47, 48	
TFU-SG3	Secondary side, 122 cm above bottom of tube sheet.			47, 48	
Steam Generator Rupture System		0 to 1533 K	0 to 584 K		
TFU-SGS3	In bottom of Accumulator Tank T-3.			49, 50	
TFU-SGS	In injection line leading from Accumulator Tank T-3 just upstream of junction with Spool 6.			51, 52	
TFB-SGS-N	In drain of injection line leading from Accumulator Tank T-3.			53, 54	
Pressurizer		0 to 1533 K	0 to 584 K		
TFU-PR12Z	In surge line, near pressurizer exit, between turbine flowmeter and pressurizer.			55, 56	
Pressure Suppression System		0 to 1533 K	0 to 584 K		
TF-PSS-33	84 cm from bottom of tank.			57, 58	
TF-PSS-130	330 cm from bottom of tank.			57, 58	
MATERIAL TEMPERATURE					
Chromel-Alumel thermocouples unless specified otherwise.					
Intact Loop		0 to 1533 K	0 to 584 K		
TMU-1T16	Hot leg, Spool 1, top, 1.6 mm from pipe ID, 54 cm from vessel center.		0 to 820 K	59, 60	
Broken Loop		0 to 1533 K	0 to 584 K		
TMB-20B16	Cold leg, Spool 20, bottom, 1.6 mm from pipe ID, 52 cm from vessel center.			61, 62	
TMB-30B16	Hot leg, Spool 30, bottom, 1.6 mm from pipe ID, 40 cm from vessel center.		0 to 820 K	61, 62	
Vessel Filler		0 to 1033 K	0 to 701 K		
TMV-FI-115A	292 cm below cold leg centerline, 1.6 mm from filler ID, 0°.			63, 64	
TMV-FI-156A	396 cm below cold leg centerline, 1.6 mm from filler ID, 0°.			63, 64	
TMV-FD-156A	396 cm below cold leg centerline, 1.65 cm from filler ID, 0°.			65, 66	

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Vessel Filler Insulator</u>		0 to 1033 K	0 to 701 K		
TIV-F0-35A	89 cm below cold leg centerline, 0°.			67, 68	
TIV-F0-115A	292 cm below cold leg centerline, 0°.			67, 68	
<u>Core Barrel</u>	Type J iron-constantan thermocouples	0 to 1033 K	0 to 701 K		
TMV-CI-70A	178 cm below cold leg centerline, 1.6 mm from core barrel ID, 0°.			69, 70	
TMV-CO-70A	178 cm below cold leg centerline, 1.6 mm from core barrel OD, 0°.			71, 72	
TMV-CO-115A	292 cm below cold leg centerline, 1.6 mm from core barrel OD, 0°.			71, 72	
<u>Core Housing Filler</u>		0 to 1533 K	0 to 820 K		
TMV-HF-115W	On core housing filler, 292 cm below cold leg centerline, 5 mm from outer surface, 315°.			73, 74	
TMV-HF-127W	On core housing filler, 323 cm below cold leg centerline, 5 mm from outer surface, 315°.			73, 74	
TMV-HF-138W	On core housing filler, 351 cm below cold leg centerline, 5 mm from outer surface, 315°.			73, 74	
<u>Steam Generator</u>		0 to 1533 K	0 to 584 K		
TMU-SG1	On a steam generator tube, 30 cm above bottom of tube sheet, on OD of tube.			75, 76	
TMU-SG2	On a steam generator tube, 61 cm above bottom of tube sheet, on OD of tube.			75, 76	
TMU-SG3	On a steam generator tube, 122 cm above bottom of tube sheet, on OD of tube.			75, 76	
<u>CORE HEATER CLADDING TEMPERATURES</u>	Chromel-Alumel thermocouples.				
<u>High Power Heaters</u>		0 to 1533 K	0 to 1579 K		
TH-D4-14 TH-D4-29	Heater at Column D, Row 4. Thermocouples 36 cm (270°) and 74 cm (315°) above bottom of core.			77, 78	
TH-D5-29	Heater at Column D, Row 5. Thermocouple 74 cm (225°) above bottom of core.			79, 80	
TH-E4-09 TH-E4-27 TH-E4-55	Heater at Column E, Row 4. Thermocouples 23 cm (180°), 69 cm (90°) and 140 cm (0°) above bottom of core.			81, 82	
TH-E5-20 TH-E5-25	Heater at Column E, Row 5. Thermocouples 53 cm (180°) and 64 cm (90°) above bottom of core.			83, 84	
<u>Low Power Heaters</u>		0 to 1533 K	0 to 1579 K		
TH-A4-09 TH-A4-29 TH-A4-39	Heater at Column A, Row 4. Thermocouples 23 cm (105°), 74 cm (240°), and 99 cm (300°) above bottom of core.			85, 86	
TH-A5-29 TH-A5-45	Heater at Column A, Row 5. Thermocouples 74 cm (180°) and 114 cm (255°) above bottom of core.			87, 88	
TH-B3-32	Heater at Column B, Row 3. Thermocouple 81 cm (135°) above bottom of core.			89, 90	
TH-B5-29 TH-B5-33	Heater at Column B, Row 5. Thermocouples 74 cm (150°) and 85 cm (45°) above bottom of core.			91, 92	
TH-B6-29	Heater at Column B, Row 6. Thermocouple 74 cm (45°) above bottom of core.			93, 94	
TH-C2-38	Heater at Column C, Row 2. Thermocouple 97 cm (225°) above bottom of core.			95, 96	

TABLE V (continued)

Range ^[a]					
Measurement	Location and Comments ^[a]	Detector	Data Acquisition System	Figure ^[a]	Measurement Comments ^[b]
Low Power Heaters (continued)					
TH-C4-20 TH-C4-26 TH-C4-53	Heater at Column C, Row 3. Thermocouples 51 cm (150°), 66 cm (75°), and 135 cm (300°) above bottom of core.			97, 98	
TH-C5-28	Heater at Column C, Row 5. Thermocouple 71 cm (315°) above bottom of core.			99, 100	
TH-C6-53	Heater at Column C, Row 6. Thermocouple 135 cm (270°) above bottom of core.			101, 102	
TH-C7-07 TH-C7-15	Heater at Column C, Row 7. Thermocouples 18 cm (345°) and 38 cm (255°) above bottom of core.			103, 104	
TH-D1-21	Heater at Column D, Row 1. Thermocouple 53 cm (330°) above bottom of core.			105, 106	
TH-D2-14 TH-D2-61	Heater at Column D, Row 2. Thermocouples 36 cm (0°) and 155 cm (270°) above bottom of core.			107, 108	
TH-D3-29 TH-D3-39	Heater at Column D, Row 3. Thermocouples 74 cm (150°) and 99 cm (210°) above bottom of core.			109, 110	
TH-D6-25	Heater at Column D, Row 6. Thermocouple 64 cm (255°) above bottom of core.			111, 112	
TH-D7-20	Heater at Column D, Row 7. Thermocouple 51 cm (60°) above bottom of core.			113, 114	
TH-D8-26	Heater at Column D, Row 8. Thermocouple 69 cm (180°) above bottom of core.			115, 116	
TH-E1-33	Heater at Column E, Row 1. Thermocouple 84 cm (60°) above bottom of core.			117, 118	
TH-E2-20 TH-E2-33	Heater at Column E, Row 2. Thermocouples 51 cm (210°) and 81 cm (315°) above bottom of core.			119, 120	
TH-E3-05 TH-E3-20 TH-E3-24	Heater at Column E, Row 3. Thermocouples 13 cm (15°), 51 cm (165°), and 61 cm (75°) above bottom of core.			121, 122	
TH-E6-08 TH-E6-28 TH-E6-37	Heater at Column E, Row 6. Thermocouples 20 cm (150°), 71 cm (285°), and 94 cm (330°) above bottom of core.			123, 124	
TH-E7-44	Heater at Column E, Row 7. Thermocouple 112 cm (195°) above bottom of core.			125, 126	
TH-E8-14 TH-E8-29	Heater at Column E, Row 8. Thermocouples 36 cm (150°) and 74 cm (225°) above bottom of core.			127, 128	
TH-F2-07 TH-F2-22 TH-F2-25	Heater at Column F, Row 2. Thermocouples 18 cm (255°), 56 cm (105°), and 64 cm (0°) above bottom of core.			129, 130	
TH-F4-14 TH-F4-29 TH-F4-44	Heater at Column F, Row 4. Thermocouples 36 cm (90°), 74 cm (165°), and 112 cm (210°) above bottom of core.			131, 132	
TH-F5-20 TH-F5-26 TH-F5-33 TH-F5-53	Heater at Column F, Row 5. Thermocouples 51 cm (255°) and 66 cm (165°), 84 cm (315°), and 135 cm (30°) above bottom of core.			133, 134	
TH-G3-13	Heater at Column G, Row 3. Thermocouples 33 cm (150°) above bottom of core.			135, 136	
TH-G4-29 TH-G4-44 TH-G4-38	Heater at Column G, Row 4. Thermocouples 74 cm (180°), 84 cm (225°), and 97 cm (30°) above bottom of core.			137, 138	
TH-G5-14 TH-G5-24	Heater at Column G, Row 5. Thermocouples 36 cm (45°) and 61 cm (330°) above bottom of core.			139, 140	
TH-H5-32	Heater at Column H, Row 5. Thermocouple 81 cm (45°) above bottom of core.			141, 142	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]			Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System			
PRESSURE						
<u>Intact Loop</u>		0 to 20 kPa				
PU-13	Cold leg, Spool 13, 138 cm from vessel center.		0 to 31 614 kPa	143, 144		
PU-15L	Cold leg, Spool 15, 55 cm from vessel center, to atmosphere (low range).	0 to 3447 kPa	0 to 3561 kPa	143, 144		Data acquisition system saturated between t=18 and t=20 s.
<u>Broken Loop</u>		0 to 17 237 kPa				
PB-21	Cold leg, Spool 21, 112 cm from vessel center.	0 to 20 684 kPa	0 to 29 666 kPa	145, 146		
PB-23	Cold leg, Spool 23, 235 cm from vessel center, upstream of nozzle (tee off DP tap).		0 to 21 480 kPa	145, 146		
PB-CN4	Cold leg, Spool 23, vessel-side nozzle, nozzle divergent section, 257 cm from vessel center along cold leg, 0°.	0 to 20 684 kPa	0 to 30 223 kPa	147, 148		
PB-37	Cold leg, Spool 37, 718 cm from vessel center along hot leg.		0 to 21 675 kPa	149, 150		
PB-42	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, upstream of pump-side nozzle (tee off DP tap).		0 to 20 359 kPa	149, 150		
PB-HN1	Pump-side nozzle, nozzle throat, 1066 cm from vessel center along hot leg (tee off DP tap)		0 to 20 654 kPa	151, 152		
<u>Vessel</u>						
PV-UP+10	In upper plenum, 25 cm above cold leg centerline, mounted on standoff, 30°.	0 to 17 237 kPa	0 to 21 261 kPa	153, 154		
PV-LP-166	In upper part of lower plenum, 422 cm below cold leg centerline, mounted on standoff, 225°.	0 to 20 684 kPa	0 to 34 769 kPa	153, 154		
<u>ECC System</u>		0 to 6895 kPa				
PU-ACC1	In intact loop accumulator.		0 to 8629 kPa	155, 156		
PB-ACC2	In broken loop accumulator.		0 to 8368 kPa	157, 158		
<u>Steam Generator</u>						
PU-SGSD	Secondary side steam dome.	0 to 20 684 kPa	0 to 13 367 kPa	159, 160		
<u>Steam Generator Rupture System</u>						
PU-SGS3	In vessel, simulating steam generator tube rupture. (Vessel accumulator.)	0 to 6895 kPa	0 to 8368 kPa	161, 162		
<u>Pressurizer</u>						
PU-PRIZE	Pressurizer steam dome.	0 to 17 237 kPa	0 to 22 113 kPa	163, 164		
<u>Pressure Suppression System</u>						
P-PSS	Suppression tank top.	0 to 1724 kPa	0 to 2173 kPa	165, 166		
DIFFERENTIAL PRESSURE						
<u>Intact Loop</u>						
DPU-3-7	Hot leg Spool 3, 158 cm from vessel center to cold leg Spool 7, 507 cm from vessel center. Spool 3 tap is 46 cm above Spool 7 tap.	+1270 cm water	+170 kPa	167, 168		
DPU-6-SGIP	Hot leg, Spool 6, 290 cm from vessel center to steam generator inlet plenum 368 cm from vessel center. Spool 6 tap is 41 cm below SGIP tap.	+2032 cm water	+268 kPa	169, 170		

