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**EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1
TEST S-06-4
(LOFT COUNTERPART TEST)**

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December 1977

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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(LOFT COUNTERPART TEST)

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-06-4

(LOFT COUNTERPART TEST)

by

Robert L. Gillins
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EG&G IDAHO, INC.

December 1977

PREPARED FOR THE
U.S. NUCLEAR REGULATORY COMMISSION
AND THE
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ABSTRACT

Recorded test data are presented for Test S-06-4 of the Semiscale Mod-1 LOFT counterpart 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-06-4 was conducted from initial conditions of 15 653 kPa and 564 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 loop to simulate emergency core coolant injection in a PWR. The heater rods in the electrically heated core were operated at an axial peak power density which was 100% of the maximum peak power density (52.5 kW/m).

The purpose of this report is to make available the uninterpreted data from Test S-06-4 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-06-4 was performed as part of the Mod-1 portion of the Semiscale Program conducted by EG&G Idaho, Inc. for the United States Government. This test was part of the LOFT counterpart test series (Test Series 6) performed to investigate the response of the Mod-1 system to specific variations in the peak power densities of the heater rods to assist the LOFT Program in the planning of the first LOFT nuclear test series. The test objective specific to Test S-06-4 was to assist the LOFT Program in assessing possible core response effects when the LOFT system, operating at 100% core power, is subjected to a postulated loss-of-coolant accident (LOCA). Hardware configuration and test parameters were selected to yield a system response that simulates the expected response of the LOFT nuclear facility during the first nuclear test series.

Test S-06-4 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, simulated reflood bypass lines, LOFT counterpart nozzles, 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 the intact loop. For Test S-06-4, four heater rods were intentionally unpowered to simulate LOFT passive rod locations, and the power in the four central heater rods was increased to produce a peaked power profile.

The test was conducted from initial conditions of 15 653 kPa and 564 K (at the intact loop cold leg vessel inlet) with a simulated full size (200%) double-ended offset shear of the broken loop cold leg piping at an initial core power level of 1.33 MW and an initial core inlet flow rate of 9.55 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 injection into the cold leg piping of the intact loop.

Test S-06-4 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 225 measurements taken, 216 produced usable data.

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-06-4

(LOFT COUNTERPART 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 Department of Energy, 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-06-4 was conducted August 31, 1977 in the Semiscale Mod-1 system as part of the LOFT counterpart test series (Test Series 6), which was designed to obtain thermal-hydraulic response data from blowdown, refill, and reflood transients in a simulated nuclear reactor with a heated core to assist the LOFT Program in the planning of the first LOFT nuclear test series. Test S-06-4 was conducted specifically to assist the LOFT Program in assessing core response effects when the LOFT system, operating at 100% core power (52.5 kW/m), is subjected to a postulated LOCA.

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-06-4; 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.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TEST S-06-4

The following system configuration, procedures, initial test conditions, and events are specific to Test S-06-4 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, simulated reflood bypass lines, LOFT counterpart nozzles^[a], and two rupture assemblies; a coolant injection accumulator for the intact loop; high and low pressure coolant injection pumps for the intact loop; and a pressure suppression system with a suppression tank, header, and heated steam supply system. Semiscale Mod-1 experimental system configuration information is provided in Reference 1. Figures 1 and 2 show the system configuration for Test S-06-4.

For Test S-06-4, the 40-rod electrically heated core was operated at an axial peak power density which was 100% of the maximum peak power density (52.5 kW/m). Four rods (Rods D-4, D-5, E-4, and E-5) were operated at approximately 52.5 kW/m, 32 rods were operated at approximately 33.2 kW/m, and 4 rods (Rods C-4, D-6, F-2, and F-5) were unpowered to simulate LOFT passive rod locations. This configuration yielded a peaked power profile which simulates that of LOFT and provides a total core power of approximately 1.33 MW.

In preparation for the test, the intact loop accumulator was filled with treated demineralized water, drained to the specified initial level, and pressurized with nitrogen to 4198 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 56-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.

[a] The Semiscale Mod-1 system normally utilizes a break nozzle of the converging-diverging type referred to as a Henry nozzle. Reference 2 provides an illustration of the LOFT counterpart break nozzle.

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

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 252 kPa with saturated steam from the steam supply system. After the core power was increased to 1328 kW, initial test conditions were held for 3845 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 LOFT counterpart 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 15 600 kPa. 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 252 kPa. During the blowdown transient, power to the electrically heated core was automatically controlled to simulate the thermal response of nuclear heated fuel rods. The steam generator feedwater flow and steam control valves were also automatically controlled to aid in the LOFT simulation. Throughout the test, the primary coolant circulation pump speed was maintained at a constant level.

For Test S-06-4, the coolant injection systems were arranged to discharge into the intact loop cold leg injection point (Spool 14). The high pressure coolant injection pump began at blowdown (0 s) and continued until test termination (300 s). Coolant injection from the intact loop accumulator started approximately 18 s after rupture at a system pressure of 4200 kPa and continued to depletion at 68 s after blowdown. Low pressure coolant injection began 25 s after blowdown at a system pressure of 1655 kPa and continued until test termination (300 s).

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-06-4	
	Measured ^[a]	Specified
Core power (MW)	1.33	1.35
Intact loop cold leg fluid temperature (K)	564	563 $\pm$ 1
Hot leg to cold leg temperature differential (K)	35	36 $\pm$ 0.5
Pressurizer pressure (kPa)	15 653	15 600 $\pm$ 172
Pressurizer liquid mass (kg) ^[b]	9.09	9.07
Steam generator feedwater temperature (K)	481	497 $\pm$ 6
Steam generator liquid level (from bottom of tube sheet) (cm)	282	295 $\pm$ 1
Broken loop fluid temperature (pump side) (K)	596	593 to 598
Broken loop fluid temperature (vessel side) (K)	563	Not Specified
Intact loop cold leg flow (L/s)	9.55	[c]
Pressure suppression tank water level (cm)	121	121 $\pm$ 1
Pressure suppression tank pressure (kPa)	252	252 $\pm$ 70
Pressure suppression tank water temperature (K)	291	<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]

	Test S-06-4	
	Detector	Temperature (K)
Vessel lower plenum (upper portion above filler block)	TFV-LP-22	563
Intact loop hot leg (near vessel)	RBU-2	599
Intact loop cold leg (near pump inlet)	TFU-10	563
Intact loop cold leg (near vessel)	RBU-14A	564
Broken loop cold leg (near nozzle)	TFB-23	563
Broken loop hot leg (near vessel)	TFB-30	596
Broken loop cold leg (near nozzle)	TFB-42	593
Reflood bypass line hot leg (near end cap)	TFB-RFBH	599
Reflood bypass line cold leg (near end cap)	TFB-RFBC	557

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

TABLE III
WATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

	<u>Test S-06-4</u>
pH	9.6
Conductivity ($\mu\text{S}/\text{cm}$)	60
Lithium ($\mu\text{g}/\text{m}\ell$)	4.4
Chlorides (ppm)	1.39
Fluorides ($\mu\text{g}/\text{m}\ell$) ^[b]	<0.53
Oxygen (cc/ℓ)	0.3
Total gas (cc/ℓ)	96.3
Suspended solids ($\mu\text{g}/\text{m}\ell$)	1.25

[a] Water sample taken at a system pressure of approximately 15 600 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 $\mu\text{g}/\text{m}\ell$.

TABLE IV
SEQUENCE OF EVENTS DURING TEST S-06-4^[a]

Event	Time Relative to Rupture (s)
Core power level established	-3845
Bypass lines valved out of system	-2.5
Blowdown initiated	0
High pressure injection system pumps started ^[b]	0
ECC accumulators valved in	0
Steam generator feedwater and discharge valves switched to automatic flow control	0
Core power decay transient started	3
Low pressure injection system pumps started ^[b]	25
Core power tripped off ^[c]	305

[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-06-4 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-06-4 was monitored by 225 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 digital data were recorded at a sample rate of 57.5 points per second. Long-term data (-20 to 300 s) were compressed at a 20 to 1 ratio giving an effective sample rate of 2.875 points per second. Short-term data and plots (-6 to 42 s) were compressed at a 3 to 1 ratio giving 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 Reference 1 and Appendix A).

Figures 3 through 8 and Table V provide supporting information for interpretation of the data graphs shown in Figures 9 through 316, and provide relative locations of all detectors used during Test S-06-4. Table V groups the measurements according to measurement type, identifies the specific measurement location and 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 316 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 explains 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. 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-3076

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

INEL-A-3075

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

TABLE V
DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-06-4

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-7	Cold leg, Spool 7, 624 cm from vessel center.			11, 12	
TFU-10	Cold leg, Spool 10, 367 cm from vessel center.			11, 12	
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	13, 14	
TFU-14B	Cold leg, Spool 14, 99 cm from vessel center, downstream of cold leg injection port.			13, 14	
TFU-15	Cold leg, Spool 15, 54 cm from vessel center.			13, 14	
<u>Broken Loop</u>					
TFB-20	Cold leg, Spool 20, 52 cm from vessel center.	0 to 1533 K	0 to 820 K	15, 16	
TFB-23	Cold leg, Spool 23, 232 cm from vessel center, upstream of vessel-side nozzle.			15, 16	
TFB-24	Cold leg, Spool 24, 264 cm from vessel center, downstream from vessel-side nozzle.			15, 16	
TFB-30	Hot leg, Spool 30, 40 cm from vessel center.			17, 18	
TFB-37	Cold leg, Spool 37, 703 cm from vessel center along hot leg, discharge of simulated steam generator.			17, 18	
TFB-42	Cold leg, Spool 42, 1054 cm from vessel center along hot leg, upstream of pump-side nozzle.			17, 18	
TFB-43	Cold leg, Spool 43, 1086 cm from vessel center along hot leg.			17, 18	
TFB-RFBC	Reflood bypass, near end cap, cold leg side.			19, 20	
TFB-RFBH	Reflood bypass, near end cap, hot leg side.			19, 20	
<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°.			21, 22	
TFV-ANN-4M	180°.			21, 22	
<u>Downcomer Annulus</u>					
	Centered in annulus, Type J iron-constantan thermocouples.	0 to 1033 K	0 to 701 K		
TFV-ANN-15T	38 cm below cold leg centerline, 270°.				Thermocouple failed.
TFV-ANN-35A	89 cm below cold leg centerline, 0°.			23, 24	
TFV-ANN-35T	89 cm below cold leg centerline, 270°.			23, 24	
TFV-ANN-70A	178 cm below cold leg centerline, 0°.			23, 24	
TFV-ANN-115A	292 cm below cold leg centerline, 0°.			25, 26	
TFV-ANN-115M	292 cm below cold leg centerline, 180°.			25, 26	
TFV-ANN-156A	396 cm below cold leg centerline, 0°.				Thermocouple failed.

