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TREE-NUREG-1126
for U.S. Nuclear Regulatory Commission

**EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1
TEST S-06-6
(LOFT COUNTERPART TEST)**

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September 1977

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IDAHO NATIONAL ENGINEERING LABORATORY

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy ~~\$8.00~~; Microfiche \$3.00

\$11.00

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TEST S-06-6

(LOFT COUNTERPART TEST)

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TREE-NUREG-1126

Distributed Under Category:
NRC-2
Water Reactor Safety Research
Systems Engineering

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TEST S-06-6

(LOFT COUNTERPART TEST)

By

Vicente Esparza
Kenneth E. Sackett

EG&G IDAHO, INC.

September 1977

PREPARED FOR THE
U. S. NUCLEAR REGULATORY COMMISSION
AND
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. EY-76-C-07-1570

ABSTRACT

Recorded test data are presented for Test S-06-6 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-06-6 was conducted from initial conditions of 15 792 kPa and 563 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 75% of the maximum peak power density (52.5 kW/m). Test S-06-6 also evaluated the effect of special hardware assumptions on the core response.

The purpose of this report is to make available the uninterpreted data from Test S-06-6 for future data analysis and test results 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-06-6 was performed as part of the Semiscale Mod-1 portion of the Semiscale Program conducted by EG&G Idaho, Inc. for the United States Government. This test is part of the 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-06-6 was to determine the maximum cladding temperature associated with a high powered rod peak power density of 39.4 kW/m, or 75% of the maximum high powered rod peak power density of 52.5 kW/m. Test S-06-6 had the additional objective of evaluating the effect of special hardware assumptions on the core response. Hardware configuration and test parameters were selected to yield a system response that simulates the response of the LOFT nuclear facility during the first nuclear test series.

Test S-06-6 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-06-6, four heater rods were intentionally unpowered to simulate LOFT passive rod locations and the power in four heater rods was increased by 5% over the surrounding rods to produce a peaked power profile.

The test was conducted from initial conditions of 15 792 kPa and 563 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 1002 kW, and an initial core inlet flow rate of 6.62 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 loss-of-coolant accident. Blowdown was accompanied by simulated emergency core coolant injection into the cold leg piping of the intact loop.

Test S-06-6 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 229 measurements taken, 224 produced usable data.

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-06-6

(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 Energy Research and Development Administration, is part of the overall program designed to investigate the response of a pressurized water reactor system to a hypothesized loss-of-coolant accident (LOCA). The underlying objectives of the Semiscale Program are to quantify the physical processes controlling system behavior during a LOCA and to provide an experimental data base for assessing reactor safety evaluation models. The Semiscale Mod-1 Program has the further objective of providing support to other experimental programs in the form of instrumentation assessment, optimization of test series, selection of test parameters, and evaluation of test results.

Test S-06-6 was conducted May 17, 1977, in the Semiscale Mod-1 system as part of the LOFT counterpart test series (Test Series 6). This series was designed to obtain thermal-hydraulic response data from blowdown, refill, and reflood transients in a simulated reactor system with a heated core to assist the Loss-of-Fluid Test (LOFT) Program in the planning of the first LOFT nuclear test series. The test objective specific to Test S-06-6 was to determine the maximum cladding temperature associated with a high powered rod peak power density of 39.4 kW/m, or 75% of the maximum peak power density of 52.5 kW/m. Test S-06-6 had the additional objective of evaluating the effect of special hardware assumptions on the core response.

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-06-6; 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-06-6

The following system configuration, procedures, initial test conditions, and events are specific to Test S-06-6 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-06-6.

For Test S-06-6, the 40-rod electrically heated core was operated at an axial peak power density which was 75% 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 39.4 kW/m, 32 rods were operated at approximately 24.9 kW/m, and four rods (Rods C-4, D-6, E-3, 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 1002 kW.

Test S-06-6 was conducted using 10 CFR-50 Appendix K^[3] hardware assumptions to evaluate their effect on the core response. The assumptions investigated are summarized as follows: (a) a loss of power to the intact loop pump occurred at the break, (b) the broken loop pump simulated the resistance of a locked rotor rather than a free-wheeling rotor, (c) the steam generator feedwater and steam controls were ramped to close 15 s after rupture and (d) the low pressure injection system (LPIS) and the high pressure injection system (HPIS) flow rates simulated flow from one HPIS and one LPIS pump with injection times delayed to 25 and 35 s, respectively.

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 4223 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.

[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.

INEL-B-3073

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

Warmup to initial test conditions was accomplished with the heaters in the vessel core. Heatup of the broken loop piping was accomplished with bypass lines which served to allow circulation through the broken loop. During warmup, the purification and sampling systems were valved into the primary system to maintain water chemistry requirements and to provide a water sample at system conditions for subsequent analysis. At 55.56-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.