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Intact Loop (continued)</u>					
DPU-SGDP-7	From steam generator outlet plenum 683 cm from vessel center along cold leg to cold leg Spool 7, 587 cm from vessel center, including orifice. Spool 7 tap is 89 cm below SGDP tap.	+1270 cm water	+169 kPa	171, 172	
DPU-7-10	Steam generator outlet to pump inlet, cold leg Spool 7, 587 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center.	+127 cm water	+17.2 kPa	173, 174	
DPU-12-10	Pump outlet to pump inlet, cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center. Spool 10 tap is 25 cm below Spool 12 tap.	+345 kPa	+343 kPa	175, 176	
DPU-12-10L	Pump outlet to pump inlet, cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center. Spool 10 tap is 25 cm below Spool 12 tap (low range).	+254 cm water	+33.2 kPa	177, 178	
DPU-12-15	Cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 15, 55 cm from vessel center.	+254 cm water	+33.9 kPa	179, 180	Data acquisition system saturated intermittently between t=1 and t=3 s.
DPU-15-3	Cold leg to hot leg; cold leg Spool 15, 55 cm from vessel center, to hot leg Spool 3, 158 cm from vessel center. Spool 15 tap is 22 cm below Spool 3 tap.	+1270 cm water	+169 kPa	181, 182	
DPU-15-3L	Cold leg to hot leg, cold leg Spool 15, 55 cm from vessel center, to hot leg Spool 3, 158 cm from vessel center. Spool 15 tap is 22 cm below Spool 3 tap (low range).	+254 cm water	+33.5 kPa	183, 184	
DPU-PRESLL	Pressurizer water level. Elevation difference between taps is 135 cm. Lower tap is 9 cm above pressurizer exit.	+127 cm water	+17.1 kPa	185, 186	
DPU-PR-4	Pressurizer bottom to Spool 4. Elevation difference between taps is 157 cm. Spool 4 tap is 140 cm below pressurizer exit.	+3447 kPa	+3456 kPa	187, 188	Data acquisition system saturated between t=0 and t=13 s.
<u>Broken Loop</u>					
DPD-21-IANN	Cold leg Spool 21, 112 cm from vessel center, to vessel inlet annulus, 23 cm below cold leg centerline at 225°. Inlet annulus tap is 23 cm below Spool 21 tap.	+254 cm water	+33.6 kPa	189, 190	
DPB-23-CN1	Cold leg, Spool 23, 235 cm from vessel center to vessel-side nozzle throat, 245 cm from vessel center.	+10 342 kPa	+13 843 kPa	191, 192	
DPB-CN1-24	Vessel-side nozzle throat, 245 cm from vessel center to Spool 24, 264 cm from vessel center.	+3447 kPa	+6961 kPa	193, 194	
DPB-30-43	Across entire broken loop hot leg including rupture assembly; hot leg Spool 30, 45 cm from vessel, to cold leg Spool 43, 1086 cm from vessel center along hot leg.	+3447 kPa	+6973 kPa	195, 196	
DPB-32U-36L	Across simulated steam generator orifice assembly, hot leg Spool 32 upper tap, 189 cm from vessel center, to Spool 36 lower tap, 41 cm from vessel center. Spool 32 upper tap is 41 cm above Spool 36 lower tap.	+1379 kPa	+1388 kPa	197, 198	
DPB-36L-37	Across nozzle assembly. Spool 36 lower tap, 617 cm from vessel center along hot leg to Spool 37, 718 cm from vessel center along hot leg. Spool 37 tap is 102 cm below Spool 36 lower tap.	+345 kPa	+346 kPa	199, 200	
DPB-38-40	Across simulated pump, cold leg Spool 38, 776 cm from vessel center along hot leg, to cold leg Spool 40, 929 cm from vessel center along hot leg.	+6895 kPa	+9227 kPa	201, 202	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Broken Loop (continued)</u>					
DPB-40-42	Across elbow leading to spool upstream of pump-side nozzle. Cold leg Spool 40, 929 from vessel center along hot leg, to Spool 42, 1057 from vessel center along hot leg. Spool 40 tap is 102 cm below Spool 42 tap.	+127 cm water	+16.2 kPa	203, 204	Data acquisition system saturated between t=0 and t=1 s.
DPB-42-HN1	Spool 42 upstream of pump-side nozzle, 1057 cm from vessel center along hot leg to nozzle throat, 1066 cm from vessel center along hot leg.	+10 342 kPa	+13 843 kPa	205, 206	
DPB-HN1-43	Pump-side nozzle, nozzle throat 1066 cm from vessel center along hot leg to Spool 43, 1086 cm from vessel center along hot leg.	+3447 kPa	+6932 kPa	207, 208	
<u>Vessel</u>					
DPV-UP-IANN	Upper plenum, 27 cm above cold leg centerline at 30° to inlet annulus, 23 cm below cold leg centerline at 225°. Elevation difference between taps is 48 cm.	+762 cm water	+102 kPa	209, 210	
DPV-0-9GQ	Inlet annulus cold leg centerline at 90°, to 23 cm below cold leg centerline at 225°. Elevation difference between taps is 23 cm.	+127 cm water	+18.4 kPa	211, 212	
DPV-9-26QQ	Inlet annulus, 23 cm below cold leg centerline at 225°, to downcomer gap, 66 cm below cold leg centerline at 225°. Elevation difference between taps is 43 cm.	+127 cm water	+16.8 kPa	213, 214	
DPV-9-166QQ	Inlet annulus, 23 cm below cold leg centerline at 225°, to lower plenum, 422 cm below cold leg centerline at 225°. Elevation difference between taps is 399 cm.	+762 cm water	+101 kPa	215, 216	
DPV-26-55QM	Across part of downcomer, 66 cm (225°), to 140 cm (180°), below cold leg centerline. Elevation difference between taps is 74 cm.	+127 cm water	+21.2 kPa	217, 218	
DPV-55-110MM	Across part of downcomer, 140 cm (180°), to 279 cm (180°), below cold leg centerline. Elevation difference between taps is 140 cm.	+254 cm water	+33.8 kPa	219, 220	
DPV-110-156MQ	Across part of downcomer, 279 cm (180°), to 396 cm (225°), below cold leg centerline. Elevation difference between taps is 117 cm.	+254 cm water	+33.8 kPa	221, 222	
DPV-156-173QQ	Across part of lower plenum, 396 cm (225°), to 439 cm (225°), below cold leg centerline. Elevation difference between taps is 43 cm.	+51 cm water	+6.47 kPa	223, 224	
DPV-166Q+10	Lower plenum, 422 cm below cold leg centerline at 225° to upper plenum, 27 cm above cold leg centerline at 30°. Elevation difference between taps is 395 cm.	+762 cm water	+101 kPa	225, 226	
<u>ECC SYSTEM</u>					
DPU-ACC1-TB	Top to bottom of intact loop accumulator. Elevation difference between taps is 274 cm.	+762 cm water	+104 kPa	227, 228	
DPB-ACC2-TB	Top to bottom of broken loop accumulator. Elevation difference between taps is 213 cm.	+127 cm water	+17.35 kPa	229, 230	
<u>Steam Generator</u>					
DPU-SG-SEC	Secondary side, differential pressure taps at 114 cm and 320 cm above bottom of tube sheet. Elevation difference between taps is 206 cm.	+254 cm water	+33.7 kPa	231, 232	
DPU-SG-DISC	Across venturi tube, 168 cm downstream from steam generator discharge.	+1770 cm water	+170 kPa	233, 234	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Steam Generator Rupture System</u>					
DPU-SGS-6	From instrumented spool piece in simulated tube rupture injection line to hot leg Spool 6, 318 cm from vessel center.	+6895 kPa	+9230 kPa	235, 236	
DPU-SGS3-TB	Top to bottom of steam generator rupture system accumulator tank.	+1270 cm water	+108 kPa	237, 238	
<u>Pressure Suppression System</u>					
DP-PSS-TB	Top to bottom of pressure suppression tank. Elevation difference between taps is 338 cm.	+762 cm water	+103 kPa	239, 240	
VOLUMETRIC FLOW RATE	Turbine flowmeter, bidirectional:				Data acquisition system range may exceed rated detector range; however, turbine response is linear to flow rates well beyond the rated range.
<u>Intact Loop</u>					
FTU-1	Hot leg, Spool 1, 42 cm from vessel center.	+1.26 to +25.2 $\pm/s$	+0 to 75.7 $\pm/s$	241, 242	
FTU-9	Cold leg, Spool 9, 393 cm from vessel center.	+5.05 to +50.5 $\pm/s$	+75.7 $\pm/s$	241, 242	
FTU-13	Cold leg, Spool 13, 163 cm from vessel center.	+1.26 to +50.5 $\pm/s$	+75.7 $\pm/s$	243, 244	
FTU-15	Cold leg, Spool 15, 42 cm from vessel center.	+1.26 to +50.5 $\pm/s$	+63.1 $\pm/s$	243, 244	
<u>Broken Loop</u>					
FTB-21	Cold leg, Spool 21, 146 cm from vessel center; 3-in. pipe.	+1.26 to +25.2 $\pm/s$	+75.7 $\pm/s$	245, 246	
FTB-30	Hot leg, Spool 30, 63 cm from vessel center; 3-in. pipe.	+1.26 to +25.2 $\pm/s$	+50.5 $\pm/s$	247, 248	
FTB-37	Cold leg, Spool 37, 739 cm from vessel center along hot leg; 2-in. pipe.	+1.26 to +50.5 $\pm/s$	+50.5 $\pm/s$	247, 248	
<u>Core</u>					
FTV-CORE-IN	Entrance to core, 401 cm below cold leg centerline.	+1.26 to +12.6 $\pm/s$	+56.78 $\pm/s$	249, 250	
<u>ECC System</u>					
FTU-HPIS	In line immediately after HPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 $\pm/s$	+0.315 $\pm/s$	251, 252	
FTB-HPIS	In line immediately after HPIS pump for broken loop, 1/2-in. line.	+0.0126 to +0.63 $\pm/s$	+0.315 $\pm/s$	253, 254	
FTU-LPIS	In line leading from LPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 $\pm/s$	+0.315 $\pm/s$	255, 256	
FTB-LPIS	In line leading from LPIS pump for broken loop, 3/4-in. line.	+0.047 to +0.47 $\pm/s$	+0.126 $\pm/s$	257, 258	
FTU-ACC1	In line leading from intact loop accumulator, 1-in. line.	+0.315 to +3.15 $\pm/s$	+4.42 $\pm/s$	259, 260	Data acquisition system saturated from t=72 and t=88 s.
FTB-ACC2	In line leading from broken loop accumulator, 1-in. line.	+0.126 to +1.26 $\pm/s$	+1.39 $\pm/s$	261, 262	Data acquisition system saturated from t=33 and t=48 s.
<u>Steam Generator Rupture System</u>					
FTU-SGS	In simulated tube rupture injection line.	+0.0126 to +0.631 $\pm/s$	+0.315 $\pm/s$	263, 264	
<u>Pressurizer</u>					
FTU-PRIZE	Surge line.	+0.315 to +3.15 $\pm/s$	+6.31 $\pm/s$	265, 266	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
FLUID VELOCITY	Turbine flowmeter, bidirectional.				
<u>Downcomer</u>					
FTV-40A	102 cm below cold leg centerline, 0°.	+0.762 to ±15.24 m/s	±15.24 m/s	267, 268	Data acquisition system saturated intermittently at t=56 s.
FTV-40M	102 cm below cold leg centerline, 180°.	+0.762 to ±15.24 m/s	±15.24 m/s	267, 268	Data acquisition system saturated intermittently between t=30 and t=60 s.
MOMENTUM FLUX	Drag disc, bidirectional.				Drag disc data may exhibit significant temperature dependence. Drag disc data should be used only for short-term transient response.
<u>Intact Loop</u>					
FDU-1	Hot leg, Spool 1, 60 cm from vessel center; target size 2.22 cm.	±298 to ±17 113 kg/m-s ²	±76 090 kg/m-s ²	269, 270	
FDU-5	Hot leg, Spool 5, 256 cm from vessel center; target size 2.54 cm.	±1.49 to ±2976 kg/m-s ²	±6994 kg/m-s ²	271, 272	
FDU-10	Cold leg, Spool 10, 349 cm from vessel center; target size 2.22 cm.	±298 to ±154 769 kg/m-s ²	±35 344 kg/m-s ²	273, 274	
FDU-13	Cold leg, Spool 13, 138 cm from vessel center; target size 2.22 cm.	±298 to ±22 025 kg/m-s ²	±28 528 kg/m-s ²	275, 276	
FDU-15	Cold leg, Spool 15, 60 cm from vessel center; target size 2.22 cm.	±298 to ±21 578 kg/m-s ²	±39 124 kg/m-s ²	277, 278	
<u>Broken Loop</u>					
FDB-21	Cold leg, Spool 21, 134 cm from vessel center, 3-in. pipe; target size 1.67 cm.	±298 to ±104 915 kg/m-s ²	±66 774 kg/m-s ²	279, 280	
FDB-23	Cold leg, Spool 23, 238 cm from vessel center, upstream of vessel side nozzle, 2-in. pipe; target size 1.03 cm.	±298 to ±180 067 kg/m-s ²	±155 320 kg/m-s ²	281, 282	Data acquisition system saturated between t=0 and t=2 s.
FDB-30	Hot leg, Spool 30, 52 cm from vessel center, 3-in. pipe; target size 1.67 cm.	±298 to ±89 290 kg/m-s ²	±67 280 kg/m-s ²	283, 284	
FDB-37	Cold leg, Spool 37, 725 cm from vessel center along hot leg, steam generator outlet, vertical pipe, 2-in. pipe; target size 1.03 cm.	±298 to ±180 067 kg/m-s ²	±374 272 kg/m-s ²	285, 286	
FDB-42	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, upstream of pump-side nozzle, downstream of injection point, 2-in. pipe; target size 1.03 cm.	±298 to ±172 627 kg/m-s ²	±165 320 kg/m-s ²	287, 288	
<u>Vessel</u>					
FNW-FNRF-IN	In core flow mixer box, 381 cm below cold leg centerline; target size 2.54 cm.	±1.44 to ±2977 kg/m-s ²	±1725 kg/m-s ²	289, 290	
DENSITY					
<u>Intact Loop</u>					
GU-1T	Hot leg, Spool 1, 77 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.	1.6 to 1600 kg/m ³	0 to 1600 kg/m ³	291, 292	
GU-1B				293, 294	
GU-1C					
GU-5VR	Hot leg, Spool 5, 246 cm from vessel center, vertical.			295, 296	
GU-10VR	Cold leg, Spool 10, 350 cm from vessel center, vertical.			295, 296	
GU-13VR	Cold leg, Spool 13, 142 cm from vessel center, vertical.			297, 298	
GU-15T	Cold leg, Spool 15, 77 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.			299, 300	Data acquisition system saturated between t=28 and t=65 s.
GU-15B				301, 302	
GU-15C					