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Upper Plenum</u>		0 to 1533 K	0 to 820 K		
TFV-UP-13	In upper plenum, 34 cm above cold leg centerline at 180°.			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-8	19 cm from bottom of vessel.			29, 30	
TFV-LP-15	37 cm from bottom of vessel.			29, 30	
TFV-LP-22	55 cm from bottom of vessel.			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	
<u>Core Grid Spacers</u>					
<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	
TFG-6DE-67	Thermocouple in space defined by Columns D and E, Rows 6 and 7.			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	
TFG-10GH-45	Thermocouple in space defined by Columns G and H, Rows 4 and 5.			37, 38	
<u>ELC System</u>		0 to 1533 K	0 to 584 K		
TFU-ECC-14	In ECC line leading to intact loop Spool 14.			39, 40	Thermocouple failed initially, recovered at blowdown.
<u>Steam Generator</u>		0 to 1533 K	0 to 584 K		
TFU-SGFW	In feedwater line leading to steam generator.			41, 42	
TFU-SGSD	In steam dome, 329 cm above bottom of tube sheet.			43, 44	
TFU-SG1	Secondary side, 30 cm above bottom of tube sheet.			45, 46	
TFU-SG3	Secondary side, 122 cm above bottom of tube sheet.			45, 46	
TFU-SG4	Secondary side, 244 cm above bottom of tube sheet.			45, 46	
<u>Pressurizer</u>					
TFU-PHILZ	In surge line, near pressurizer exit, between turbine flowmeter and pressurizer.	0 to 1533 K	0 to 820 K	47, 48	
<u>Pressure Suppression System</u>		0 to 1533 K	0 to 584 K		
TF-PSS-33	81 cm from bottom of tank.			49, 50	
TF-PSS-63	160 cm from bottom of tank.			49, 50	
TF-PSS-130	330 cm from bottom of tank.			49, 50	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
MATERIAL TEMPERATURE					
	Chromel-Alumel thermocouples unless specified otherwise.				
<u>Intact Loop</u>		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	51, 52	
TMU-15T16	Cold leg, Spool 15, top, 1.6 mm from pipe ID, 54 cm from vessel center.			51, 52	
<u>Broken Loop</u>		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.			53, 54	
TMB-30B16	Hot leg, Spool 30, bottom, 1.6 mm from pipe ID, 40 cm from vessel center.		0 to 820 K	53, 54	
<u>Vessel Filler</u>	Type J iron-constantan	0 to 1033 K	0 to 701 K		
TMV-FI-115A	292 cm below cold leg centerline, 1.6 mm from filler ID, 0°.			55, 56	
<u>Core Barrel</u>	Type J iron-constantan thermocouples	0 to 1033 K	0 to 701 K		
TMV-CI-35A	89 cm below cold leg centerline, 1.6 mm from core barrel ID, 0°.				Thermocouple failed.
CORE HEATER CLADDING TEMPERATURES					
	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.			57, 58	
TH-D5-09 TH-D5-29 TH-D5-39	Heater at Column D, Row 5. Thermocouples 23 cm (45°), 74 cm (225°) and 99 cm (135°) above bottom of core.			59, 60	
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.			61, 62	
TH-E5-21 TH-E5-25	Heater at Column E, Row 5. Thermocouples 53 cm (180°) and 64 cm (90°) above bottom of core.			63, 64	
<u>Low Power Heaters</u>		0 to 1533 K	0 to 1579 K		
TH-A4-09 TH-A4-29	Heater at Column A, Row 4. Thermocouples 23 cm (105°) and 74 cm (240°) above bottom of core.			65, 66	TH-A4-29 thermocouple failed.
TH-A5-29 TH-A5-45	Heater at Column A, Row 5. Thermocouples 74 cm (180°) and 114 cm (255°) above bottom of core.			67, 68	
TH-B2-32	Heater at Column B, Row 3. Thermocouple 81 cm (135°) above bottom of core.			69, 70	
TH-B5-29 TH-B5-33	Heater at Column B, Row 5. Thermocouples 74 cm (150°) and 85 cm (45°) above bottom of core.			71, 72	
TH-B6-14 TH-B6-29	Heater at Column B, Row 6. Thermocouples 36 cm (0°) and 74 cm (45°) above bottom of core.			73, 74	TH-B6-14 thermocouple failed.
TH-C2-28 TH-C2-38	Heater at Column C, Row 2. Thermocouples 71 cm (135°) and 97 cm (225°) above bottom of core.			75, 76	
TH-C3-60	Heater at Column C, Row 3. Thermocouple 152 cm (135°) above bottom of core.			77, 78	
TH-C4-20 TH-C4-26	Heater at Column C, Row 4. Thermocouples 51 cm (150°) and 66 cm (75°) above bottom of core.			79, 80	
TH-C5-28	Heater at Column C, Row 5. Thermocouple 71 cm (315°) above bottom of core.			81, 82	

TABLE V (continued)

Range ^[a]					
Measurement	Location and Comments ^[a]	Detector	Data Acquisition System	Figure ^[a]	Measurement Comments ^[b]
Low Power Heaters (continued)					
TH-C6-32 TH-C6-53	Heater at Column C, Row 6. Thermocouples 81 cm (225°) and 135 cm (270°) above bottom of core.			83, 84	
TH-C7-07 TH-C7-15	Heater at Column C, Row 7. Thermocouples 18 cm (345°) and 38 cm (255°) above bottom of core.			85, 86	
TH-D1-21	Heater at Column D, Row 1. Thermocouple 53 cm (330°) above bottom of core.			87, 88	
TH-D2-14 TH-D2-61	Heater at Column D, Row 2. Thermocouples 36 cm (0°) and 155 cm (270°) above bottom of core.			89, 90	
TH-D3-29 TH-D3-39	Heater at Column D, Row 3. Thermocouples 74 cm (150°), 84 cm (45°), and 99 cm (210°) above bottom of core.			91, 92	
TH-D7-20	Heater at Column D, Row 7. Thermocouple 51 cm (60°) above bottom of core.			93, 94	
TH-D8-57	Heater at Column D, Row 8. Thermocouple 145 cm (15°) above bottom of core.			95, 96	
TH-E1-26 TH-E1-33	Heater at Column E, Row 1. Thermocouples 66 cm (195°) and 84 cm (60°) above bottom of core.			97, 98	TH-E1-26 thermocouple intermittently opened, t=4 to 8 s.
TH-E2-20 TH-E2-33	Heater at Column E, Row 2. Thermocouples 51 cm (210°) and 84 cm (315°) above bottom of core.				Both thermocouples failed.
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.			99, 100	
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.			101, 102	
TH-E7-13 TH-E7-44	Heater at Column E, Row 7. Thermocouples 33 cm (45°) and 112 cm (195°) above bottom of core.			103, 104	
TH-F8-14 TH-F8-29 TH-F8-45	Heater at Column F, Row 8. Thermocouples 36 cm (150°), 74 cm (225°), and 114 cm (300°) above bottom of core.			105, 106	
TH-F3-06 TH-F3-22 TH-F3-25	Heater at Column F, Row 3. Thermocouples 15 cm (315°), 56 cm (105°), and 64 cm (30°) above bottom of core.			107, 108	
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.			109, 110	
TH-F6-08 TH-F6-28	Heater at Column F, Row 6. Thermocouples 20 cm (60°) and 71 cm (210°) above bottom of core.			111, 112	
TH-F7-29	Heater at Column F, Row 7. Thermocouple 74 cm (145°) above bottom of core.			113, 114	
TH-G3-13	Heater at Column G, Row 3. Thermocouples 33 cm (150°) above bottom of core.			115, 116	
TH-G4-29 TH-G4-33 TH-G4-38	Heater at Column G, Row 4. Thermocouples 74 cm (300°), 84 cm (225°), and 97 cm (30°) above bottom of core.			117, 118	
TH-G5-14 TH-G5-24	Heater at Column G, Row 5. Thermocouples 36 cm (45°) and 61 cm (330°) above bottom of core.			119, 120	
TH-H5-32	Heater at Column H, Row 5. Thermocouple 81 cm (45°) above bottom of core.			121, 122	