Prior to the initial core power level being established, the pressure suppression system was pressurized to 241 kPa with saturated steam from the steam supply system. After the core power was increased to 1002 kW, initial test conditions were held for 1440 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 with gaseous nitrogen. Immediately (within 0.02 s) after initiation of blowdown, the lines to the accumulator were again isolated. The effluent from the primary system was ejected into the pressure suppression system which was vented to maintain a constant pressure of 241 kPa. During the blowdown transient, power to the electrically heated core was automatically controlled to aid in the LOFT simulation. The primary coolant circulation pump speed was controlled by a predetermined coastdown.

For Test S-06-6 all coolant injection systems were arranged to discharge into the intact loop cold leg injection point (Spool 14). Coolant injection from the high pressure injection system pump began at blowdown and continued until test termination (300 s). Coolant injection from the accumulator started approximately 19 s after rupture at a system pressure of 5190 kPa and continued to depletion at 66 s after blowdown. Low pressure coolant injection began 35 s after rupture at a system pressure of 1165 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-06-6	
	Measured ^[a]	Specified
Core power (kW)	1002	1010
Intact loop cold leg fluid temperature (K)	563	563 $\pm$ 1
Hot leg to cold leg temperature differential (K)	35.5	35.6 $\pm$ 0.5
Pressurizer pressure (kPa)	15 792	15 603 $\pm$ 172
Pressurizer liquid mass (kg) ^[b]	8.92	9.072
Steam generator feedwater temperature (K)	498	497 $\pm$ 5.5
Steam generator liquid level (from bottom of tube sheet) (cm)	292.25	295 $\pm$ 5
Broken loop fluid temperature (pump side) (K)	596	596 $\pm$ 3
Broken loop fluid temperature (vessel side) (K)	562	Not Specified
Intact loop cold leg flow (L/s)	6.62	[c]
Pressure suppression tank water level (cm)	121	121 $\pm$ 1
Pressure suppression tank pressure (kPa)	200	196 $\pm$ 7
Pressure suppression tank water temperature (K)	290	<297

[a] Measured initial conditions are taken from a digital scan read 0.5 s before 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-06-6	
	<u>Detector</u>	<u>Temperature (K)</u>
Vessel lower plenum	TFV-LP-22	563
Intact loop hot leg (near vessel)	RBU-2	599
Intact loop cold leg (near pump inlet)	TFU-10	564
Intact loop cold leg (near vessel)	RBU-14A	563
Broken loop cold leg (near nozzle)	TFB-23	562
Broken loop hot leg (near vessel)	TFB-30	596
Broken loop cold leg (near nozzle)	TFB-42	590
Reflood bypass line hot leg (near end cap)	TFB-RFB-H	590
Reflood bypass line cold leg (near end cap)	TFB-RFB-C	562

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

TABLE III
WATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

	<u>Test S-06-6</u>
pH	10.20
Conductivity ($\mu\text{mho/cm}$)	463
Lithium ($\mu\text{g/ml}$)	1.2
Chlorides (ppm)	<0.1
Fluorides (ppm) ^[b] ($\mu\text{g/ml}$)	<0.4
Oxygen (cc/l)	0.04
Total gas (cc/l)	160.9
Suspended solids ($\mu\text{g/ml}$)	1.20

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

[b] Present analytical methods prevent accurate determination of fluorides at concentrations of less than 0.4 $\mu\text{g/ml}$.

TABLE IV
SEQUENCE OF EVENTS DURING TEST S-06-6^[a]

Event	Time Relative To Rupture (s)
Core power level established	1440
Bypass lines valved out of system	-2.5
Blowdown initiated	0
Pump power reduced ^[d]	0
ECC accumulators valved in	0
Steam generator feedwater and discharge valves closed	1
Core power decay transient started	1.0
High pressure injection system pumps started ^[b]	25
Low pressure injection system pumps started ^[b]	35
Core power tripped off ^[c]	300

[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.

[d] Pump power was reduced on a predetermined decay curve.

III. DATA PRESENTATION

The data from Semiscale Mod-1 Test S-06-6 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-06-6 was monitored by 224 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. Long term plots are given for -20 to 200 s to provide better resolution of the plots. 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 analog system was used to provide better resolution capability (needed as input to various data analysis codes).

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).

Figures 3 through 8 and Table V provide supporting information for interpretation of the data graphs shown in Figures 9 through 350, and provide relative locations of all detectors used during Test S-06-6. 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 350 present all the blowdown and reflood data obtained. Time zero on the graphs is the time of rupture initiation. Appendix A provides information explaining posttest data processing for data conversion into engineering units and data adjustments. Presented in Appendix B is an analysis of selected data which provide a guide to the uncertainty associated with data measurements in the Semiscale Mod-1 system.