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Broken Loop					
		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GB-21T GB-21B GB-21C	Cold leg, Spool 21, 123 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.			303, 304 305, 306	
GB-23VR	Cold leg, Spool 23, 235 cm from vessel center, vertical.			307, 308	
GB-30T GB-30B GB-30C	Hot leg, Spool 30, 49 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.			309, 310 311, 312	
GB-37HZ	Cold leg, Spool 37, 711 cm from vessel center along hot leg, across vertical pipe, simulated steam generator discharge.			313, 314	
GB-42VR	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, vertical.			315, 316	
Vessel					
		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GV-CUR-150HZ	Core flow mixer box, 386 cm below cold leg centerline, horizontal, 0 to 180°.			317, 318	
GVLP-165HZ	Upper part of lower plenum, 419 cm below cold leg centerline, 4.379 cm below downcomer exit, horizontal 0 to 180°.			319, 320	
GVLP-172HZ	Lower plenum, 437 cm below cold leg centerline, 22 cm below downcomer exit, horizontal, 90 to 270°.			319, 320	
Pressurizer					
GU-PRIZE	Surge line.	1.6 to 1600 kg/m ³	0 to 1600 kg/m ³	321, 322	
MASS FLOW RATE	Mass flow rate obtained by combining density (gamma attenuation technique) with volumetric flow rate (turbine flowmeter) or momentum flux (dray disc).	Range for mass flow is determined from range of individual detectors used in calculation.			
Intact Loop					
FDU-1, GU-1C FTU-1, GU-1C	Hot leg, Spool 1.			323, 324 325, 326	
FDU-5, GU-5VR	Hot leg, Spool 5.			327, 328	
FTU-9, GU-10VR	Cold leg, Spool 9.			329, 330	
FDU-11, GU-11VR FTU-11, GU-11VR	Cold leg, Spool 11.			331, 332	
FDU-13, GU-13VR FTU-13, GU-13VR	Cold leg, Spool 13.			333, 334 335, 336	
FDU-15, GU-15C FTU-15, GU-15C	Cold leg, Spool 15.			337, 338 339, 340	
Broken Loop					
FDB-21, GB-21C FTB-21, GB-21C	Cold leg, Spool 21.			341, 342 343, 344	
FDB-23, GB-23VR	Cold leg, Spool 23.			345, 346	
FDB-30, GB-30C FTB-30, GB-30C	Hot leg, Spool 30.			347, 348 349, 350	
FDB-37, GB-37HZ FTB-37, GB-37HZ	Cold leg, Spool 37.			351, 352 353, 354	
Vessel					
FDV-CORE-IN GV-COR-150HZ	Entrance to core.			355, 356	
FTV-CORE-IN GV-COR-150HZ	Entrance to core.			357, 358	
Pressurizer					
FTU-PRIZE GU-PRIZE	Pressurizer surge line.			359, 360	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
CORE CHARACTERISTICS					
PWRCOR T-1	Core power.	0 to 1600 kW	0 to 2076 kW	361, 362	
PWRCOR T-2	Core power.	0 to 1600 kW	0 to 2602 kW	361, 362	
VOLTCOR-T	Core voltage.		0 to 200 Vdc	363, 364	
AMPCOR-T	Core current.	0 to 10 000 A	0 to 9645 A	365, 366	
PUMP CHARACTERISTICS					
PUMPU-CUR	Pump current.	0 to 25 A	0 to 44 A	367, 368	
PUMPU-RPM	Pump speed.	0 to 3600 rpm	0 to 3600 rpm	369, 370	

[a] Statements at the beginning of a measurement category regarding location and comments, range, and figure apply to all subsequent measurements within the given category unless specified otherwise.

[b] Detectors which were subjected to overrange conditions during portions of the test were capable of withstanding these conditions without change in operating or measuring characteristics when the physical conditions were again within the detector range.

Fig. 9 Fluid temperature in intact loop hot leg (TFU-1 and RBU-2), from -20 to 350 s.

Fig. 10 Fluid temperature in intact loop hot leg (TFU-1 and RBU-2), from -6 to 42 s.

Fig. 11 Fluid temperature in intact loop hot leg (TFU-6), from -20 to 350 s.

Fig. 12 Fluid temperature in intact loop hot leg (TFU-6), from -6 to 42 s.

Fig. 13 Fluid temperature in intact loop cold leg (TFU-7 and TFU-10), from -20 to 350 s.

Fig. 14 Fluid temperature in intact loop cold leg (TFU-7 and TFU-10), from -6 to 42 s.

Fig. 15 Fluid temperature in intact loop cold leg (RBU-14A and TFU-14B), from -20 to 350 s.

Fig. 16 Fluid temperature in intact loop cold leg (RBU-14A and TFU-14B), from -6 to 42 s.

Fig. 17 Fluid temperature in intact loop cold leg (TFU-15), from -20 to 350 s.

Fig. 18 Fluid temperature in intact loop cold leg (TFU-15), from -6 to 42 s.

Fig. 19 Fluid temperature in broken loop, vessel side (TFB-20 and TFB-23), from -20 to 350 s.

Fig. 20 Fluid temperature in broken loop, vessel side (TFB-20 and TFB-23), from -6 to 42 s.

Fig. 21 Fluid temperature in broken loop, pump side (TFB-30, TFB-37, and TFB-42), from -20 to 350 s.

Fig. 22 Fluid temperature in broken loop, pump side (TFB-30, TFB-37, and TFB-42), from -6 to 42 s.

Fig. 23 Fluid temperature in inlet annulus (TFV-ANN-4A and TFV-ANN-4M), from -20 to 350 s.

Fig. 24 Fluid temperature in inlet annulus (TFV-ANN-4A and TFV-ANN-4M), from -6 to 42 s.

Fig. 25 Fluid temperature in downcomer annulus (TFV-ANN-35A, TFV-ANN-70A, TFV-ANN-115A, and TFV-ANN-156A), from -20 to 350 s.

Fig. 26 Fluid temperature in downcomer annulus (TFV-ANN-35A, TFV-ANN-70A, TFV-ANN-115A, and TFV-ANN-156A), from -6 to 42 s.

Fig. 27 Fluid temperature in upper plenum (TFV-UP+13), from -20 to 350 s.

Fig. 28 Fluid temperature in upper plenum (TFV-UP+13), from -6 to 42 s.

Fig. 29 Fluid temperature in lower plenum (TFV-LP-2, TFV-LP-4, and TFV-LP-7), from -20 to 350 s.

Fig. 30 Fluid temperature in lower plenum (TFV-LP-2, TFV-LP-4, and TFV-LP-7), from -6 to 42 s.

Fig. 31 Fluid temperature in core inlet (TFV-CORE-IN), from -20 to 350 s.

Fig. 32 Fluid temperature in core inlet (TFV-CORE-IN), from -6 to 42 s.

Fig. 33 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45), from -20 to 350 s.

Fig. 34 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45), from -6 to 42 s.

Fig. 35 Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45), from -20 to 350 s.

Fig. 36 Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45), from -6 to 42 s.

Fig. 37 Fluid temperature in core, Grid Spacer 10 (TFG-10AB-45), from -20 to 350 s.

Fig. 38 Fluid temperature in core, Grid Spacer 10 (TFG-10AB-45), from -6 to 42 s.

Fig. 39 Fluid temperature in intact loop coolant injection line (TFU-ECC-14), from -20 to 350 s.

Fig. 40 Fluid temperature in intact loop coolant injection line (TFU-ECC-14), from -6 to 42 s.

Fig. 41 Fluid temperature in broken loop coolant injection line (TFB-ECC-42), from -20 to 350 s.

Fig. 42 Fluid temperature in broken loop coolant injection line (TFB-ECC-42), from -6 to 42 s.

Fig. 43 Fluid temperature in steam generator, feedwater line (TFU-SGFW), from -20 to 350 s.

Fig. 44 Fluid temperature in steam generator, feedwater line (TFU-SGFW), from -6 to 42 s.

Fig. 45 Fluid temperature in steam generator, steam dome (TFU-SGSD), from -20 to 350 s.

Fig. 46 Fluid temperature in steam generator, steam dome (TFU-SGSD), from -6 to 42 s.

Fig. 47 Fluid temperature in steam generator, secondary side (TFU-SG1, TFU-SG2, and TFU-SG3), from -20 to 350 s.

Fig. 48 Fluid temperature in steam generator, secondary side (TFU-SG1, TFU-SG2, and TFU-SG3), from -6 to 42 s.

Fig. 49 Fluid temperature in steam generator rupture system accumulator (TFU-SGS3), from -20 to 350 s.

Fig. 50 Fluid temperature in steam generator rupture system accumulator (TFU-SGS3), from -6 to 42 s.

Fig. 51 Fluid temperature in steam generator rupture system injection line (TFU-SGS), from -20 to 350 s.

Fig. 52 Fluid temperature in steam generator rupture system injection line (TFU-SGS), from -6 to 42 s.

Fig. 53 Fluid temperature in steam generator rupture system (TFU-SGS-D), from -20 to 350 s.

Fig. 54 Fluid temperature in steam generator rupture system (TFU-SGS-D), from -6 to 42 s.

Fig. 55 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -20 to 350 s.

Fig. 56 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -6 to 42 s.

Fig. 57 Fluid temperature in pressure suppression tank (TF-PSS-33 and TF-PSS-130), from -20 to 350 s.

Fig. 58 Fluid temperature in pressure suppression tank (TF-PSS-33 and TF-PSS-130), from -6 to 42 s.

Fig. 59 Material temperature in intact loop (TMU-1T16), from -20 to 350 s.

Fig. 60 Material temperature in intact loop (TMU-1T16), from -6 to 42 s.

Fig. 61 Material temperature in broken loop (TMB-20B16 and TMB-30B16), from -20 to 350 s.

Fig. 62 Material temperature in broken loop (TMB-20B16 and TMB-30B16), from -6 to 42 s.

Fig. 63 Material temperature in vessel filler (TMV-FI-115A and TMV-FI-156A), from -20 to 350 s.

Fig. 64 Material temperature in vessel filler (TMV-FI-115A and TMV-FI-156A), from -6 to 42 s.

Fig. 65 Material temperature in vessel filler (TMV-F0-156A), from -20 to 350 s.

Fig. 66 Material temperature in vessel filler (TMV-F0-156A), from -6 to 42 s.