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 20 684 kPa			
PU-13	Cold leg, Spool 13, 138 cm from vessel center.		0 to 31 992 kPa	123, 124	
PU-15L	Cold leg, Spool 15, 55 cm from vessel center, to atmosphere (low range).	0 to 3447 kPa	0 to 3561 kPa	123, 124	Detector saturated to t=19 s.
<u>Broken Loop</u>					
		0 to 20 684 kPa			
PB-21	Cold leg, Spool 21, 112 cm from vessel center.		0 to 29 931 kPa	125, 126	
PB-23	Cold leg, Spool 23, 235 cm from vessel center, upstream of nozzle (tee off DP tap).	0 to 17 237 kPa	0 to 21 440 kPa	125, 126	
PB-24	Cold leg, Spool 24, 264 cm from vessel center downstream of nozzle.		35 612 kPa	125, 126	
PB-CN1	Vessel-side nozzle, nozzle throat, 245 cm from vessel center, (tee off DP tap).		33 924 kPa	127, 128	
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 17 237 kPa	0 to 20 569 kPa	129, 130	
PB-43	Cold leg, Spool 43, 1086 cm from vessel center along hot leg, upstream of rupture discs.	0 to 17 237 kPa	0 to 20 655 kPa	129, 130	
<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	131, 132	
PV-LP-180	In upper part of lower plenum, 457 cm below cold leg centerline, mounted on standoff, 225°.	0 to 20 684 kPa	0 to 34 226 kPa	131, 132	
<u>ECC System</u>					
		0 to 6895 kPa			
PU-ACC1	In intact loop accumulator.		0 to 8629 kPa	133, 134	
<u>Steam Generator</u>					
PU-SGSD	Secondary side steam dome.	0 to 20 684 kPa	0 to 14 018 kPa	135, 136	
<u>Pressurizer</u>					
PU-PRIZE	Pressurizer steam dome.	0 to 17 237 kPa	0 to 22 329 kPa	137, 138	
<u>Pressure Suppression System</u>					
P-PSS	Suppression tank top.	0 to 345 kPa	0 to 122 kPa	139, 140	
DIFFERENTIAL PRESSURE					
<u>Intact Loop</u>					
DPU-UP-3	Upper plenum 26.7 cm above cold leg centerline at 30° to hot leg, Spool 3, 158 cm from vessel center. Upper plenum tap is approximately 5 cm above Spool 3 tap.	+127 cm water	+16.8 kPa	141, 142	
DPU-3-6	Hot leg Spool 3, 158 cm from vessel center to hot leg Spool 6, 290 cm from vessel center.	+1270 cm water	+170 kPa	143, 144	
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.	+1270 cm water	+169 kPa	145, 146	

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-6-7	Across steam generator, hot leg Spool 6, 290 cm from vessel center to cold leg. Spool 7, 587 cm from vessel center. Spool 6 tap is 48 cm above Spool 7 tap.	+1270 cm water	+170 kPa	147, 148	
DPU-SGOP-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 SGOP tap.	+1270 cm water	+169 kPa	149, 150	
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	151, 152	Data acquisition system saturated at t=0 s.
DPU-12-10	Pump outlet to pump inlet, cold leg Spool 12, 182 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	153, 154	
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	+33.5 kPa	155, 156	
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	157, 158	
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	+33.8 kPa	159, 160	Data acquisition system saturated to t=0 s.
DPU-15-IANN	Cold leg Spool 15, 55 cm from vessel center, to inlet annulus, 23 cm below cold leg centerline at 225°. Spool 15 tap is 23 cm above inlet annulus tap.	+254 cm water	+33.5 kPa	161, 162	
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	163, 164	
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	165, 166	Data acquisition system saturated from t=0 to 10 s.
<u>Broken Loop</u>					
DPB-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	167, 168	
DPB-21-23	Cold leg, Spool 21, 112 cm from vessel center, to cold leg 23, 235 cm from vessel center.	+2032 cm water	+267 kPa	169, 170	
DPB-23-CNL	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	171, 172	
DPB-23-24	Across vessel-side nozzle, Spool 23, 235 cm from vessel center to Spool 24, 245 cm from vessel center.	+10 342 kPa	+13 837 kPa	173, 174	
DPB-30-36L	Across entire simulated steam generator assembly, hot leg Spool 30, 45 cm from vessel center, to cold leg Spool 36 lower tap, 617 cm from vessel center. Spool 30 tap is 48 cm below Spool 36 lower tap.	+3447 kPa	+3480 kPa	175, 176	
DPB-30-38	Across entire simulated steam generator assembly and instrument spool downstream of simulated steam generator; hot leg Spool 30, 45 cm from vessel center to cold leg, Spool 38, 776 cm from vessel center along hot leg. Spool 30 tap is 102 cm above Spool 38 tap.	+689 kPa	+886 kPa	177, 178	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Broken Loop (continued)					
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, 617 cm from vessel center. Spool 32 upper tap is 41 cm above Spool 36 lower tap.	+3447 kPa	+3466 kPa	179, 180	
DPB-38-40	Across simulated pump, cold leg Spool 38, 776 cm from vessel center along hot leg, to cold leg Spool 40, 929 from vessel center along hot leg.	+6895 kPa	+9227 kPa	181, 182	
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	183, 184	Detector saturated from t=0 to 1 s.
DPB-42-43	Across pump-side nozzle cold leg Spool 42, 1057 cm from vessel center along hot leg, to cold leg, Spool 43 1086 cm from vessel center along hot leg.	+6895 kPa	+9230 kPa	185, 186	Data acquisition system saturated at t=0 to 2 s.
Vessel					
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	187, 188	
DPV-O-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	189, 190	
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	191, 192	
DPV-9-180QQ	Inlet annulus, 23 cm below cold leg centerline at 225°, to lower plenum, 457 cm below cold leg centerline at 225°. Elevation difference between taps is 434 cm.	+762 cm water	+103 kPa		Detector failed.
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 kPa water	+21.2 kPa	193, 194	
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	195, 196	
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	+33.7 kPa	197, 198	
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.	+127 cm water	+17.7 kPa	199, 200	
DPV-166-192QT	Across lower plenum, 422 cm (225°) to 488 cm (270°), below cold leg centerline. Elevation difference between taps is 66 cm.	+127 cm water	+17.1 kPa	201, 202	
DPV-173-100QQ	Across part of lower plenum, 439 cm (225°) to 457 cm (225°), below cold leg centerline. Elevation difference between taps is 18 cm.	+51 cm water	+6.65 kPa	203, 204	
DPV-LP-UP	Lower plenum, 457 cm below cold leg centerline at 225° to upper plenum, 27 cm above cold leg centerline at 30°. Elevation difference between taps is 485 cm.	+762 cm water	+101 kPa	205, 206	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
ECC SYSTEM					
DPU-ACC1-TB	Top to bottom of intact loop accumulator. Elevation difference between taps is 274 cm.	+762 cm water	+104 kPa	207, 208	
Steam Generator					
DPU-SGFW	In steam generator feedwater line.	+762 cm water	+762 cm water	209, 210	
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	211, 212	
DPU-SG-DISC	Across venturi tube, 160 cm downstream from steam generator discharge.	+1270 cm water	+170 kPa	213, 214	Data acquisition system saturated at t=41 s.
Pressure Suppression System					
DP-PSS-TB	Top to bottom of pressure suppression tank. Elevation difference between taps is 338 cm.	+762 cm water	+103 kPa		Detector failed.
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.
Intact Loop					
FTU-1	Hot leg, Spool 1, 42 cm from vessel center.	+1.26 to +25.2 m/s	+75.7 m/s	215, 216	
FTU-9	Cold leg, Spool 9, 393 cm from vessel center.	+5.05 to +50.5 m/s	+75.7 m/s	215, 216	
FTU-13	Cold leg, Spool 13, 163 cm from vessel center.	+1.26 to +50.5 m/s	+75.7 m/s	217, 218	Data acquisition system saturated at t=26 s and t=65 to 68 s.
FTU-15	Cold leg, Spool 15, 42 cm from vessel center.	+1.26 to +50.5 m/s	+63.1 m/s	217, 218	
Broken Loop					
FTB-21	Cold leg, Spool 21, 146 cm from vessel center; 3 in. pipe.	+1.26 to +25.2 m/s	+75.7 m/s	219, 220	
FTB-30	Hot leg, Spool 30, 63 cm from vessel center; 7-in. pipe.	+1.26 to +50.5 m/s	+50.5 m/s	221, 222	
FTB-37	Cold leg, Spool 37, 739 cm from vessel center along hot leg; 2-in. pipe.	+1.26 to +50.5 m/s	+50.5 m/s	221, 222	
Core					
FTV-CORE-IN	Entrance to core, 401 cm below cold leg centerline.	+1.26 to +12.6 m/s	+56.78 m/s	223, 224	
ECC System					
FTU-HPIS	In line immediately after HPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 m/s	+0.126 m/s	225, 226	
FTU-LPIS	In line leading from LPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 m/s	+0.631 m/s	227, 228	Data acquisition system saturated at t=26 s.
FTU-ACC	In line leading from intact loop accumulator, 1-in. line.	+0.315 to +3.15 m/s	+4.47	229, 230	
Pressurizer					
FTU-PRIZE	Surge Line.	+0.126 to +1.26 m/s	+6.3 m/s	231, 232	
FLUID VELOCITY	Turbine flowmeter, bidirectional.				
Downcomer					
FTV-40A	102 cm below cold leg centerline, 0°.	+0.762 to +15.24 m/s	+15.24 m/s	233, 234	Data acquisition system saturated intermittently from t=26 to 37 s.
FTV-40M	102 cm below cold leg centerline, 180°.	+0.762 to +15.24 m/s	+15.24 m/s	233, 234	Data acquisition system saturated at t=29 and 36 s.

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
MOMENTUM FLUX	Drag disc, bidirectional.				Momentum flux reported only for -6 to 42 s, except as noted. Drag disc data may exhibit significant temperature dependence. Drag disc data should be used only for short-term transient response.
<u>Intact Loop</u>	3-in. pipe.				
FDU-1	Hot leg, Spool 1, 60 cm from vessel center; target size 2.22 cm.	+298 to +17 113 kg/m-s ²	+56 739 kg/m-s ²	235	
FDU-5	Hot leg, Spool 5, 256 cm from vessel center; target size 2.54 cm.	+1.49 to +2997 kg/m-s ²	+6994 kg/m-s ²	236	
FDU-10	Cold leg, Spool 10, 349 cm from vessel center; target size 2.22 cm.	+298 to +154 800 kg/m-s ²	+35 344 kg/m-s ²	237	
FDU-13	Cold leg, Spool 13, 138 cm from vessel center; target size 2.22 cm.	+298 to +22 029 kg/m-s ²	+28 528 kg/m-s ²	238	
<u>Broken Loop</u>					
FDB-21	Cold leg, Spool 21, 134 cm from vessel center, 3-in. pipe; target size 2.22 cm.	+298 to +104 915 kg/m-s ²	+66 774 kg/m-s ²	239	
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	+155 319 kg/m-s ²	240	
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	241	Questionable data, transducer was mounted horizontally and possibly filled with subcooled water.
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	242	Questionable data, transducer was mounted horizontally and possibly filled with subcooled water.
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	+165 353 kg/m-s ²	243	
<u>Vessel</u>					
FDV-CORE-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	244	
DENSITY					
<u>Intact Loop</u>		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
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.			245, 246	
GU-1B				247, 248	
GU-1C					
GU-5VR	Hot leg, Spool 5, 246 cm from vessel center, vertical.			249, 250	
GU-10VR	Cold leg, Spool 10, 359 cm from vessel center, vertical.			249, 250	
GU-13VR	Cold leg, Spool 13, 142 cm from vessel center, vertical.			251, 252	
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.			253, 254	
GU-15B				255, 256	
GU-15C					
<u>Broken Loop</u>		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GB-21T	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.			257, 258	
GB-21B				259, 260	
GB-21C					
GB-23VR	Cold leg, Spool 23, 235 cm from vessel center, vertical.			261, 262	

TABLE V (continued)

Range ^[a]					
Measurement	Location and Comments ^[a]	Detector	Data Acquisition System	Figure ^[a]	Measurement Comments ^[b]
<u>Broken Loop (continued)</u>					
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.			263, 264 265, 266	
GB-37	Cold leg, Spool 37, 809 cm from vessel center along hot leg, across vertical pipe, simulated steam generator discharge.			267, 268	
GB-42VR	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, vertical.			269, 270	
<u>Vessel</u>		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GV-COR-150HZ	Core flow mixer box, 386 cm below cold leg centerline, horizontal, 0 to 180°.			271, 272	
GV-162/192D	Lower plenum, 409 cm below cold leg centerline (270°) to 488 cm below cold leg centerline (90°), 79 cm vertical, 82 cm diagonal.			273, 274	
GVLP-165HZ	Upper part of lower plenum, 419 cm below cold leg centerline, 4.379 cm below downcomer exit, horizontal 0 to 180°.			275, 276	Data acquisition system saturated from t=20 to 58 s.
GVLP-172HZ	Lower plenum, 437 cm below cold leg centerline, 22 cm below downcomer exit, horizontal, 90 to 270°.			275, 276	
<u>Pressurizer</u>					
GU-PRIZE	Surge line.	1.6 to 1600 kg/m ³	0 to 1600 kg/m ³	277, 278	
MASS FLOW RATE	Mass flow rate obtained by combining density (gamma attenuation technique) with volumetric flow rate (turbine flowmeter) or momentum flux (drag disc).	Range for mass flow is determined from range of individual detectors used in calculation.			Mass flow reported only for -6 to 42 s, except as noted; see comments on individual detectors.
<u>Intact Loop</u>					
FDU-1, GU-1C FTU-1, GU-1C	Hot leg, Spool 1.			279 280, 281	
FNU-5, GU-5VR	Hot leg, Spool 5.			282	
FTU-9, GU-10VR	Cold leg, Spool 9.			283, 284	
FDU-10, GU-10VR	Cold leg, Spool 10.			285	
FDU-13, GU-13VR FTU-13, GU-13VR	Cold leg, Spool 13.			286 287, 288	FTU-13 saturated at t=26 s and t=65 to 68 s.
FTU-15, GU-15C	Cold leg, Spool 15.			289, 290	
<u>Broken Loop</u>					
FDB-21, GB-21C FTB-21, GB-21C	Cold leg, Spool 21.			291 292, 293	
FDB-23, GB-23VR	Cold leg, Spool 23.			294	
FDB-30, GB-30C FTB-30, GB-30C	Hot leg, Spool 30.			295 296, 297	
FDB-37, GB-37 FTB-37, GB-37	Cold leg, Spool 37			298 299, 300	
FDB-42, GB-42VR	Cold leg, Spool 42.			301	
<u>Vessel</u>					
FDV-CORE-IN GV-COR-150HZ	Entrance to core.			302	
FTV-CORE-IN GV-COR-150HZ	Entrance to core.			303, 304	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Pressurizer</u>					
FTU-PRIZE GU-PRIZE	Pressurizer surge line.			305, 306	
CORE CHARACTERISTICS					
PWRCOR T-1	Core power.	0 to 1600 kw	2119 kW	307, 308	
PWRCOR T-2	Core power.	0 to 1600 kW	2670 kW	307, 308	
VOLTCOR-T	Core voltage.		0 to 200 Vdc	309, 310	
AMPCOR-1	Core current.	0 to 1000 amps	0 to 9790 A	311, 312	
PUMP CHARACTERISTICS					
PUMPU-CUR	Pump current.		0 to 44 A	313, 314	
PUMPU-RPM	Pump speed.		0 to 3600 rpm	315, 316	

[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 300 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 cold leg (TFU-7 and TFU-10), from -20 to 300 s.

Fig. 12 Fluid temperature in intact loop cold leg (TFU-7 and TFU-10), from -6 to 42 s.

Fig. 13 Fluid temperature in intact loop cold leg (RBU-14A, TFU-14B, and TFU-15), from -20 to 300 s.

Fig. 14 Fluid temperature in intact loop cold leg (RBU-14A, TFU-14B, and TFU-15), from -6 to 42 s.

Fig. 15 Fluid temperature in broken loop, vessel side (TFB-20, TFB-23, and TFB-24), from -20 to 300 s.

Fig. 16 Fluid temperature in broken loop, vessel side (TFB-20, TFB-23, and TFB-24), from -6 to 42 s.

Fig. 17 Fluid temperature in broken loop, pump side (TFB-30, TFB-37, TFB-42, and TFB-43), from -20 to 300 s.

Fig. 18 Fluid temperature in broken loop, pump side (TFB-30, TFB-37, TFB-42, and TFB-43), from -6 to 42 s.

Fig. 19 Fluid temperature in broken loop, reflux bypass simulators (TFB-RFBC and TFB-RFBH), from -20 to 300 s.

Fig. 20 Fluid temperature in broken loop, reflux bypass simulators (TFB-RFBC and TFB-RFBH), from -6 to 42 s.

Fig. 21 Fluid temperature in inlet annulus (TFV-ANN-4A and TFV-ANN-4M), from -20 to 300 s.

Fig. 22 Fluid temperature in inlet annulus (TFV-ANN-4A and TFV-ANN-4M), from -6 to 42 s.

Fig. 23 Fluid temperature in downcomer annulus (TFV-ANN-35A, TFV-ANN-35T, and TFV-ANN-70A), from -20 to 300 s.

Fig. 24 Fluid temperature in downcomer annulus (TFV-ANN-35A, TFV-ANN-35T, and TFV-ANN-70A), from -6 to 42 s.

Fig. 25 Fluid temperature in downcomer annulus (TFV-ANN-115A and TFV-ANN-115M), from -20 to 300 s.

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

Fig. 27 Fluid temperature in upper plenum (TFV-UP+13), from -20 to 300 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-8, TFV-LP-15, and TFV-LP-22), from -20 to 300 s.

Fig. 30 Fluid temperature in lower plenum (TFV-LP-8, TFV-LP-15, and TFV-LP-22), from -6 to 42 s.

Fig. 31 Fluid temperature in core inlet (TFV-CORE-IN), from -20 to 300 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 300 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 and TFG-6DE-67), from -20 to 300 s.

Fig. 36 Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45 and TFG-6DE-67), from -6 to 42 s.

Fig. 37 Fluid temperature in core, Grid Spacer 10 (TFG-10AB-45 and TFG-10GH-45), from -20 to 300 s.

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

Fig. 39 Fluid temperature in intact loop coolant injection line (TFU-ECC-14), from -20 to 300 s.

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

Fig. 41 Fluid temperature in steam generator, feedwater line (TFU-SGFW), from -20 to 300 s.

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

Fig. 43 Fluid temperature in steam generator, secondary side (TFU-SGSD), from -20 to 300 s.

Fig. 44 Fluid temperature in steam generator, secondary side (TFU-SGSD), from -6 to 42 s.

Fig. 45 Fluid temperature in steam generator, secondary side (TFU-SG1, TFU-SG3, and TFU-SG4), -20 to 300 s.

Fig. 46 Fluid temperature in steam generator, secondary side (TFU-SG1, TFU-SG3, and TFU-SG4), from -6 to 42 s.

Fig. 47 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -20 to 300 s.

Fig. 48 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -6 to 42 s.

Fig. 49 Fluid temperature in pressure suppression tank (TF-PSS-33, TF-PSS-63, and TF-PSS-130), from -20 to 300 s.

Fig. 50 Fluid temperature in pressure suppression tank (TF-PSS-33, TF-PSS-63, and TF-PSS-130), from -6 to 42 s.

Fig. 51 Material temperature in intact loop (TMU-1T16 and TMU-15T16), from -20 to 300 s.

Fig. 52 Material temperature in intact loop (TMU-1T16 and TMU-15T16), from -6 to 42 s.

Fig. 53 Material temperature in broken loop (TMB-20B16 and TMB-30B16), from -20 to 300 s.

Fig. 54 Material temperature in broken loop (TMB-20B16 and TMB-30B16), from -6 to 42 s.

Fig. 55 Material temperature in vessel filler (TMV-FI-115A), from -20 to 300 s.

Fig. 56 Material temperature in vessel filler (TMV-FI-115A), from -6 to 42 s.

Fig. 57 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -20 to 300 s.

Fig. 58 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -6 to 42 s.

Fig. 59 Core heater temperature, Rod D-5 (TH-D5-09, TH-D5-29, and TH-D5-39), from -20 to 300 s.

Fig. 60 Core heater temperature, Rod D-5 (TH-D5-09, TH-D5-29, and TH-D5-39), from -6 to 42 s.