Fig. 67 Material temperature in vessel filler (TIV-F0-35A and TIV-F0-115A), from -20 to 350 s.

Fig. 68 Material temperature in vessel filler (TIV-F0-35A and TIV-F0-115A), from -6 to 42 s.

Fig. 69 Material temperature in core barrel inner diameter (TMV-CI-70A), from -20 to 350 s.

Fig. 70 Material temperature in core barrel inner diameter (TMV-CI-70A), from -6 to 42 s.

Fig. 71 Material temperature in core barrel inner diameter (TMV-CO-70A and TMV-CO-115A), from -20 to 350 s.

Fig. 72 Material temperature in core barrel inner diameter (TMV-CO-70A and TMV-CO-115A), from -6 to 42 s.

Fig. 73 Material temperature in core housing filler (TMV-HF-115W, TMV-HF-127W, and TMV-HF-138W), from -20 to 350 s.

Fig. 74 Material temperature in core housing filler (TMV-HF-115W, TMV-HF-127W, and TMV-HF-138W), from -6 to 42 s.

Fig. 75 Material temperature in steam generator (TMU-SG1, TMU-SG2, and TMU-SG3), from -20 to 350 s.

Fig. 76 Material temperature in steam generator (TMU-SG1, TMU-SG2, and TMU-SG3), from -6 to 42 s.

Fig. 77 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -20 to 350 s.

Fig. 78 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -6 to 42 s.

Fig. 79 Core heater temperature, Rod D-5 (TH-D5-29), from -20 to 350 s.

Fig. 80 Core heater temperature, Rod D-5 (TH-D5-29), from -6 to 42 s.

Fig. 81 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -20 to 350 s.

Fig. 82 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -6 to 42 s.

Fig. 83 Core heater temperature, Rod E-5 (TH-E5-20 and TH-E5-25), from -20 to 350 s.

Fig. 84 Core heater temperature, Rod E-5 (TH-E5-20 and TH-E5-25), from -6 to 42 s.

Fig. 85 Core heater temperature, Rod A-4 (TH-A4-09, TH-A4-29, and TH-A4-39), from -20 to 350 s.

Fig. 86 Core heater temperature, Rod A-4 (TH-A4-09, TH-A4-29, and TH-A4-39), from -6 to 42 s.

Fig. 87 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -20 to 350 s.

Fig. 88 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -6 to 42 s.

Fig. 89 Core heater temperature, Rod B-3 (TH-B3-32), from -20 to 350 s.

Fig. 90 Core heater temperature, Rod B-3 (TH-B3-32), from -6 to 42 s.

Fig. 91 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -20 to 350 s.

Fig. 92 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -6 to 42 s.

Fig. 93 Core heater temperature, Rod B-6 (TH-B6-29), from -20 to 350 s.

Fig. 94 Core heater temperature, Rod B-6 (TH-B6-29), from -6 to 42 s.

Fig. 95 Core heater temperature, Rod C-2 (TH-C2-38), from -20 to 350 s.

Fig. 96 Core heater temperature, Rod C-2 (TH-C2-38), from -6 to 42 s.

Fig. 97 Core heater temperature, Rod C-4 (TH-C4-20, TH-C4-26, and TH-C4-53), from -20 to 350 s.

Fig. 98 Core heater temperature, Rod C-4 (TH-C4-20, TH-C4-26, and TH-C4-53), from -6 to 42 s.

Fig. 99 Core heater temperature, Rod C-5 (TH-C5-28), from -20 to 350 s.

Fig. 100 Core heater temperature, Rod C-5 (TH-C5-28), from -6 to 42 s.

Fig. 101 Core heater temperature, Rod C-6 (TH-C6-53), from -20 to 350 s.

Fig. 102 Core heater temperature, Rod C-6 (TH-C6-53), from -6 to 42 s.

Fig. 103 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -20 to 350 s.

Fig. 104 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -6 to 42 s.

Fig. 105 Core heater temperature, Rod D-1 (TH-D1-21), from -20 to 350 s.

Fig. 106 Core heater temperature, Rod D-1 (TH-D1-21), from -6 to 42 s.

Fig. 107 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -20 to 350 s.

Fig. 108 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -6 to 42 s.

Fig. 109 Core heater temperature, Rod D-3 (TH-D3-29 and TH-D3-39), from -20 to 350 s.

Fig. 110 Core heater temperature, Rod D-3 (TH-D3-29 and TH-D3-39), from -6 to 42 s.

Fig. 111 Core heater temperature, Rod D-6 (TH-D6-25), from -20 to 350 s.

Fig. 112 Core heater temperature, Rod D-6 (TH-D6-25), from -6 to 42 s.

Fig. 113 Core heater temperature, Rod D-7 (TH-D7-20), from -20 to 350 s.

Fig. 114 Core heater temperature, Rod D-7 (TH-D7-20), from -6 to 42 s.

Fig. 115 Core heater temperature, Rod D-8 (TH-D8-26), from -20 to 350 s.

Fig. 116 Core heater temperature, Rod D-8 (TH-D8-26), from -6 to 42 s.

Fig. 117 Core heater temperature, Rod E-1 (TH-E1-33), from -20 to 350 s.

Fig. 118 Core heater temperature, Rod E-1 (TH-E1-33), from -6 to 42 s.

Fig. 119 Core heater temperature, Rod E-2 (TH-E2-20 and TH-E2-33), from -20 to 350 s.

Fig. 120 Core heater temperature, Rod E-2 (TH-E2-20 and TH-E2-33), from -6 to 42 s.

Fig. 121 Core heater temperature, Rod E-3 (TH-E3-05, TH-E3-20, and TH-E3-24), from -20 to 350 s.

Fig. 122 Core heater temperature, Rod E-3 (TH-E3-05, TH-E3-20, and TH-E3-24), from -6 to 42 s.

Fig. 123 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -20 to 350 s.

Fig. 124 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -6 to 42 s.

Fig. 125 Core heater temperature, Rod E-7 (TH-E7-44), from -20 to 350 s.

Fig. 126 Core heater temperature, Rod E-7 (TH-E7-44), from -6 to 42 s.

Fig. 127 Core heater temperature, Rod E-8 (TH-E8-14 and TH-E8-29), from -20 to 350 s.

Fig. 128 Core heater temperature, Rod E-8 (TH-E8-14 and TH-E8-29), from -6 to 42 s.

Fig. 129 Core heater temperature, Rod F-2 (TH-F2-07, TH-F2-22, and TH-F2-25), from -20 to 350 s.

Fig. 130 Core heater temperature, Rod F-2 (TH-F2-07, TH-F2-22, and TH-F2-25), from -6 to 42 s.

Fig. 131 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -20 to 350 s.

Fig. 132 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -6 to 42 s.

Fig. 133 Core heater temperature, Rod F-5 (TH-F5-20, TH-F5-26, TH-F5-33, and TH-F5-53), from -20 to 350 s.

Fig. 134 Core heater temperature, Rod F-5 (TH-F5-20, TH-F5-26, TH-F5-33, and TH-F5-53), from -6 to 42 s.

Fig. 135 Core heater temperature, Rod G-3 (TH-G3-13), from -20 to 350 s.

Fig. 136 Core heater temperature, Rod G-3 (TH-G3-13), from -6 to 42 s.

Fig. 137 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -20 to 350 s.

Fig. 138 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -6 to 42 s.

Fig. 139 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -20 to 350 s.

Fig. 140 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -6 to 42 s.

Fig. 141 Core heater temperature, Rod H-5 (TH-H5-32), from -20 to 350 s.

Fig. 142 Core heater temperature, Rod H-5 (TH-H5-32), from -6 to 42 s.

Fig. 143 Pressure in intact loop (PU-13 and PU-15L), from -20 to 350 s.

Fig. 144 Pressure in intact loop (PU-13 and PU-15L), from -6 to 42 s.

Fig. 145 Pressure in broken loop, vessel side (PB-21 and PB-23), from -20 to 350 s.

Fig. 146 Pressure in broken loop, vessel side (PB-21 and PB-23), from -6 to 42 s.

Fig. 147 Pressure in broken loop, vessel side (PB-CN4), from -20 to 350 s.

Fig. 148 Pressure in broken loop, vessel side (PB-CN4), from -6 to 42 s.

Fig. 149 Pressure in broken loop, pump side (PB-37 and PB-42), from -20 to 350 s.

Fig. 150 Pressure in broken loop, pump side (PB-37 and PB-42), from -6 to 42 s.

Fig. 151 Pressure in broken loop, vessel side (PB-HN1), from -20 to 350 s.

Fig. 152 Pressure in broken loop, vessel side (PB-HN1), from -6 to 42 s.

Fig. 153 Pressure in vessel (PV-UP+10 and PV-LP-166), from -20 to 350 s.

Fig. 154 Pressure in vessel (PV-UP+10 and PV-LP-166), from -6 to 42 s.

Fig. 155 Pressure in intact loop accumulator (PU-ACC1), from -20 to 350 s.

Fig. 156 Pressure in intact loop accumulator (PU-ACC1), from -6 to 42 s.

Fig. 157 Pressure in broken loop accumulator (PB-ACC2), from -20 to 350 s.

Fig. 158 Pressure in broken loop accumulator (PB-ACC2), from -6 to 42 s.

Fig. 159 Pressure in steam generator, secondary side (PU-SGSD), from -20 to 350 s.

Fig. 160 Pressure in steam generator, secondary side (PU-SGSD), from -6 to 42 s.

Fig. 161 Pressure in steam generator, secondary side (PU-SGS3), from -20 to 350 s.

Fig. 162 Pressure in steam generator, secondary side (PU-SGS3), from -6 to 42 s.

Fig. 163 Pressure in pressurizer (PU-PRIZE), from -20 to 350 s.

Fig. 164 Pressure in pressurizer (PU-PRIZE), from -6 to 42 s.

Fig. 165 Pressure in pressure suppression tank (P-PSS), from -20 to 350 s.

Fig. 166 Pressure in pressure suppression tank (P-PSS), from -6 to 42 s.

Fig. 167 Differential pressure in intact loop (DPU-3-7), from -20 to 350 s.

Fig. 168 Differential pressure in intact loop (DPU-3-7), from -6 to 42 s.

Fig. 169 Differential pressure in intact loop (DPU-6-SGIP), from -20 to 350 s.

Fig. 170 Differential pressure in intact loop (DPU-6-SGIP), from -6 to 42 s.

Fig. 171 Differential pressure in intact loop (DPU-SGOP-7), from -20 to 350 s.

Fig. 172 Differential pressure in intact loop (DPU-SGOP-7), from -6 to 42 s.

Fig. 173 Differential pressure in intact loop (DPU-7-10), from -20 to 350 s.

Fig. 174 Differential pressure in intact loop (DPU-7-10), from -6 to 42 s.

Fig. 175 Differential pressure in intact loop (DPU-12-10), from -20 to 350 s.

Fig. 176 Differential pressure in intact loop (DPU-12-10), from -6 to 42 s.

Fig. 177 Differential pressure in intact loop, low range (DPU-12-10L), from -20 to 350 s.

Fig. 178 Differential pressure in intact loop, low range (DPU-12-10L), from -6 to 42 s.

Fig. 179 Differential pressure in intact loop (DPU-12-15), from -20 to 350 s.

Fig. 180 Differential pressure in intact loop (DPU-12-15), from -6 to 42 s.

Fig. 181 Differential pressure in intact loop (DPU-15-3), from -20 to 350 s.

Fig. 182 Differential pressure in intact loop (DPU-15-3), from -6 to 42 s.

Fig. 183 Differential pressure in intact loop, low range (DPU-15-3L), from -20 to 350 s.

Fig. 184 Differential pressure in intact loop, low range (DPU-15-3L), from -6 to 42 s.

Fig. 185 Differential pressure in intact loop (DPU-PRESLL), from -20 to 350 s.

Fig. 186 Differential pressure in intact loop (DPU-PRESLL), from -6 to 42 s.

Fig. 187 Differential pressure in intact loop (DPU-PR-4), from -20 to 350 s.

Fig. 188 Differential pressure in intact loop (DPU-PR-4), from -6 to 42 s.

Fig. 189 Differential pressure in broken loop (DPB-21-IANN), from -20 to 350 s.

Fig. 190 Differential pressure in broken loop (DPB-21-IANN), from -6 to 42 s.

Fig. 191 Differential pressure in broken loop (DPB-23-CN1), from -20 to 350 s.

Fig. 192 Differential pressure in broken loop (DPB-23-CN1), from -6 to 42 s.

Fig. 193 Differential pressure in broken loop (DPB-CN1-24), from -20 to 350 s.