Fig. 61 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -20 to 300 s.

Fig. 62 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -6 to 42 s.

Fig. 63 Core heater temperature, Rod E-5 (TH-E5-21 and TH-E5-25), from -20 to 300 s.

Fig. 64 Core heater temperature, Rod E-5 (TH-E5-21 and TH-E5-25), from -6 to 42 s.

Fig. 65 Core heater temperature, Rod A-4 (TH-A4-09), from -20 to 300 s.

Fig. 66 Core heater temperature, Rod A-4 (TH-A4-09), from -6 to 42 s.

Fig. 67 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -20 to 300 s.

Fig. 68 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -6 to 42 s.

Fig. 69 Core heater temperature, Rod B-3 (TH-B3-32), from -20 to 300 s.

Fig. 70 Core heater temperature, Rod B-3 (TH-B3-32), from -6 to 42 s.

Fig. 71 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -20 to 300 s.

Fig. 72 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -6 to 42 s.

Fig. 73 Core heater temperature, Rod B-6 (TH-B6-29), from -20 to 300 s.

Fig. 74 Core heater temperature, Rod B-6 (TH-B6-29), from -6 to 42 s.

Fig. 75 Core heater temperature, Rod C-2 (TH-C2-28 and TH-C2-38), from -20 to 300 s.

Fig. 76 Core heater temperature, Rod C-2 (TH-C2-28 and TH-C2-38), from -6 to 42 s.

Fig. 77 Core heater temperature, Rod C-3 (TH-C3-60), from -20 to 300 s.

Fig. 78 Core heater temperature, Rod C-3 (TH-C3-60), from -6 to 42 s.

Fig. 79 Core heater temperature, Rod C-4 (TH-C4-20 and TH-C4-26), from -20 to 300 s.

Fig. 80 Core heater temperature, Rod C-4 (TH-C4-20 and TH-C4-26), from -6 to 42 s.

Fig. 81 Core heater temperature, Rod C-5 (TH-C5-28), from -20 to 300 s.

Fig. 82 Core heater temperature, Rod C-5 (TH-C5-28), from -6 to 42 s.

Fig. 83 Core heater temperature, Rod C-6 (TH-C6-32 and TH-C6-53), from -20 to 300 s.

Fig. 84 Core heater temperature, Rod C-6 (TH-C6-32 and TH-C6-53), from -6 to 42 s.

Fig. 85 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -20 to 300 s.

Fig. 86 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -6 to 42 s.

Fig. 87 Core heater temperature, Rod D-1 (TH-D1-21), from -20 to 300 s.

Fig. 88 Core heater temperature, Rod D-1 (TH-D1-21), from -6 to 42 s.

Fig. 89 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -20 to 300 s.

Fig. 90 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -6 to 42 s.

Fig. 91 Core heater temperature, Rod D-3 (TH-D3-29, TH-D3-33, and TH-D3-39), from -20 to 300 s.

Fig. 92 Core heater temperature, Rod D-3 (TH-D3-29, TH-D3-33, and TH-D3-39), from -6 to 42 s.

Fig. 93 Core heater temperature, Rod D-7 (TH-D7-20), from -20 to 300 s.

Fig. 94 Core heater temperature, Rod D-7 (TH-D7-20), from -6 to 42 s.

Fig. 95 Core heater temperature, Rod D-8 (TH-D8-57), from -20 to 300 s.

Fig. 96 Core heater temperature, Rod D-8 (TH-D8-57), from -6 to 42 s.

Fig. 97 Core heater temperature, Rod E-1 (TH-E1-26 and TH-E1-33), from -20 to 300 s.

Fig. 98 Core heater temperature, Rod E-1 (TH-E1-26 and TH-E1-33), from -6 to 42 s.

Fig. 99 Core heater temperature, Rod E-3 (TH-E3-05, TH-E3-20, and TH-E3-24), from -20 to 300 s.

Fig. 100 Core heater temperature, Rod E-3 (TH-E3-05, TH-E3-20, and TH-E3-24), from -6 to 42 s.

Fig. 101 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -20 to 300 s.

Fig. 102 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -6 to 42 s.

Fig. 103 Core heater temperature, Rod E-7 (TH-E7-13 and TH-E7-44), from -20 to 300 s.

Fig. 104 Core heater temperature, Rod E-7 (TH-E7-13 and TH-E7-44), from -6 to 42 s.

Fig. 105 Core heater temperature, Rod E-8 (TH-E8-14, TH-E8-29, and TH-E8-45), from -20 to 300 s.

Fig. 106 Core heater temperature, Rod E-8 (TH-E8-14, TH-E8-29, and TH-E8-45), from -6 to 42 s.

Fig. 107 Core heater temperature, Rod F-3 (TH-F3-06, TH-F3-22, and TH-F3-25), from -20 to 300 s.

Fig. 108 Core heater temperature, Rod F-3 (TH-F3-06, TH-F3-22, and TH-F3-25), from -6 to 42 s.

Fig. 109 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -20 to 300 s.

Fig. 110 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -6 to 42 s.

Fig. 111 Core heater temperature, Rod F-6 (TH-F6-08 and TH-F6-28), from -20 to 300 s.

Fig. 112 Core heater temperature, Rod F-6 (TH-F6-08 and TH-F6-28), from -6 to 42 s.

Fig. 113 Core heater temperature, Rod F-7 (TH-F7-29), from -20 to 300 s.

Fig. 114 Core heater temperature, Rod F-7 (TH-F7-29), from -6 to 42 s.

Fig. 115 Core heater temperature, Rod G-3 (TH-G3-13), from -20 to 300 s.

Fig. 116 Core heater temperature, Rod G-3 (TH-G3-13), from -6 to 42 s.

Fig. 117 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -20 to 300 s.

Fig. 118 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -6 to 42 s.

Fig. 119 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -20 to 300 s.

Fig. 120 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -6 to 42 s.

Fig. 121 Core heater temperature, Rod H-5 (TH-H5-32), from -20 to 300 s.

Fig. 122 Core heater temperature, Rod H-5 (TH-H5-32), from -6 to 42 s.

Fig. 123 Pressure in intact loop (PU-13 and PU-15L), from -20 to 300 s.

Fig. 124 Pressure in intact loop (PU-13 and PU-15L), from -6 to 42 s.

Fig. 125 Pressure in broken loop, vessel side (PB-21, PB-23, and PB-24), from -20 to 300 s.

Fig. 126 Pressure in broken loop, vessel side (PB-21, PB-23, and PB-24), from -6 to 42 s.

Fig. 127 Pressure in broken loop, pump side (PB-42 and PB-43), from -20 to 300 s.

Fig. 128 Pressure in broken loop, pump side (PB-42 and PB-43), from -6 to 42 s.

Fig. 129 Pressure in broken loop, vessel side (PB-CN1), from -20 to 300 s.

Fig. 130 Pressure in broken loop, vessel side (PB-CN1), from -6 to 42 s.

Fig. 131 Pressure in vessel (PV-UP+10 and PV-LP-180), from -20 to 300 s.

Fig. 132 Pressure in vessel (PV-UP+10 and PV-LP-180), from -6 to 42 s.

Fig. 133 Pressure in intact loop accumulator (PU-ACC1), from -20 to 300 s.

Fig. 134 Pressure in intact loop accumulator (PU-ACC1), from -6 to 42 s.

Fig. 135 Pressure in steam generator, secondary side (PU-SGSD), from -20 to 300 s.

Fig. 136 Pressure in steam generator, secondary side (PU-SGSD), from -6 to 42 s.

Fig. 137 Pressure in pressurizer (PU-PRIZE), from -20 to 300 s.

Fig. 138 Pressure in pressurizer (PU-PRIZE), from -6 to 42 s.

Fig. 139 Pressure in pressure suppression tank (P-PSS), from -20 to 300 s.

Fig. 140 Pressure in pressure suppression tank (P-PSS), from -6 to 42 s.

Fig. 141 Differential pressure in intact loop (DPU-UP-3), from -20 to 300 s.

Fig. 142 Differential pressure in intact loop (DPU-UP-3), from -6 to 42 s.

Fig. 143 Differential pressure in intact loop (DPU-3-6), from -20 to 300 s.

Fig. 144 Differential pressure in intact loop (DPU-3-6), from -6 to 42 s.

Fig. 145 Differential pressure in intact loop (DPU-6-SGIP), from -20 to 300 s.

Fig. 146 Differential pressure in intact loop (DPU-6-SGIP), from -6 to 42 s.

Fig. 147 Differential pressure in intact loop (DPU-6-7), from -20 to 300 s.

Fig. 148 Differential pressure in intact loop (DPU-6-7), from -6 to 42 s.

Fig. 149 Differential pressure in intact loop (DPU-SGOP-7), from -20 to 300 s.

Fig. 150 Differential pressure in intact loop (DPU-SGOP-7), from -6 to 42 s.

Fig. 151 Differential pressure in intact loop (DPU-7-10), from -20 to 300 s.

Fig. 152 Differential pressure in intact loop (DPU-7-10), from -6 to 42 s.

Fig. 153 Differential pressure in intact loop (DPU-12-10), from -20 to 300 s.

Fig. 154 Differential pressure in intact loop (DPU-12-10), from -6 to 42 s.

Fig. 155 Differential pressure in intact loop (DPU-12-15), from -20 to 300 s.

Fig. 156 Differential pressure in intact loop (DPU-12-15), from -6 to 42 s.

Fig. 157 Differential pressure in intact loop (DPU-15-3), from -20 to 300 s.

Fig. 158 Differential pressure in intact loop (DPU-15-3), from -6 to 42 s.

Fig. 159 Differential pressure in intact loop, low range (DPU-15-3L), from -20 to 300 s.

Fig. 160 Differential pressure in intact loop, low range (DPU-15-3L), from -6 to 42 s.

Fig. 161 Differential pressure in intact loop (DPU-15-IANN), from -20 to 300 s.