Fig. 194 Differential pressure in broken loop (DPB-CN1-24), from -6 to 42 s.

Fig. 195 Differential pressure in broken loop (DPB-30-43), from -20 to 350 s.

Fig. 196 Differential pressure in broken loop (DPB-30-43), from -6 to 42 s.

Fig. 197 Differential pressure in broken loop (DPB-32U-36L), from -20 to 350 s.

Fig. 198 Differential pressure in broken loop (DPB-32U-36L), from -6 to 42 s.

Fig. 199 Differential pressure in broken loop (DPB-36L-37), from -20 to 350 s.

Fig. 200 Differential pressure in broken loop (DPB-36L-37), from -6 to 42 s.

Fig. 201 Differential pressure in broken loop (DPB-38-40), from -20 to 350 s.

Fig. 202 Differential pressure in broken loop (DPB-38-40), from -6 to 42 s.

Fig. 203 Differential pressure in broken loop (DPB-40-42), from -20 to 350 s.

Fig. 204 Differential pressure in broken loop (DPB-40-42), from -6 to 42 s.

Fig. 205 Differential pressure in broken loop (DPB-42-HN1), from -20 to 350 s.

Fig. 206 Differential pressure in broken loop (DPB-42-HN1), from -6 to 42 s.

Fig. 207 Differential pressure in broken loop (DPB-HN1-43), from -20 to 350 s.

Fig. 208 Differential pressure in broken loop (DPB-HN1-43), from -6 to 42 s.

Fig. 209 Differential pressure in vessel (DPV-UP-IANN), from -20 to 350 s.

Fig. 210 Differential pressure in vessel (DPV-UP-IANN), from -6 to 42 s.

Fig. 211 Differential pressure in vessel (DPV-0-9GQ), from -20 to 350 s.

Fig. 212 Differential pressure in vessel (DPV-0-9GQ), from -6 to 42 s.

Fig. 213 Differential pressure in vessel (DPV-9-26QQ), from -20 to 350 s.

Fig. 214 Differential pressure in vessel (DPV-9-26QQ), from -6 to 42 s.

Fig. 215 Differential pressure in vessel (DPV-9-166QQ), from -20 to 350 s.

Fig. 216 Differential pressure in vessel (DPV-9-166QQ), from -6 to 42 s.

Fig. 217 Differential pressure in vessel (DPV-26-55QM), from -20 to 350 s.

Fig. 218 Differential pressure in vessel (DPV-26-55QM), from -6 to 42 s.

Fig. 219 Differential pressure in vessel (DPV-55-110MM), from -20 to 350 s.

Fig. 220 Differential pressure in vessel (DPV-55-110MM), from -6 to 42 s.

Fig. 221 Differential pressure in vessel (DPV-110-156MQ), from -20 to 350 s.

Fig. 222 Differential pressure in vessel (DPV-110-156MQ), from -6 to 42 s.

Fig. 223 Differential pressure in vessel (DPV-156-173QQ), from -20 to 350 s.

Fig. 224 Differential pressure in vessel (DPV-156-173QQ), from -6 to 42 s.

Fig. 225 Differential pressure in vessel (DPV-166Q+10), from -20 to 350 s.

Fig. 226 Differential pressure in vessel (DPV-166Q+10), from -6 to 42 s.

Fig. 227 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -20 to 350 s.

Fig. 228 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -6 to 42 s.

Fig. 229 Differential pressure in broken loop accumulator (DPB-ACC2-TB), from -20 to 350 s.

Fig. 230 Differential pressure in broken loop accumulator (DPB-ACC2-TB), from -6 to 42 s.

Fig. 231 Differential pressure in steam generator secondary (DPU-SG-SEC), from -20 to 350 s.

Fig. 232 Differential pressure in steam generator secondary (DPU-SG-SEC), from -6 to 42 s.

Fig. 233 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -20 to 350 s.

Fig. 234 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -6 to 42 s.

Fig. 235 Differential pressure between simulated rupture injection line and Spool 6 (DPU-SGS-6), from -20 to 350 s.

Fig. 236 Differential pressure between simulated rupture injection line and Spool 6 (DPU-SGS-6), from -6 to 42 s.

Fig. 237 Differential pressure in intact loop accumulator (DPU-SGS3-TB), from -20 to 350 s.

Fig. 238 Differential pressure in intact loop accumulator (DPU-SGS3-TB), from -6 to 42 s.

Fig. 239 Differential pressure in pressure suppression tank (DP-PSS-TB), from -20 to 350 s.

Fig. 240 Differential pressure in pressure suppression tank (DP-PSS-TB), from -6 to 42 s.

Fig. 241 Volumetric flow in intact loop (FTU-1 and FTU-9), from -20 to 350 s.

Fig. 242 Volumetric flow in intact loop (FTU-1 and FTU-9), from -6 to 42 s.

Fig. 243 Volumetric flow in intact loop (FTU-13 and FTU-15), from -20 to 350 s.

Fig. 244 Volumetric flow in intact loop (FTU-13 and FTU-15), from -6 to 42 s.

Fig. 245 Volumetric flow in broken loop (FTB-21), from -20 to 350 s.

Fig. 246 Volumetric flow in broken loop (FTB-21), from -6 to 42 s.

Fig. 247 Volumetric flow in broken loop (FTB-30 and FTB-37), from -20 to 350 s.

Fig. 248 Volumetric flow in broken loop (FTB-30 and FTB-37), from -6 to 42 s.

Fig. 249 Volumetric flow in core entrance (FTV-CORE-IN), from -20 to 350 s.

Fig. 250 Volumetric flow in core entrance (FTV-CORE-IN), from -6 to 42 s.

Fig. 251 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -20 to 350 s.

Fig. 252 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -6 to 42 s.

Fig. 253 Volumetric flow in broken loop high pressure injection line (FTB-HPIS), from -20 to 350 s.

Fig. 254 Volumetric flow in broken loop high pressure injection line (FTB-HPIS), from -6 to 42 s.

Fig. 255 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -20 to 350 s.

Fig. 256 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -6 to 42 s.

Fig. 257 Volumetric flow in broken loop low pressure injection line (FTB-LPIS), from -20 to 350 s.

Fig. 258 Volumetric flow in broken loop low pressure injection line (FTB-LPIS), from -6 to 42 s.

Fig. 259 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -20 to 350 s.

Fig. 260 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -6 to 42 s.

Fig. 261 Volumetric flow in broken loop accumulator discharge line (FTB-ACC2), from -20 to 350 s.

Fig. 262 Volumetric flow in broken loop accumulator discharge line (FTB-ACC2), from -6 to 42 s.

Fig. 263 Volumetric flow in intact loop steam generator (FTU-SGS), from -20 to 350 s.

Fig. 264 Volumetric flow in intact loop steam generator (FTU-SGS), from -6 to 42 s.

Fig. 265 Volumetric flow from pressurizer (FTU-PRIZE), from -20 to 350 s.

Fig. 266 Volumetric flow from pressurizer (FTU-PRIZE), from -6 to 42 s.

Fig. 267 Fluid velocity in vessel (FTV-40A and FTV-40M), from -20 to 350 s.

Fig. 268 Fluid velocity in vessel (FTV-40A and FTV-40M), from -6 to 42 s.

Fig. 269 Momentum flux in intact loop (FDU-1), from -20 to 350 s.

Fig. 270 Momentum flux in intact loop (FDU-1), from -6 to 42 s.

Fig. 271 Momentum flux in intact loop (FDU-5), from -20 to 350 s.

Fig. 272 Momentum flux in intact loop (FDU-5), from -6 to 42 s.

Fig. 273 Momentum flux in intact loop (FDU-10), from -20 to 350 s.

Fig. 274 Momentum flux in intact loop (FDU-10), from -6 to 42 s.

Fig. 275 Momentum flux in intact loop (FDU-13), from -20 to 350 s.

Fig. 276 Momentum flux in intact loop (FDU-13), from -6 to 42 s.

Fig. 277 Momentum flux in intact loop (FDU-15), from -20 to 350 s.

Fig. 278 Momentum flux in intact loop (FDU-15), from -6 to 42 s.

Fig. 279 Momentum flux in broken loop (FDB-21), from -20 to 350 s.

Fig. 280 Momentum flux in broken loop (FDB-21), from -6 to 42 s.

Fig. 281 Momentum flux in broken loop (FDB-23), from -20 to 350 s.

Fig. 282 Momentum flux in broken loop (FDB-23), from -6 to 42 s.

Fig. 283 Momentum flux in broken loop (FDB-30), from -20 to 350 s.

Fig. 284 Momentum flux in broken loop (FDB-30), from -6 to 42 s.

Fig. 285 Momentum flux in broken loop (FDB-37), from -20 to 350 s.

Fig. 286 Momentum flux in broken loop (FDB-37), from -6 to 42 s.

Fig. 287 Momentum flux in broken loop (FDB-42), from -20 to 350 s.

Fig. 288 Momentum flux in broken loop (FDB-42), from -6 to 42 s.

Fig. 289 Momentum flux in core entrance (FDV-CORE-IN), from -20 to 350 s.

Fig. 290 Momentum flux in core entrance (FDV-CORE-IN), from -6 to 42 s.

Fig. 291 Density in intact loop (GU-1T and GU-1B), from -20 to 350 s.

Fig. 292 Density in intact loop (GU-1T and GU-1B), from -6 to 42 s.

Fig. 293 Density in intact loop (GU-1C), from -20 to 350 s.

Fig. 294 Density in intact loop (GU-1C), from -6 to 42 s.

Fig. 295 Density in intact loop (GU-5VR and GU-10VR), from -20 to 350. s.

Fig. 296 Density in intact loop (GU-5VR and GU-10VR), from -6 to 42. s.

Fig. 297 Density in intact loop (GU-13VR), from -20 to 350 s.

Fig. 298 Density in intact loop (GU-13VR), from -6 to 42 s.

Fig. 299 Density in intact loop (GU-15T and GU-15B), from -20 to 350 s.

Fig. 300 Density in intact loop (GU-15T and GU-15B), from -6 to 42 s.

Fig. 301 Density in intact loop (GU-15C), from -20 to 350 s.

Fig. 302 Density in intact loop (GU-15C), from -6 to 42 s.

Fig. 303 Density in broken loop (GB-21T and GB-21B), from -20 to 350 s.

Fig. 304 Density in broken loop (GB-21T and GB-21B), from -6 to 42 s.

Fig. 305 Density in broken loop (GB-21C), from -20 to 350 s.

Fig. 306 Density in broken loop (GB-21C), from -6 to 42 s.

Fig. 307 Density in broken loop (GB-23VR), from -20 to 350 s.

Fig. 308 Density in broken loop (GB-23VR), from -6 to 42 s.

Fig. 309 Density in broken loop (GB-30I and GB-30B), from -20 to 350 s.

Fig. 310 Density in broken loop (GB-30T and GB-30B), from -6 to 42 s.

Fig. 311 Density in broken loop (GB-30C), from -20 to 350 s.

Fig. 312 Density in broken loop (GB-30C), from -6 to 42 s.

Fig. 313 Density in broken loop (GB-37HZ), from -20 to 350 s.

Fig. 314 Density in broken loop (GB-37HZ), from -6 to 42 s.

Fig. 315 Density in broken loop (GB-42VR), from -20 to 350 s.

Fig. 316 Density in broken loop (GB-42VR), from -6 to 42 s.

Fig. 317 Density in vessel (GV-COR-150HZ), from -20 to 350 s.

Fig. 318 Density in vessel (GV-COR-150HZ), from -6 to 42 s.

Fig. 319 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -20 to 350 s.

Fig. 320 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -6 to 42 s.

Fig. 321 Density in pressurizer (GU-PRIZE), from -20 to 350 s.

Fig. 322 Density in pressurizer (GU-PRIZE), from -6 to 42 s.

Fig. 323 Mass flow in intact loop (FDU-1, GU-1C), from -20 to 350 s.

Fig. 324 Mass flow in intact loop (FDU-1, GU-1C), from -6 to 42 s.

Fig. 325 Mass flow in intact loop (FTU-1, GU-1C), from -20 to 350 s.

Fig. 326 Mass flow in intact loop (FTU-1, GU-1C), from -6 to 42 s.

Fig. 327 Mass flow in intact loop (FDU-5, GU-5VR), from -20 to 350 s.

Fig. 328 Mass flow in intact loop (FDU-5, GU-5VR), from -6 to 42 s.

Fig. 329 Mass flow in intact loop (FTU-9, GU-10VR), from -20 to 350 s.

Fig. 330 Mass flow in intact loop (FTU-9, GU-10VR), from -6 to 42 s.

Fig. 331 Mass flow in intact loop (FDU-10, GU-10VR), from -20 to 350 s.

Fig. 332 Mass flow in intact loop (FDU-10, GU-10VR), from -6 to 42 s.

Fig. 333 Mass flow in intact loop (FDU-13, GU-13VR), from -20 to 350 s.

Fig. 334 Mass flow in intact loop (FDU-13, GU-13VR), from -6 to 42 s.

Fig. 335 Mass flow in intact loop (FTU-13, GU-13VR), from -20 to 350 s.

Fig. 336 Mass flow in intact loop (FTU-13, GU-13VR), from -6 to 42 s.

Fig. 337 Mass flow in intact loop (FDU-15, GU-15C), from -20 to 350 s.

Fig. 338 Mass flow in intact loop (FDU-15, GU-15C), from -6 to 42 s.

Fig. 339 Mass flow in intact loop (FTU-15, GU-15C), from -20 to 350 s.

Fig. 340 Mass flow in intact loop (FTU-15, GU-15C), from -6 to 42 s.

Fig. 341 Mass flow in broken loop (FDB-21, GB-21C), from -20 to 350 s.

Fig. 342 Mass flow in broken loop (FDB-21, GB-21C), from -6 to 42 s.

Fig. 343 Mass flow in broken loop (FTB-21, GB-21C), from -20 to 350 s.

Fig. 344 Mass flow in broken loop (FTB-21, GB-21C), from -6 to 42 s.

Fig. 345 Mass flow in broken loop (FDB-23, GB-23VR), from -20 to 350 s.

Fig. 346 Mass flow in broken loop (FDB-23, GB-23VR), from -6 to 42 s.

Fig. 347 Mass flow in broken loop (FDB-30, GB-30C), from -20 to 350 s.

Fig. 348 Mass flow in broken loop (FDB-30, GB-30C), from -6 to 42 s.

Fig. 349 Mass flow in broken loop (FTB-30, GB-30C), from -20 to 350 s.

Fig. 350 Mass flow in broken loop (FTB-30, GB-30C), from -6 to 42 s.

Fig. 351 Mass flow in broken loop (FDB-37, GB-37HZ), from -20 to 350 s.

Fig. 352 Mass flow in broken loop (FDB-37, GB-37HZ), from -6 to 42 s.

Fig. 353 Mass flow in broken loop (FTB-37, GB-37HZ), from -20 to 350 s.

Fig. 354 Mass flow in broken loop (FTB-37, GB-37HZ), from -6 to 42 s.

Fig. 355 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ), from -20 to 350 s.

Fig. 356 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 357 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -20 to 350 s.

Fig. 358 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 359 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -20 to 350 s.

Fig. 360 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -6 to 42 s.

Fig. 361 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -20 to 350 s.

Fig. 362 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -6 to 42 s.

Fig. 363 Core heater voltage (VOLT COR-T), from -20 to 350 s.

Fig. 364 Core heater voltage (VOLT COR-T), from -6 to 42 s.

Fig. 365 Core heater total current (AMPCOR-T), from -20 to 350 s.

Fig. 366 Core heater total current (AMPCOR-T), from -6 to 42 s.

Fig. 367 Primary pump current (PUMPU-CUR), from -20 to 350 s.

Fig. 368 Primary pump current (PUMPU-CUR), from -6 to 42 s.

Fig. 369 Primary pump speed (PUMPU-RPM), from -20 to 350 s.

Fig. 370 Primary pump speed (PUMPU-RPM), from -6 to 42 s.

IV. REFERENCE

1. E. M. Feldman and D. J. Olson, *Semiscale Mod-1 Program and System Description for the Blowdown Heat Transfer Tests (Test Series 2)*, ANCR-1230 (August 1975).

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APPENDIX A

DATA ACQUISITION SYSTEM CAPABILITIES

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APPENDIX A

DATA ACQUISITION SYSTEM CAPABILITIES

The Semiscale Mod-1 system provides for the acquisition, processing, and presentation of test data. Detectors, signal conditioners, signal processors, and recording and display equipment comprise the test data system. The data obtained are principally recorded on an on-line digital system. Selected data channels are also recorded on an analog system.

The on-line digital system is called the digital data acquisition and processing system (DDAPS). The DDAPS has dual and single speed capabilities with identical storage and data output limitations. The dual speed mode is used to extend the recording time when obtaining high frequency data.

From each of up to 240 data channels, the test data system stores 20 blocks of data. Each block of data contains 920 words (each word is the abscissa and ordinate of a data point) of digital information. These 920 words represent a fixed storage display.

The maximum measured throughput rate for the system is 24 000 words per second. This throughput rate can be reduced in increments of 100 words per second. The throughput rate, the number of data channels recorded, and the fixed display of 920 words per block determine the time base for displaying the data.

After the data have been stored, data reduction can be made for presentation and analysis purposes. Because of hardware limitations and aesthetic considerations of data presentation, only certain time bases are used when the data are reduced. For data displayed from -20 to 300 s, the recorded data are made to occupy a 320 s span. This yields a time base of 16 s, which is the 320 s span divided by the 20 blocks of recorded data.

Generally, 920 words from a given data channel are displayed in the nominal time base of 16 s. Integral (1 to 20) multiples of 16 s may be used as variations on the nominal time base. Because the output is fixed at 920 words, data compression is made by averaging adjacent data points to give the desired compression.

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APPENDIX B

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1 TEST S-28-2

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APPENDIX B

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1 TEST S-28-2

Many of the transducers used in the Semiscale Mod-1 system exhibit significant sensitivity to one or more spurious inputs. Strain gage bridge circuits used in pressure transducers, differential pressure transducers, and drag discs are sensitive to changes in ambient temperature. Differential pressure cells are also sensitive to changes in system pressure. Photomultiplier tubes used as gamma ray detectors in the density transducers are sensitive to temperature changes, as well as to random variations in the locations of the radiation sources. Core power measurements depend on a calibrated resistor, whose resistance changes in value as a function of time and power level as it heats up.

Although the errors introduced into the data by spurious secondary inputs generally do not exceed the specified error ranges of the transducers, significant improvement in measurement accuracy can be achieved if the secondary sensitivity can be identified and removed. In the case of the drag discs, corrections are absolutely necessary because the signal due to temperature fluctuations can exceed that due to flow by several hundred percent. Since the exact values of the spurious inputs to which different transducers might be sensitive cannot often be easily predicted and are sometimes inconvenient to measure, secondary effects have been accounted for by correcting the data after the test rather than by using elaborate real time programs in the data acquisition system computer. The methods and results of the posttest data correction analysis for Test S-28-2 are presented in the following paragraphs and tables.

1. PRESSURE MEASUREMENTS

Corrections to pressure transducer measurements in the main system loop are based on data taken from the standard reference (Heise) gauge at Spool 4, taken 15 s before initiation of blowdown and at 300 s after initiation of blowdown. The pressure readings are adjusted to account for pressure variations around the main loop, using the readings of nearby differential pressure cells. A linear correction is then applied to the pressure data to match the data to the calculated reference data at the two specified time points.

Correction of the steam generator secondary pressure (PU-SGSD) and intact and broken loop emergency core coolant (ECC) accumulator pressure (PU-ACC1 and PB-ACC2) measurements are done in the same manner as for the main loop pressures using Heise gauges installed expressly for this purpose. The data from the pressure transducer for the pressure suppression system (P-PSS) are corrected to match the process instrumentation at preblowdown conditions.

Pressure measurement corrections are performed using the data acquisition system (DAS) computer using the following equation:

$$F'(t) = C_0 + C_1 [F(t)]$$

where

$F'(t)$ = corrected data

$F(t)$ = raw data

C_0 = offset

C_1 = scaling factor.

The values of the offset and scaling factor are given in Table B-I.

TABLE B-I

CONSTANTS FOR PRESSURE MEASUREMENT
CORRECTIONS (TEST S-28-2)

<u>Detector Identification</u>	<u>C_0</u>	<u>C_1</u>
PB-23	-1.6	0.985 6
PU-SGSD	-0.6	1.023 4
PU-PRIZE	-6.2	0.986 4
PV-LP-166	3.5	0.979 8

2. DIFFERENTIAL PRESSURE MEASUREMENTS

Pressure sensitivity in the differential pressure cells in the main system loop is determined from the pretest system pressure check. Digital data are recorded for all measurements at ambient temperature, with no system flow, at pressures of ambient, 1380, 3450, 6900, 10 350, 13 800, and 15 500 kPa. The output of the differential pressure cells is plotted against system pressure, with the resulting plots used to describe the pressure response of the transducers.

The response of the differential pressure cells due to ambient temperature is determined from a digital data scan taken at 533 K and 12 150 kPa with no system flow. The measured transducer outputs are corrected for pressure and compared with the values calculated due only to the density difference between the water inside the loop (533 K) and outside the loop in the sense lines (300 to 311 K).

The difference between the measured pressure corrected value and the calculated value is the thermal drift. After the data scan at 533 K is made, no more opportunities exist to obtain data with the pump stopped and the system full of fluid; therefore, for lack of later data, the thermal drift calculated from the 533 K data is assumed to be constant throughout the test.

For some differential pressure measurements, the data scan at 533 K cannot be used as a reference for thermal drift, so other references are used. The reading from the steam generator discharge venturi (DPU-SG-DISC) is shifted to read zero after flow is stopped. For these detectors, and those having nonlinear pressure sensitivities, the corrections are performed according to the following equations:

$$F'(t) = KF(t) + C_1 \text{ for } t < t_1 \text{ or when no } t_i \text{ are listed}$$

for time points t , where $t_1 \leq t \leq t_n$

$$F'(t) = KF(t) + C_i + \frac{t - t_i}{t_{i+1} - t_i} (C_{i+1} - C_i) \text{ for } t_i \leq t \leq t_{i+1}$$

where i takes on values 1 to $n-1$

$$F'(t) = KF(t) + C_n \text{ for } t > t_n$$

where

t	=	time
$F'(t)$	=	corrected data
$F(t)$	=	raw data
K	=	scaling factor
C_i and t_i	=	corrections and time points.

The values of the constants are given in Table B-II.

TABLE B-II
CONSTANTS FOR DIFFERENTIAL PRESSURE
MEASUREMENT CORRECTIONS (TEST S-28-2)

<u>Detector Identification</u>	<u>K</u>	<u>C₁</u>	<u>t₁</u>	<u>C₂</u>	<u>t₂</u>	<u>C₃</u>	<u>t₃</u>
DPU-7-10	1	0.689	0	0.648	0.01	0.545	30.0
DPU-12-10	1	-7.129	0	-5.750	0.01	-1.269	30.0
DPB-23-CN1	1	115.141	0	97.905	0.01	22.063	30.0
DPB-42-HN1	-1	0					
DPV-166+10	1	-83.385					

3. MOMENTUM FLUX MEASUREMENTS

The temperature sensitivity of drag discs is determined from pretest warmup data taken at 366 and 533 K with no system flow. The temperature sensitivity is removed before the data are converted to momentum flux. The temperature of each transducer is taken from the signal of a nearby fluid or metal temperature thermocouple. Slight corrections for errors in setting the transducer output to zero at ambient conditions are also made at this time. Corrections are made using the following equation:

$$F'(t) = F(t) + C_0 - T_i T(t) - P_i P(t)$$

where

$F'(t)$ = corrected data

$F(t)$ = raw data

T_i = temperature sensitivity

$T(t)$ = temperature data from the transducer used for temperature correction sensitivity

C_0 = ambient sensitivity

P_1 = pressure sensitivity

$P(t)$ = pressure data from the indicated transducer used for pressure correction sensitivity.

Values of the constants are given in Table B-III.

TABLE B-III
CONSTANTS FOR MOMENTUM FLUX
MEASUREMENT CORRECTIONS (TEST S-28-2)

<u>Detector Identification</u>	<u>C_o</u>	<u>T_1</u>	<u>$T(t)^{[a]}$</u>	<u>P_1</u>	<u>$P(t)^{[c]}$</u>
FDU-1	0.270	0.000 364	RBU-2	-0.000 006 3	PV-UP+10
FDU-5	0	-0.000 169	TFU-6	0.000 010 7	PV-UP+10
FDU-10	0	0.000 148	TFU-10	0.000 004 7	PU-13
FDU-13	0.120	0.000 862	RBU-14A		
FDU-15	0	-0.001 235	RBU-14A	-0.000 019 1	PU-13
FDB-21	0	-0.000 643	TFB-20	-0.000 018 9	PB-21
FDB-23	0	-0.000 841	TFB-23		
FDB-30 ^[b]	-0.055	-0.000 821	TFB-30	0.000 008 1	PV-UP+10
FDB-37 ^[b]	0.170	0.000 810	TFB-37	0.000 000 3	PB-42
FDB-42	0.129	0.000 981	TFB-42	-0.000 008 7	PB-42
FDV-CORE-IN	0	-0.000 024	TFV-CORE-IN		

[a] $T(t)$ is the temperature data used for temperature sensitivity correction. The symbols listed identify the thermocouples from which the data are obtained.