Fig. 162 Differential pressure in intact loop (DPU-15-IANN), from -6 to 42 s.

Fig. 163 Differential pressure in intact loop (DPU-PRESLL), from -20 to 300 s.

Fig. 164 Differential pressure in intact loop (DPU-PRESLL), from -6 to 42 s.

Fig. 165 Differential pressure in intact loop (DPU-PR-4), from -20 to 300 s.

Fig. 166 Differential pressure in intact loop (DPU-PR-4), from -6 to 42 s.

Fig. 167 Differential pressure in broken loop (DPB-21-IANN), from -20 to 300 s.

Fig. 168 Differential pressure in broken loop (DPB-21-IANN), from -6 to 42 s.

Fig. 169 Differential pressure in broken loop (DPB-21-23), from -20 to 300 s.

Fig. 170 Differential pressure in broken loop (DPB-21-23), from -6 to 42 s.

Fig. 171 Differential pressure in broken loop (DPB-23-CN1), from -20 to 300 s.

Fig. 172 Differential pressure in broken loop (DPB-23-CN1), from -6 to 42 s.

Fig. 173 Differential pressure in broken loop (DPB-23-24), from -20 to 300 s.

Fig. 174 Differential pressure in broken loop (DPB-23-24), from -6 to 42 s.

Fig. 175 Differential pressure in broken loop (DPB-30-36L), from -20 to 300 s.

Fig. 176 Differential pressure in broken loop (DPB-30-36L), from -6 to 42 s.

Fig. 177 Differential pressure in broken loop (DPB-30-38), from -20 to 300 s.

Fig. 178 Differential pressure in broken loop (DPB-30-38), from -6 to 42 s.

Fig. 179 Differential pressure in broken loop (DPB-32U-36L), from -20 to 300 s.

Fig. 180 Differential pressure in broken loop (DPB-32U-36L), from -6 to 42 s.

Fig. 181 Differential pressure in broken loop (DPB-38-40), from -20 to 300 s.

Fig. 182 Differential pressure in broken loop (DPB-38-40), from -6 to 42 s.

Fig. 183 Differential pressure in broken loop (DPB-40-42), from -20 to 300 s.

Fig. 184 Differential pressure in broken loop (DPB-40-42), from -6 to 42 s.

Fig. 185 Differential pressure in broken loop (DPB-42-43), from -20 to 300 s.

Fig. 186 Differential pressure in broken loop (DPB-42-43), from -6 to 42 s.

Fig. 187 Differential pressure in vessel (DPV-UP-IANN), from -20 to 300 s.

Fig. 188 Differential pressure in vessel (DPV-IIP-IANN), from -6 to 42 s.

Fig. 189 Differential pressure in vessel (DPV-0-9GQ), from -20 to 300 s.

Fig. 190 Differential pressure in vessel (DPV-0-9GQ), from -6 to 42 s.

Fig. 191 Differential pressure in vessel (DPV-9-26QQ), from -20 to 300 s.

Fig. 192 Differential pressure in vessel (DPV-9-26QQ), from -6 to 42 s.

Fig. 193 Differential pressure in vessel (DPV-26-55QM), from -20 to 300 s.

Fig. 194 Differential pressure in vessel (DPV-26-55QM), from -6 to 42 s.

Fig. 195 Differential pressure in vessel (DPV-55-110MM), from -20 to 300 s.

Fig. 196 Differential pressure in vessel (DPV-55-110MM), from -6 to 42 s.

Fig. 197 Differential pressure in vessel (DPV-110-156MQ), from -20 to 300 s.

Fig. 198 Differential pressure in vessel (DPV-110-156MQ), from -6 to 42 s.

Fig. 199 Differential pressure in vessel (DPV-156-173QQ), from -20 to 300 s.

Fig. 200 Differential pressure in vessel (DPV-156-173QQ), from -6 to 42 s.

Fig. 201 Differential pressure in vessel (DPV-166-192QT), from -20 to 300 s.

Fig. 202 Differential pressure in vessel (DPV-166-192QT), from -6 to 42 s.

Fig. 203 Differential pressure in vessel (DPV-173-180QQ), from -20 to 300 s.

Fig. 204 Differential pressure in vessel (DPV-173-180QQ), from -6 to 42 s.

Fig. 205 Differential pressure in vessel (DPV-LP-UP), from -20 to 300 s.

Fig. 206 Differential pressure in vessel (DPV-LP-UP), from -6 to 42 s.

Fig. 207 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -20 to 300 s.

Fig. 208 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -6 to 42 s.

Fig. 209 Differential pressure across steam generator feedwater orifice (DPU-SGFW), from -20 to 300 s.

Fig. 210 Differential pressure across steam generator feedwater orifice (DPU-SGFW), from -6 to 42 s.

Fig. 211 Differential pressure in steam generator secondary (DPU-SG-SEC), from -20 to 300 s.

Fig. 212 Differential pressure in steam generator secondary (DPU-SG-SEC), from -6 to 42 s.

Fig. 213 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -20 to 300 s.

Fig. 214 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -6 to 42 s.

Fig. 215 Volumetric flow in intact loop (FTU-1 and FTU-9), from -20 to 300 s.

Fig. 216 Volumetric flow in intact loop (FTU-1 and FTU-9), from -6 to 42 s.

Fig. 217 Volumetric flow in intact loop (FTU-13 and FTU-15), from -20 to 300 s.

Fig. 218 Volumetric flow in intact loop (FTU-13 and FTU-15), from -6 to 42 s.

Fig. 219 Volumetric flow in broken loop (FTB-21), from -20 to 300 s.

Fig. 220 Volumetric flow in broken loop (FTB-21), from -6 to 42 s.

Fig. 221 Volumetric flow in broken loop (FTB-30 and FTB-37), from -20 to 300 s.

Fig. 222 Volumetric flow in broken loop (FTB-30 and FTB-37), from -6 to 42 s.

Fig. 223 Volumetric flow in core entrance (FTV-CORE-IN), from -20 to 300 s.

Fig. 224 Volumetric flow in core entrance (FTV-CORE-IN), from -6 to 42 s.

Fig. 225 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -20 to 300 s.

Fig. 226 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -6 to 42 s.

Fig. 227 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -20 to 300 s.

Fig. 228 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -6 to 42 s.

Fig. 229 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -20 to 300 s.

Fig. 230 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -6 to 42 s.

Fig. 231 Volumetric flow from pressurizer (FTU-PRIZE), from -20 to 300 s.

Fig. 232 Volumetric flow from pressurizer (FTU-PRIZE), from -6 to 42 s.

Fig. 233 Fluid velocity in vessel (FTV-40A and FTV-40M), from -20 to 300 s.

Fig. 234 Fluid velocity in vessel (FTV-40A and FTV-40M), from -6 to 42 s.

Fig. 235 Momentum flux in intact loop (FDU-1), from -6 to 42 s.

Fig. 236 Momentum flux in intact loop (FDU-5), from -6 to 42 s.

Fig. 237 Momentum flux in intact loop (FDU-10), from -6 to 42 s.

Fig. 238 Momentum flux in intact loop (FDU-13), from -6 to 42 s.

Fig. 239 Momentum flux in broken loop (FDB-21), from -6 to 42 s.

Fig. 240 Momentum flux in broken loop (FDB-23), from -6 to 42 s.

Fig. 241 Momentum flux in broken loop (FDB-30), from -6 to 42 s.

Fig. 242 Momentum flux in broken loop (FDB-37), from -6 to 42 s.

Fig. 243 Momentum flux in broken loop (FDB-42), from -6 to 42 s.

Fig. 244 Momentum flux in core entrance (FDV-CORE-IN), from -6 to 42 s.

Fig. 245 Density in intact loop (GU-1T and GU-1B), from -20 to 300 s.

Fig. 246 Density in intact loop (GU-1T and GU-1B), from -6 to 42 s.

Fig. 247 Density in intact loop (GU-1C), from -20 to 300 s.

Fig. 248 Density in intact loop (GU-1C), from -6 to 42 s.

Fig. 249 Density in intact loop (GU-5VR and GU-10VR), from -20 to 300 s.

Fig. 250 Density in intact loop (GU-5VR and GU-10VR), from -6 to 42 s.

Fig. 251 Density in intact loop (GU-13VR), from -20 to 300 s.

Fig. 252 Density in intact loop (GU-13VR), from -6 to 42 s.

Fig. 253 Density in intact loop (GU-15T and GU-15B), from -20 to 300 s.

Fig. 254 Density in intact loop (GU-15T and GU-15B), from -6 to 42 s.

Fig. 255 Density in intact loop (GU-15C), from -20 to 300 s.

Fig. 256 Density in intact loop (GU-15C), from -6 to 42 s.

Fig. 257 Density in broken loop (GB-21T and GB-21B), from -20 to 300 s.

Fig. 258 Density in broken loop (GB-21T and GB-21B), from -6 to 42 s.

Fig. 259 Density in broken loop (GB-21C), from -20 to 300 s.

Fig. 260 Density in broken loop (GB-21C), from -6 to 42 s.

Fig. 261 Density in broken loop (GB-23VR), from -20 to 300 s.

Fig. 262 Density in broken loop (GB-23VR), from -6 to 42 s.

Fig. 263 Density in broken loop (GB-30T and GB-30B), from -20 to 300 s

Fig. 264 Density in broken loop (GB-30T and GB-30B), from -6 to 42 s.

Fig. 265 Density in broken loop (GB-30C), from -20 to 300 s.

Fig. 266 Density in broken loop (GB-30C), from -6 to 42 s.

Fig. 267 Density in broken loop (GB-37), from -20 to 300 s.

Fig. 268 Density in broken loop (GB-37), from -6 to 42 s.

Fig. 269 Density in broken loop (GB-42VR), from -20 to 300 s.

Fig. 270 Density in broken loop (GB-42VR), from -6 to 42 s.

Fig. 271 Density in vessel (GV-COR-150HZ), from -20 to 300 s.