[b] Temperature sensitivity corrections were applied as usual; however, because FDB-30 and FDB-37 are mounted horizontally, during blowdown they were partially filled with subcooled water which affected the temperature sensitivity. Therefore, the temperature sensitivity correction is more uncertain than that applied to other temperature sensitivity corrections.

4. DENSITY MEASUREMENTS

Density calculations are based on the voltage output of the photomultiplier tubes in the gamma-attenuation densitometer assemblies. The equation used for converting voltage to density is as follows:

$$\rho = (1/C) \ln \left\{ D / [A F(t) + B] \right\}$$

where

ρ = the density in kg/m^3

C = a constant based on the length of the gamma beam path

D = a theoretical voltage for zero attenuation inside the vessel

A = an amplification factor

B = a biasing factor

$F(t)$ = the transducer voltage output.

Constants A and B are adjusted to match the final data to density values calculated from measured pressure and temperature values at the preblowdown and postdrain conditions, effectively giving the data an in-place calibration. The values of the constants for various transducers are given in Table B-IV.

The density measurements GVLP-172HZ and GV-COR-150HZ use amplifiers which precalculate the logarithm function, and hence have a simpler conversion formula:

$$\text{GVLP-172HZ} \quad \rho = -1.76 F(t) - 69.4$$

$$\text{GV-COR-150HZ} \quad \rho = -3.2 F(t) - 126.6.$$

TABLE B-IV
 CONSTANTS FOR DENSITY MEASUREMENT
 CONVERSIONS TO ENGINEERING UNITS (TEST S-28-2)

<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-1T	1.086	-0.281	0.005 7	6.21
GU-1B	1.033	0.009	0.008	6.99
GU-5VR	1.395	-1.883	0.009 5	5.46
GU-10VR	1.097	-0.432	0.009 5	6.84
GU-13VR	1.560	-1.784	0.009 5	3.54
GU-15T	1.162	-0.756	0.005 7	6.34
GU-15B	1.060	-0.163	0.008	6.42
GB-21T	1.105	-0.391	0.005 7	5.98
GB-21B	1.056	-0.150	0.008	7.04
GB-23VR	1.234	-1.327	0.006	7.06
GB-30T	1.172	-0.703	0.005 7	5.48
GB-30B	1.075	-0.257	0.008	6.58
GB-37HZ	1.841	-3.345	0.009 5	4.34
GB-42VR	1.318	-1.748	0.006	6.55
GVLP-165HZ	1.085	-0.207	0.009 5	3.09
GU-PRIZE	1.38	-0.303	0.009 5	1.08

Some density measurements are obtained using a two-beam gamma densitometer which operates on the same basic principle of gamma attenuation as does the single-beam gamma densitometer. Each beam originates from the same gamma source and is allowed to pass through separate portions of the piping cross-sectional flow area to obtain an average density measurement in that particular region. The geometrical relationship of the gamma beam path through the piping and geometrically related variables used for processing of data from a two-beam gamma densitometer are shown in Figure B-1.

Fig. B-1 Geometry used for processing of density data obtained from two-beam gamma densitometers.

The average density measured by each individual gamma beam is obtained using the same equation as is used for the single-beam gamma densitometers. Values for the constants for the single-beam density measurements obtained with the two-beam gamma densitometers are presented in Table A-IV along with the constants for single-beam gamma densitometers.

In the Semiscale Mod-1 system, two-beam gamma densitometers provide added information which allows the calculation of a better average density than that obtained from a single beam. A mathematical model is used for processing the two-beam data to obtain the improved average density information. The processing method used is based on a froth-water model coupled with information from the two individual gamma beams and related beam path and piping cross-sectional geometry. The resulting information is recorded and reported under the density measurement identification ending with a "C", for example, GB-21C.

The use of the froth-water model for obtaining average density from a two-beam gamma densitometer is based on observations indicating that flow regimes in the Semiscale Mod-1 system can be modeled by a layer of water on the bottom of the pipe with a degree of froth on the surface. For homogeneous flow conditions such as all froth or all liquid the model remains valid. At any point in time slug flow is also modeled. The froth-water model does not model annular or inverted annular flows very well. However, these flows are not expected to exist for significant portions of a Semiscale Mod-1 system blowdown in horizontal piping. Density gradients from the top to the bottom of the pipe may exist showing no distinct location change from water to froth. This flow is neither totally homogeneous nor stratified, but the froth-water model does provide an adequate approximation of the average density characteristic of this flow pattern.

The average density obtained by using the gamma beam geometry shown in Figure B-1 and by applying the froth-water model is given by

$$\bar{\rho} = \alpha_f \rho_1 + (1 - \alpha_f) \rho_w \text{ kg/m}^3$$

where

$\bar{\rho}$ = average cross-sectional density

ρ_1 = average density measured by the upper gamma beam
(measures the froth density)

ρ_w = density of liquid water (at local system conditions)

α_f = $1 + (1/2\pi) (\sin\beta - \beta)$ = froth fraction.

The angle which β represents is shown in Figure B-1. Values for β are obtained as follows:

$$\beta = 2 \cos^{-1}(1 - 2h)$$

where

$$h = \frac{H}{D} = \cos^2 \theta \frac{\rho_2 - \rho_1}{\rho_w - \rho_1}$$

where

H = $\ell_w \cos \theta$ (ℓ_w and θ are defined in Figure A-1)

D = piping inside diameter

ρ_2 = the average density measured by the lower gamma beam.

Average density is not calculated using the two-beam froth-water model when the angle θ is not favorable due to system hardware restrictions in positioning the source. The froth-water model requires separate density sampling in both the upper portions of the piping cross section.

APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TEST S-28-2

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APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TEST S-28-2

Analysis has been performed on selected data from Test S-28-2 to provide a guide to the uncertainty associated with data measurements in the Semiscale Mod-1 system. The end result of the analysis is presented as error bands about the measured data which represent a 95% confidence level.

The error bands are obtained by combining uncertainties obtained from analysis of the data itself (random error) and engineering analysis of the measurement system (engineering error). The procedure by which error bands were established for the data presented in this appendix is described in the following paragraphs.

The data trace under analysis was empirically fitted with a linear difference equation, which was subject to a white noise input at each sampling time point. The objective of the empirical fitting procedure was to characterize the white noise, which was taken to represent the random error. The procedures for fitting the difference equation are discussed in depth in Reference C-1. A data trace was often segmented and different equations were fitted to each segment with statistical correlations between successive observations accounted for by the fitting procedure. The white noise input was assumed to arise from a normally distributed population. The standard deviation of the white noise, as found during the fitting procedures, was taken as an estimate of the random error standard deviation and is shown in Table C-I. The data traces of the error band analysis are shown in Figures C-1 through C-40.

TABLE C-I

RANDOM ERROR VARIANCE

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFB-23	11.892	0 to 81	B-1	
	3.386	81 to 89		
	0.611	89 to 350		
TFV-ANN-35A	15.754	0 to 82	B-2	The error bands should be smaller than what is represented from 82 to 89 s [a].
	0.344	82 to 350		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFV-LP-7	61.998	0 to 40	B-3	
	33.203	40 to 62		
	45.333	62 to 70		
	0.243	70 to 350		
TFU-PRIZE	4.594	0 to 29	B-4	
	2.283	29 to 67		
	0.179	67 to 350		
TMU-1T16	0.259	0 to 350	B-5	
TMV-CI-70A	0.561	0 to 62	B-6	
	5.599	62 to 91		
	1.582	91 to 350		
TH-E4-09	2.981	0 to 70	B-7	The error bands should be smaller than what is represented from 69 to 77 s [a].
	19.010	70 to 116		
	2.670	116 to 129		
	0.237	129 to 350		
TH-E4-27	12.772	0 to 29	B-8	The error bands should be smaller than what is represented from 136 to 142 s [a].
	1.404	29 to 136		
	12.813	136 to 216		
	30.993	216 to 224		
	0.247	224 to 350		
TH-E4-55	1.665	0 to 173	B-9	
	0.546	173 to 341		
	19.940	341 to 348		
	11.900	348 to 350		
PU-13	10.527	0 to 40	B-10	
	1.003	40 to 350		
PB-23	10.677	0 to 40	B-11	
	1.188	40 to 350		
DPU-7-10	0.135	0 to 70	B-12	
	0.037	70 to 350		
DPU-12-10	0.750	0 to 8	B-13	
	0.315	8 to 29		
	0.292	29 to 70		
	0.092	70 to 350		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
DPU-12-15	0.281 0.049	0 to 70 70 to 350	B-14	
FTU-1	108.207 121.187 15.958 13.666	0 to 53 53 to 71 71 to 101 101 to 350	B-15	
FTU-15	33.714 16.581 32.959 39.171 59.839 10.549 28.467	0 to 18 18 to 59 59 to 72 72 to 80 80 to 94 94 to 235 235 to 350	B-16	
FTU-HPIS	0.380 0.185	0 to 70 70 to 350	B-17	
FTU-LPIS	0.198 0.961 0.520 0.009 0.012	0 to 20 20 to 27 27 to 67 67 to 341 341 to 350	B-18	
FTU-ACC1	1.966	0 to 65	B-19	
FTV-40A	8.463 1.392	0 to 75 75 to 350	B-20	
FTV-40M	7.620 0.746	0 to 80 80 to 350	B-21	The error bands should be smaller than what is represented from 80 to 87 s [a].
GU-1T	2.166 0.229 0.310	0 to 11 11 to 29 29 to 350	B-22	
GU-1B	3.116 0.558 0.746 1.369	0 to 12 12 to 120 120 to 220 220 to 350	B-23	

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GU-1C	1.439 0.369 0.338 0.594	0 to 11 11 to 29 29 to 262 262 to 350	B-24	
GU-10VR	1.626 0.239	0 to 29 29 to 350	B-25	The error bands are smaller than what is represented from 29 to 37 s [a].
GU-15T	3.878 12.586 6.133 11.401 0.603 5.319	0 to 7 7 to 18 18 to 60 60 to 67 67 to 235 235 to 350	B-26	
GU-15B	2.696 10.632 1.415 10.971 0.629 2.586 1.362 5.689	0 to 7 7 to 22 22 to 59 59 to 72 72 to 86 86 to 94 94 to 235 235 to 350	B-27	
GU-15C	3.018 9.552 0.862 10.208 0.938 0.547 5.287	0 to 7 7 to 23 23 to 60 60 to 72 72 to 101 101 to 235 235 to 350	B-28	
GB-23VR	10.845 8.193 1.735	0 to 61 61 to 69 69 to 350	B-29	
GV-COR-150HZ	1.888 7.688 9.120 3.303 1.651	0 to 62 62 to 73 73 to 80 80 to 304 304 to 350	B-30	

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GVLP-165HZ	7.183	0 to 18	B-31	
	0.363	18 to 61		
	9.250	61 to 69		
	2.195	69 to 350		
GVLP-172HZ	4.660	0 to 37	B-32	The error bands are smaller than what is represented from 55 to 62 s [a].
	2.758	37 to 61		
	10.663	61 to 69		
	1.571	69 to 180		
	0.477	180 to 350		
FDU-1, GU-1C	0.858	0 to 11	B-33	
	0.192	11 to 41		
	0.092	41 to 350		
FTU-1, GU-1C	1.212	0 to 7	B-34	
	0.362	7 to 70		
	0.123	70 to 247		
	0.249	247 to 350		
FDU-5, GU-5VR	1.028	0 to 10	B-35	
	0.373	10 to 40		
	0.373	40 to 75		
	0.151	75 to 129		
	0.339	129 to 350		
FTU-13, GU-13VR	0.889	0 to 26	B-36	
	2.075	26 to 46		
	0.510	46 to 62		
	1.500	62 to 70		
	0.526	70 to 155		
	0.271	155 to 350		
FTU-15, GU-15C	2.443	0 to 50	B-37	
	1.147	50 to 94		
	0.112	94 to 235		
	1.129	235 to 350		
FDB-21, GB-21C	3.690	0 to 7	B-38	
	3.029	7 to 68		
	0.408	68 to 350		
FTB-21, GB-21C	4.225	0 to 7	B-39	
	3.004	7 to 68		
	0.444	68 to 350		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FTV-CORE-IN, GV-COR-150HZ	0.389 0.094 5.055	0 to 7 7 to 61 61 to 350	B-40	The error bands are smaller than what is represented from 61 to 69 s [a].

[a] Due to present software limitations, error bands are uncertain wherever segments with different size error bands are merged together.

Fig. C-1 Fluid temperature in broken loop (TFB-23).

Fig. C-2 Fluid temperature in downcomer annulus (TFV-ANN-35A).

Fig. C-3 Fluid temperature in lower plenum (TFV-LP-8).

Fig. C-4 Fluid temperature in pressurizer surge line (TFU-PRIZE).

Fig. C-5 Material temperature in intact loop (TMU-1T16).

Fig. C-6 Material temperature in vessel filler (TMV-CI-70A).

Fig. C-7 Core heater temperature, Rod E-4 (TH-E4-09).

Fig. C-8 Core heater temperature, Rod E-4 (TH-E4-27).

Fig. C-9 Core heater temperature, Rod E-4 (TH-E4-55).

Fig. C-10 Pressure in intact loop, Spool 13 (PU-13).

Fig. C-11 Pressure in broken loop, Spool 23 (PB-23).

Fig. C-12 Differential pressure in intact loop (DPU-7-10).

Fig. C-13 Differential pressure in intact loop (DPU-12-10).

Fig. C-14 Differential pressure in intact loop (DPU-12-15).

Fig. C-15 Volumetric flow in intact loop (FTU-1).

Fig. C-16 Volumetric flow in intact loop (FTU-15).

Fig. C-17 Volumetric flow in intact loop high pressure injection line (FTU-HPIS).

Fig. C-18 Volumetric flow in intact loop low pressure injection line (FTU-LPIS).

Fig. C-19 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1).

Fig. C-20 Fluid velocity in vessel (FTV-40A).

Fig. C-21 Fluid velocity in vessel (FTV-40M).

Fig. C-22 Density in intact loop (GU-1T).

Fig. C-23 Density in intact loop (GU-1B).

Fig. C-24 Density in intact loop (GU-1C).

Fig. C-25 Density in intact loop (GU-10VR).

Fig. C-26 Density in intact loop (GU-15T).

Fig. C-27 Density in intact loop (GU-15B).

Fig. C-28 Density in intact loop (GU-15C).

Fig. C-29 Density in broken loop (GB-23VR).

Fig. C-30 Density in vessel (GV-COR-150HZ).

Fig. C-31 Density in vessel (GVLP-165HZ).

Fig. C-32 Density in vessel (GVLP-172HZ).

Fig. C-33 Mass flow in intact loop (FDU-1, GU-1C).

Fig. C-34 Mass flow in intact loop (FTU-1, GU-1C).

Fig. C-35 Mass flow in intact loop (FDU-5, GU-5VR).

Fig. C-36 Mass flow in intact loop (FTU-13, GU-13VR).

Fig. C-37 Mass flow in intact loop (FTU-15, GU-15C).

Fig. C-38 Mass flow in broken loop (FDB-21, GB-21C).

Fig. C-39 Mass flow in broken loop (FTB-21, GB-21C).

Fig. C-40 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ).

Other errors in the data exist because of such factors as variability in installation procedures and techniques, calibration errors, variability in materials, and temperature and pressure sensitivities. These errors and the procedures for estimating them are discussed in Reference C-2. They are referred to as engineering errors and the estimates are largely subjective. Because of the continuing effort to improve the accuracy of the measured data, such as through the use of better transducers, better signal conditioning and processing equipment, and better calibration and installation techniques, the engineering errors for data from most of the transducer systems have changed from those published in Reference C-2. Table C-II provides a summary of engineering error values obtained from current analysis techniques as applied to the data presented herein.

In addition to the normal hardware and installation related sources of engineering error, a significant measurement uncertainty results when the current transducer systems are subjected to separated two-phase flow regimes during the course of the blowdown transient. Accordingly, for those data affected (fluid density, momentum flux, volumetric flow, and mass flow), which are presented in this appendix, a more extensive assessment was conducted for additional engineering error due to flow regime effects. Table C-III identifies the data analyzed and the period in the blowdown process for which flow regime errors were included as a part of the total engineering error. The time of occurrence of separated two-phase flow and the resulting effect on the uncertainty of the data were evaluated by considering, on an individual basis, each detector output with reference to indications by other auxiliary measurements.

TABLE C-II

GENERAL MEASUREMENT ENGINEERING ERROR SOURCES AND ERROR VALUES (TEST S-28-2)

Measurement Category	Error Sources	Error Value	Expected Error Value
Fluid Temperature	Changes in homogeneity of the thermocouple wire due to cold working	± 1.11 K	± 2.8 K ^[a]
	Data interpretation from standard reference tables	± 1.11 K	
	General data acquisition processing	± 2.50 K	
	Thermal aging of the thermocouples	± 0.28 K	
Material Temperature	Changes in homogeneity of the thermocouple wire due to cold working	± 1.11 K	± 3.9 K
	Thermocouple radial position	± 2.78 K	
	Data interpretation from standard reference tables	± 1.11 K	
	General data acquisition and processing	± 2.50 K	
	Thermal aging of the thermocouples	± 0.28 K	

TABLE C-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
Pressure	Entrance effects	+0.3% of transducer full scale	+89.63 kPa ^[b]
	Calibration	+0.26% of transducer full scale	
	Temperature sensitivity	+0.13% of transducer full scale	
	General data acquisition and processing	+0.1% of system full scale	
Differential Pressure	Installation	+0.3% of transducer full scale	+2% of transducer full scale ^[c]
	Calibration Transducer ranges +4.96 through +199.26 kPa	$\pm[(0.05) + (0.5 R/FS)^2]^{1/2}\%$ of transducer full scale	
	Transducer ranges +344.74, +689.47, +3447 kPa	$\pm[(0.03) + (0.5 R/FS)^2]^{1/2}\%$ of full scale	
	Transducer ranges +6894, +10 342 kPa	$\pm[(0.02) + (0.5 R/FS)^2]^{1/2}\%$ of full scale	
		where	
		R = transducer reading (kPa)	
		FS = transducer range full scale (kPa)	

TABLE C-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
Differential Pressure (continued)	Temperature sensitivity	$\pm 0.5\%$ of transducer full scale	$\pm 2\%$ of transducer full scale ^[c]
	General data acquisition and processing	$\pm 0.1\%$ of system full scale	
	Air entrapment	± 0.069 kPa	
Fluid Velocity (point velocities measured with turboprobes)	Installation	$\pm 0.8\%$ of transducer full scale	$\pm [0.5825 + (0.008R)^2]^{1/2}$ m/s
	Calibration	$\pm 5\%$ of transducer full scale	
	Data acquisition and processing frequency conversion	$\pm 0.25\%$ of transducer full scale	
	General	$\pm 0.1\%$ of system full scale	
Density	Calibration	$\pm 1.0\%$ of reading (kg/m^3)	[d]
	Detector system error	± 2.1 kg/m^3	
	General data acquisition and processing	± 1.6 kg/m^3	

where
 R = transducer reading (m/s)

TABLE C-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
Density (continued)	Flow regime	Gr[d]	[d]
		where	
		Gr = flow regime error (kg/ms ²)	
Momentum Flux (drag disc)	Installation alignment and velocity profile changes from calibration conditions	[d]	[d]
	Calibration	[e]	
	General data acquisition and processing	+0.1% of system full scale (kg/ms ²)	
	Flow regimes	[d]	
Volumetric Flow (turbine flow-meter)	Calibration instrument reading	+0.25% of transducer full scale	[d]
	Calibration standards	+19.56 x 10 ⁻² g/s	
	Velocity profile	+2.9% of reading	
	Frequency-to-voltage conversion	+0.25% of transducer full scale	
	General data acquisition and processing	+0.1% of system full scale	

TABLE C-II (continued)

<u>Measurement Category</u>	<u>Error Sources</u>	<u>Error Value</u>	<u>Expected Error Value</u>
Volumetric Flow (turbine flow-meter) (continued)	Dead bands	+5% of transducer full scale	[d]
	Flow regimes	[d]	
Mass Flow Rate (from volumetric flow and density data)	Combined results from individual error sources for volumetric flow and density data ^[f]	[d]	[d]
Mass Flow Rate (from momentum flux and density data)	Combined results from individual error sources for momentum flux and density data ^[f]	[d]	[d]

[a] This value is no longer valid after thermocouple dryout occurs.

[b] Value for transducers with 20 684 kPa full-scale ranges.

[c] Value is based on observed system performance. It is more conservative than that obtained from the statistical summation of the identified engineering errors.

[d] Error value is time and flow regime dependent.

[e] Dependent on transducer full-scale range reading.

[f] The general method for combining volumetric flow or momentum flux with density data to obtain mass flow rate and the resulting errors in the data are explained in Reference C-2.

TABLE C-III

TIME PERIODS WHEN FLOW REGIME ERRORS WERE APPLIED (TEST S-28-2)

<u>Transducer Identification</u>	<u>Time During Which Flow Regime Errors Were Applied (s)</u>	<u>Figure Number</u>
GU-1C	2 to 40	C-24
GU-10VR	10 to 25	C-25
GU-15C	13 to 20 and 57 to 100	C-28
GB-23VR	3 to 15 and 58 to 300	C-29
FDU-1, GU-1C	2 to 40	C-33
FDU-5, GU-5VR	3 to 10 and 27 to 44	C-35
FTU-13, GU-13VR	11 to 33	C-36
FTU-15, GU-15C	13 to 20 and 57 to 100	C-37
FTD-21, GB-21C	3 to 15 and 58 to 300	C-39

The gamma densitometer density measurement data are affected by two-phase separated flow regimes. The resulting transducer output is a measurement of the average attenuation of the gamma beam through the measured medium. The beam attenuation, in turn, is interpreted through physical relationship to be a measure of the average density along the beam path. When stratified type flow was considered present, the gamma beam attenuation was considered to be a result of a liquid layer and steam at system conditions. With this assumption and the system geometry, a void fraction was calculated and a new "effective" average density was calculated. The difference between the average density based on the assumption of homogeneous conditions and the average density for stratified conditions was considered to be the error.

Momentum flux measurement uncertainties for two-phase flow regimes present the most difficult engineering evaluation problems. The drag target and arm location, degree of flow stratification, transducer temperature sensitivity, and slip ratios all combine to produce possible flow regime errors ranging from a small fraction of the transducer output value to multiples of it. Therefore, the error values were obtained, where possible, through use of the observed discrepancies between the momentum flux and turbine flowmeter data in combination with system pressure measurements and the analysis of system fluid density measurements.

The flow regime errors of the turbine flowmeter were estimated by calculating a void fraction and the cross-sectional liquid and steam flow areas for stratified flow. This calculation was accomplished using methods similar to those used to calculate the average density for stratified flows. A simple model was used to equate the forces on the turbine with the assumption of a known void fraction, stratified flow, known component densities, and slip ratio greater than unity. This process provided phase velocities. With the phase densities, velocities, and void fraction, a volumetric flow rate could be calculated. The difference between this value and the measured value was considered to be the error.

The overall standard deviation of a data point is taken as the root mean of the sum of the random error variation and the total engineering error variance; that is,

$$\sigma_O = \sigma_R^2 + \sigma_E^2 \quad (C-1)$$

where

σ_O = overall standard deviation of a data point

σ_R = random error standard deviation

σ_E = engineering error standard deviation.

The error bands for the data are computed about the value given by the fitted difference equation y_i at time point, i ; that is,

$$\text{error band} = y_i \pm 1.96\sigma_O \quad (C-2)$$

With due regard to the fact that σ_E has been estimated subjectively, the error band may be interpreted as an approximate 95% confidence interval within which any true value of the measured variable is consistent with the data.

On certain occasions, the symmetrical error band given by Equation (C-2) is not appropriate. On those occasions, asymmetrical error bands were computed. (That is, with the width being greater on one side of y_i than on the other.)

Finally, the original data trace, along with its error band from Equation (C-2), was input to a computer plot package. The resulting plot contained the actual data trace surrounded by an error band derived both from random error and engineering error considerations. The indicated error bands after thermocouple dryout occurred for the fluid temperature measurements should be ignored. Error bands indicated during periods when detector or data acquisition system saturation occurred should also be ignored. Error bands for these segments of the data were not obtained and bands only appear because of limitations in the plotting package.

REFERENCES

- C-1. G. E. P. Box and B. M. Jenkins, *Time Series Analysis – Forecasting and Control*, San Francisco: Holden-Day, 1970.
- C-2. E. M. Feldman and S. A. Naff, *Error Analysis for 1-1/2-Loop Semiscale System Isothermal Test Data*, ANCR-1188 (May 1975).

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