Fig. 272 Density in vessel (GV-COR-150HZ), from -6 to 42 s.

Fig. 273 Density in vessel (GV-162/192D), from -20 to 300 s.

Fig. 274 Density in vessel (GV-162/192D), from -6 to 42 s.

Fig. 275 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -20 to 300 s.

Fig. 276 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -6 to 42 s.

Fig. 277 Density in pressurizer (GU-PRIZE), from -20 to 300 s.

Fig. 278 Density in pressurizer (GU-PRIZE), from -6 to 42 s.

Fig. 279 Mass flow in intact loop (FDU-1, GU-1C), from -6 to 42 s.

Fig. 280 Mass flow in intact loop (FTU-1, GU-1C), from -20 to 300 s.

Fig. 281 Mass flow in intact loop (FTU-1, GU-1C), from -6 to 42 s.

Fig. 282 Mass flow in intact loop (FDU-5, GU-5VR), from -6 to 42 s.

Fig. 283 Mass flow in intact loop (FTU-9, GU-10VR), from -20 to 300 s.

Fig. 284 Mass flow in intact loop (FTU-9, GU-10VR), from -6 to 42 s.

Fig. 285 Mass flow in intact loop (FDU-10, GU-10VR), from -6 to 42 s.

Fig. 286 Mass flow in intact loop (FDU-13, GU-13VR), from -6 to 42 s.

Fig. 287 Mass flow in intact loop (FTU-13, GU-13VR), from -20 to 300 s.

Fig. 288 Mass flow in intact loop (FTU-13, GU-13VR), from -6 to 42 s.

Fig. 289 Mass flow in intact loop (FTU-15, GU-15C), from -20 to 300 s.

Fig. 290 Mass flow in intact loop (FTU-15, GU-15C), from -6 to 42 s.

Fig. 291 Mass flow in intact loop (FDB-21, GB-21C), from -6 to 42 s.

Fig. 292 Mass flow in broken loop (FTB-21, GB-21C), from -20 to 300 s.

Fig. 293 Mass flow in broken loop (FTB-21, GB-21C), from -6 to 42 s.

Fig. 294 Mass flow in broken loop (FDB-23, GB-23VR), from -6 to 42 s.

Fig. 295 Mass flow in broken loop (FDB-30, GB-30C), from -6 to 42 s.

Fig. 296 Mass flow in broken loop (FTB-30, GB-30C), from -20 to 300 s.

Fig. 297 Mass flow in broken loop (FTB-30, GB-30C), from -6 to 42 s.

Fig. 298 Mass flow in broken loop (FDB-37, GB-37), from -6 to 42 s.

Fig. 301 Mass flow in broken loop (FDB-42, GB-42VR), from -6 to 42 s.

Fig. 302 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 299 Mass flow in broken loop (FTB-37, GB-37), from -20 to 300 s.

Fig. 300 Mass flow in broken loop (FTB-37, GB-37), from -6 to 42 s.

Fig. 303 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -20 to 300 s.

Fig. 304 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 305 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -20 to 300 s.

Fig. 306 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -6 to 42 s.

Fig. 307 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -20 to 300 s.

Fig. 308 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -6 to 42 s.

Fig. 309 Core heater voltage (VOLTCOR-T), from -20 to 300 s.

Fig. 310 Core heater voltage (VOLTCOR-T), from -6 to 42 s.

Fig. 311 Core heater total current (AMPCOR-T), from -20 to 300 s.

Fig. 312 Core heater total current (AMPCOR-T), from -6 to 42 s.

Fig. 313 Primary pump current (PUMPU-CUR), from -20 to 300 s.

Fig. 314 Primary pump current (PUMPU-CUR), from -6 to 42 s.

Fig. 315 Primary pump speed (PUMPU-RPM), from -20 to 300 s.

Fig. 316 Primary pump speed (PUMPU-RPM), from -6 to 42 s.

IV. REFERENCES

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).
2. V. Esparza and K. E. Sackett, *Experiment Data Report for Semiscale Mod-1 Test S-06-5 (LOFT Counterpart Test)*, TREE-NUREG-1125 (June 1977).

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 yielding 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 done 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-06-4

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APPENDIX B

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1

TEST S-06-4

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-06-4 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 pressurizer pressure (PU-PRIZE) is done in the same manner as for the main loop pressures using a Heise gauge 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, kPa

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-06-4)

<u>Detector Identification</u>	<u>C_0</u>	<u>C_1</u>
PU-PRIZE	0	0.989 6
PB-24	0	0.982 2

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, 2010, 5100, 6880, 8580, 12 040 and 15 060 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.

Pressure cell ambient offsets are evaluated using a posttest, system-drained digital data scan. The measured transducer outputs are compared with values calculated from the differences in standing leg heights for the sense lines to each pressure cell. The difference between the measured value and the calculated value is the ambient offset.

For some differential pressure measurements, other references are used. The liquid level measurement in the intact loop accumulator (DPU-ACC1-TB) is referenced to a calculated value based on geometrical considerations at the time when the water is depleted from the accumulator and gas flow begins. The reading from the steam generator discharge venturi (DPU-SG-DISC) is shifted to read zero after flow is stopped.

In correcting differential pressure data for pressure sensitivity, the data are initially corrected for errors in amplification and ambient offsets. The data are then corrected for pressure sensitivity to arrive at the final values. Corrections were made using the following equations:

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

where

$F'(t)$ = data corrected for amplification and ambient offsets, kPa

K = amplification factor

$F(t)$ = raw data, kPa

C_0 = ambient offset, kPa

$$F''(t) = F'(t) + C_1 \text{ for } t < t_1$$

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

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

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

where

t = time

$F''(t)$ = final corrected data, kPa

C_i = data correction points, kPa

t_i = times corresponding to data correction points, s.

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

TABLE B-II
CONSTANTS FOR DIFFERENTIAL PRESSURE
MEASUREMENT CORRECTIONS (TEST S-06-4)

Detector Identification	K	C ₀	C ₁	t ₁	C ₂	t ₂	C ₃	t ₃
DPU-12-10	1		-6.3	0	-4.7	0.01	-0.3	32
DPU-ACC1-TB	1	-10.3						
DPB-23-24	1	-5.5						
DPB-30-38	1		-29.6	0	-24.1	0.01	-1.4	32
DPB-32U-36L	1		63.4	0	46.9	0.01	2.8	32
DPV-UP-IANN	1	2.6						
DPV-9-26QQ	1		0.23	0	0.21	0.01	0.06	32
DPV-26-55QM	1		-1.7	0	-1.4	0.01	-0.3	32
DPV-173-180QQ	1	-0.15						
DPV-LP-UP	1	-95.0						

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 and pressure sensitivities are removed before the data are converted to momentum flux. The temperature and pressure of each transducer are 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:

$$F'(t) = F(t) + C_0 - T_1 \cdot T(t) - P_1 \cdot P(t)$$

where

$F'(t)$ = corrected data, DAS volts

$F(t)$ = raw data, DAS volts

T_1 = temperature sensitivity, DAS volts/K

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

C_o = ambient offset, DAS volts

P_1 = pressure sensitivity, DAS volts/kPa

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

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

TABLE B-III
CONSTANTS FOR MOMENTUM FLUX
MEASUREMENT CORRECTIONS (TEST S-06-4)

ID	C_0	T_1	$T(t)$ [a]	P_1	$P(t)$ [b]
FDU-5	0	0.000 943	TFU-7	-0.000 001 6	PV-UP+10
FDV-CORE-IN	0	-0.000 038	TFV-CORE-IN		
FDU-10	0	0.000 198	TFU-10	0.000 000 7	PV-UP+10
FDU-13	0	0.001 327	RBU-14A		
FDB-30 ^[c]	-0.092	-0.001 436	TFB-30	0.000 000 7	PV-UP+10
FDB-21	0	-0.001 046	TFB-20	-0.000 003 9	PB-21
FDB-23	0	-0.001 885	TFB-23	-0.000 003 8	PB-23
FDB-42	-0.037	0.001 413	TFB-42	-0.000 003 2	PB-42
FDB-37 ^[c]	-0.125	0.000 839	TFB-37	-0.000 000 5	PB-42
FDU-1	0	-0.002 225	RBU-2	-0.000 004 3	PV-UP+10

- [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] $P(t)$ is the pressure data from the indicated transducer used for pressure sensitivity correction. The symbols listed identify the pressure transducers from which the data are obtained.
- [c] 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 detectors.

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:

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

where

- ρ = the density in kg/m^3
- C = a constant based on the length of the gamma beam path,
DAS volts/ kg/m^3
- D = a theoretical voltage for zero attenuation inside the vessel, DAS volts
- A = an amplification factor
- B = a biasing factor, DAS volts
- $F(t)$ = the transducer voltage output, DAS volts.

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

$$\text{GVL-172HZ} \quad \rho = -20.936 F(t) - 546.7$$

$$\text{GV-COR-150HZ} \quad \rho = -60.068 F(t) - 2877.9.$$

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.

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 B-IV along with the constants for single-beam gamma densitometers.

TABLE B-IV
 CONSTANTS FOR DENSITY MEASUREMENT
 CONVERSIONS TO ENGINEERING UNITS (TEST S-06-4)

<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-1T	1.031	-0.201	0.000 36	6.48
GU-1B	0.987	0.150	0.000 50	7.18
GU-5VR	1.100	-0.450	0.000 59	4.51
GU-10VR	1.076	-0.468	0.000 59	6.72
GU-13VR	0.839	0.315	0.000 59	1.94
GU-15T	1.151	-0.952	0.000 36	6.34
GU-15B	0.992	0.055	0.000 50	6.76
GB-21T	1.057	-0.348	0.000 36	6.50
GB-21B	1.112	-0.814	0.000 50	7.40
GB-23VR	0.977	0.187	0.000 37	7.40
GB-30T	1.119	-0.711	0.000 36	5.98
GB-30B	1.014	-0.085	0.000 50	7.73
GB-37	1.918	-3.621	0.000 59	3.95
GB-42VR	-0.621	7.624	0.000 37	4.71
GV-162/192D	1.389	-0.578	0.005 40	1.60
GVL P 165HZ	1.061	-0.138	0.001 50	10.50
GU-PRIZE	1.207	-0.193	0.000 59	0.955

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

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

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 B-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 and lower portions of the piping cross section.

APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR

BANDS FROM SEMISCALE MOD-1 TEST S-06-4

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APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR

BANDS FROM SEMISCALE MOD-1 TEST S-06-4

Analysis has been performed on selected data from Test S-06-4 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-43.

TABLE C-I

RANDOM ERROR VARIANCE (TEST S-06-4)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFB-23	9.888	0 to 80	C-1	
	3.545	80 to 300		
TFV-ANN-35A	7.795	0 to 80	C-2	
	1.289	80 to 300		
TFV-LP-8	1.194	0 to 300	C-3	

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFV-LP-15	1.557	0 to 300	C-4	
TFV-LP-22	1.855	0 to 300	C-5	
TFG-5CD-45	16.213 31.205 4.333	0 to 61 61 to 65 65 to 300	C-6	
TFU-SG3	0.175	0 to 300	C-7	
TFU-PRIZE	1.403	0 to 300	C-8	
TH-E4-09	11.622 27.372 0.387	0 to 86 86 to 93 93 to 300	C-9	
TH-E4-27	7.846	0 to 300	C-10	
TH-E4-55	1.420 23.746 0.436	0 to 268 268 to 275 275 to 300	C-11	
PU-13	2.493	0 to 300	C-12	
PB-23	3.595	0 to 300	C-13	
DPU-6-SGIP	0.406 0.770 0.146	0 to 66 66 to 80 80 to 300	C-14	
DPU-SGOP-7	0.425 0.852 0.223	0 to 66 66 to 80 80 to 300	C-15	
DPU-7-10	0.128 0.267	0 to 14 14 to 300	C-16	
DPU-12-10	0.850 0.348	0 to 14 14 to 300	C-17	
DPU-12-15	0.157 0.221	0 to 25 25 to 300	C-18	
FTU-1	59.772 54.819	0 to 60 60 to 300	C-19	

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FTU-15	7.457	0 to 15	C-20	
	31.998	15 to 19		
	22.977	19 to 66		
	88.407	66 to 300		
FTU-HPIS	0.069	0 to 22	C-21	
	0.730	22 to 27		
	0.473	27 to 300		
FTU-LPIS	0.192	0 to 22	C-22	
	1.879	22 to 26		
	0.011	26 to 300		
FTU-ACC1	3.516	0 to 15	C-23	Error bands are not presepted from t=91 to 300 s ^[a] .
	1.393	15 to 19		
	0.191	19 to 65		
	1.033	65 to 68		
	2.585	68 to 87		
	4.193	87 to 91		
FTV-40A	7.284	0 to 57	C-24	
	2.263	57 to 300		
FTV-40M	5.881	0 to 57	C-25	
	1.692	57 to 300		
GU-1T	0.666	0 to 14	C-26	
	0.250	14 to 300		
GU-1B	1.859	0 to 22	C-27	
	0.042	22 to 87		
	0.206	87 to 300		
GU-1C	0.858	0 to 14	C-28	
	0.179	14 to 300		
GU-10VR	1.662	0 to 14	C-29	
	0.195	14 to 300		
GU-15T	2.538	0 to 15	C-30	
	9.604	15 to 24		
	3.684	24 to 67		
	7.919	67 to 72		
	0.858	72 to 98		
	15.823	98 to 300		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GU-15B	1.388	0 to 15	C-31	
	4.589	15 to 23		
	4.301	23 to 67		
	10.280	67 to 72		
	1.530	72 to 98		
	12.972	98 to 300		
GU-15C	2.024	0 to 15	C-32	
	7.237	15 to 24		
	3.648	24 to 67		
	8.555	67 to 72		
	2.614	72 to 98		
	14.535	98 to 300		
GB-23VR	1.202	0 to 19	C-33	
	10.397	19 to 57		
	3.711	57 to 300		
GV-COR-150HZ	4.355	0 to 14	C-34	
	1.086	14 to 55		
	10.863	55 to 59		
	13.912	59 to 81		
	0.720	81 to 112		
	5.866	112 to 300		
GVLP-165HZ	3.699	0 to 20	C-35	
	0.735	20 to 55		
	6.128	55 to 59		
	9.212	59 to 73		
	0.743	73 to 117		
	6.073	117 to 239		
	1.391	239 to 300		
GVLP-172HZ	3.136	0 to 55	C-36	
	8.004	55 to 59		
	0.284	59 to 121		
	2.095	121 to 300		
FTU-1, GU-1C	0.689	0 to 15	C-37	
	0.105	15 to 300		
FDU-5, GU-5VR	0.431	0 to 14	C-38	Only short-term (0 to 42 s) error bands reported.
	0.174	14 to 42		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FTU-13, GU-13VR	0.830 10.854 0.771 9.082	0 to 23 23 to 71 71 to 101 101 to 300	C-39	
FTU-15, GU-15C	0.817 3.098 1.066 5.261	0 to 18 18 to 70 70 to 100 100 to 300	C-40	
FDB-21, GB-21C	1.349 3.618	0 to 19 19 to 42	C-41	Only short-term (0 to 42 s) error bands reported.
FTB-21, GB-21C	1.790 2.318 0.926 0.510	0 to 14 14 to 79 79 to 177 177 to 300	C-42	
FTV-CORE-IN, GV-COR-150HZ	1.255 7.915	0 to 57 57 to 300	C-43	

[a] Error bands are not represented in this region. The sensor gave a constant reading due to one of the following: (a) sensor saturation, (b) sensor dropout, or (c) sensor deadband. Random error in measurement cannot be modeled under these conditions.

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 lower plenum (TFV-LP-15).

Fig. C-5 Fluid temperature in lower plenum (TFV-LP-22).

Fig. C-6 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45).

Fig. C-7 Fluid temperature in steam generator (TFU-SG3).

Fig. C-8 Fluid temperature in pressurizer surge line (TFU-PRIZE).

Fig. C-9 Core heater temperature, Rod E-4 (TH-E4-09).

Fig. C-10 Core heater temperature, Rod E-4 (TH-E4-27).

Fig. C-11 Core heater temperature, Rod E-4 (TH-E4-55).

Fig. C-12 Pressure in intact loop, Spool 13 (PU-13).

Fig. C-13 Pressure in broken loop, Spool 23 (PB-23).

Fig. C-14 Differential pressure in intact loop (DPU-6-SGIP).

Fig. C-15 Differential pressure in intact loop (DPU-SGOP-7).

Fig. C-16 Differential pressure in intact loop (DPU-7-10).

Fig. C-17 Differential pressure in intact loop (DPU-12-10).

Fig. C-18 Differential pressure in intact loop (DPU-12-15).

Fig. C-19 Volumetric flow in intact loop (FTU-1).

Fig. C-20 Volumetric flow in intact loop (FTU-15).

Fig. C-21 Volumetric flow in intact loop high pressure injection line / (FTU-HPIS).

Fig. C-22 Volumetric flow in intact loop low pressure injection line (FTU-LPIS).

Fig. C-23 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1).

Fig. C-24 Fluid velocity in vessel (FTV-40A).

Fig. C-25 Fluid velocity in vessel (FTV-40M).

Fig. C-26 Density in intact loop (GU-1T).

Fig. C-27 Density in intact loop (GU-1B).

Fig. C-28 Denstiy in intact loop (GU-1C).

Fig. C-29 Density in intact loop (GU-10VR).

Fig. C-30 Density in intact loop (GU-15T).

Fig. C-31 Density in intact loop (GU-15B).

Fig. C-32 Density in intact loop (GU-15C).

Fig. C-33 Density in broken loop (GB-23VR).

Fig. C-34 Density in vessel (GV-COR-150HZ).

Fig. C-35 Density in vessel (GVLP-165HZ).

Fig. C-36 Density in vessel (GVLP-172HZ).

Fig. C-37 Mass flow in intact loop (FTU-1, GU-1C).

Fig. C-38 Mass flow in intact loop (FDU-5, GU-5VR).

Fig. C-39 Mass flow in intact loop (FTU-13, GU-13VR).

Fig. C-40 Mass flow in intact loop (FTU-15, GU-15C).

Fig. C-41 Mass flow in broken loop (FDB-21, GB-21C).

Fig. C-42 Mass flow in broken loop (FTB-21, GB-21C).

Fig. C-43 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-06-4)

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] where Gr = flow regime error (kg/m ²)	[d]
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)	
Volumetric Flow (turbine flow-meter)	Flow regimes	[d]	[d]
	Calibration instrument reading	+0.25% of transducer full scale	
	Calibration standards	+19.56 x 10 ⁻² l/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-06-4)

<u>Transducer Identification</u>	<u>Time during which Flow Regime Errors Were Applied (s)</u>	<u>Figure</u>
FTU-1	1 to 20	C-19
FTU-15	7 to 95	C-20
GU-1C	1 to 20	C-28
GU-10VR	8 to 20	C-29
GU-15C	7 to 95	C-32
GB-23VR	16 to 300	C-33
FTU-1, GU-1C	1 to 20	C-37
FDU-5, GU-5VR	1 to 20	C-38
FTU-15, GU-15C	7 to 95	C-40
FDB-21, GB-21C	7 to 300	C-41
FTB-21, GB-21C	7 to 300	C-42

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,

$$\sigma_o^2 = \sqrt{\sigma_R^2 + \sigma_E^2} \quad (C-1)$$

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 for these segments of the data were not obtained and bands only appear because of limitations in the plotting package.

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- C-1. G. E. P. Box and B. M. Jenkins, *Time Series Analysis – Forecasting and Control*, San Francisco: Holden-Day, 1970.
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