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

Fig. 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-3077

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

INEL-A-3075

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

TABLE V
DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-06-6

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-RFB-C	Reflood bypass, near end cap, cold leg side.			19, 20	
TFB-RFB-H	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°.			23, 24	Questionable data, possibly reading material temperature of vessel filler insulator.
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°.			25, 26	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Upper Plenum</u>					
TFV-UP-13	In upper plenum, 34 cm above cold leg centerline at 180°.	0 to 1533 K	0 to 820 K	27, 28	
<u>Lower Plenum</u>					
TFV-LP-8	On fluid thermocouple rack, 2.54 cm from vessel center, 45°.	0 to 1533 K	0 to 820 K		
TFV-LP-15	19 cm from bottom of vessel.			29, 30	
TFV-LP-22	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>					
TFG-5CD-45	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>					
TFG-6CD-45	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>					
TFG-10AB-45	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>ECC System</u>					
TFU-ECC-14	In ECC line leading to intact loop Spool 14.	0 to 1533 K	0 to 584 K		
TFU-ECC-14				39, 40	
<u>Steam Generator</u>					
TFU-SGFW	In feedwater line leading to steam generator.	0 to 1533 K	0 to 584 K		
TFU-SGFW				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-PRIZE	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>					
TF-PSS-33	84 cm from bottom of tank.	0 to 1622 K	0 to 584 K		
TF-PSS-33				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)

Range ^[a]					
Measurement	Location and Comments ^[a]	Detector	Data Acquisition System	Figure ^[a]	Measurement Comments ^[b]
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	Data acquisition system saturated to t=3 s.
<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°.			57, 58	
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.			59, 60	
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.			61, 62	
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.			63, 64	
TH-E5-21	Heater at Column E, Row 5. Thermocouple 53 cm (180°) above bottom of core.			65, 66	
<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.			67, 68	
TH-A5-29 TH-A5-45	Heater at Column A, Row 5. Thermocouples 74 cm (180°) and 114 cm (255°) above bottom of core.			69, 70	
TH-B3-32	Heater at Column B, Row 3. Thermocouple 81 cm (135°) above bottom of core.			71, 72	
TH-B5-29 TH-B5-33	Heater at Column B, Row 5. Thermocouples 74 cm (150°) and 85 cm (45°) above bottom of core.			73, 74	
TH-B6-14 TH-B6-29	Heater at Column B, Row 6. Thermocouples 36 cm (0°) and 74 cm (45°) above bottom of core.			75, 76	
TH-C2-28 TH-C2-38	Heater at Column C, Row 2. Thermocouple 97 cm (225°) above bottom of core.			77, 78	
TH-C3-60	Heater at Column C, Row 3. Thermocouple 152 cm (135°) above bottom of core.			79, 80	
TH-C4-20 TH-C4-26	Heater at Column C, Row 4. Thermocouples 51 cm (150°) and 66 cm (75°) above bottom of core.			81, 82	
TH-C5-28	Heater at Column C, Row 5. Thermocouple 71 cm (315°) above bottom of core.			83, 84	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Low Power Heaters (continued)		0 to 1533 K	0 to 1579 K		
TH-C6-32 TH-C6-53	Heater at Column C, Row 6. Thermo- couples 81 cm (225°) and 135 cm (270°) above bottom of core.			85, 86	
TH-C7-07 TH-C7-15	Heater at Column C, Row 7. Thermo- couples 18 cm (345°) and 38 cm (255°) above bottom of core.			87, 88	
TH-D1-21	Heater at Column D, Row 1. Thermo- couple 53 cm (330°) above bottom of core.			89, 90	
TH-D2-14 TH-D2-61	Heater at Column D, Row 2. Thermo- couples 36 cm (0°) and 155 cm (270°) above bottom of core.			91, 92	
TH-D3-29 TH-D3-33 TH-D3-39	Heater at Column D, Row 3. Thermo- couples 74 cm (150°), 84 cm (315°), and 99 cm (210°) above bottom of core			93, 94	
TH-D7-20	Heater at Column D, Row 7. Thermo- couple 51 cm (60°) above bottom of core.			95, 96	
TH-D8-57	Heater at Column D, Row 8. Thermo- couple 145 cm (15°) above bottom of core.			97, 98	
TH-E1-33	Heater at Column E, Row 1. Thermo- couple 84 cm (60°) above bottom of core.			99, 100	
TH-E2-20 TH-E2-33	Heater at Column E, Row 2. Thermo- couples 51 cm (210°) and 84 cm (315°) above bottom of core.			101, 102	
TH-E3-24	Heater at Column E, Row 3. Thermo- couple 61 cm (75°) above bottom of core.			103, 104	
TH-E6-08 TH-E6-28 TH-E6-37	Heater at Column E, Row 6. Thermo- couples 20 cm (150°), 71 cm (285°), and 94 cm (330°) above bottom of core.			105, 106	
TH-E7-13 TH-E7-44	Heater at Column E, Row 7. Thermo- couples 33 cm (45°) and 112 cm (195°) above bottom of core.			107, 108	
TH-E8-14 TH-E8-29 TH-E8-45	Heater at Column E, Row 8. Thermo- couples 36 cm (150°), 74 cm (225°), and 114 cm (300°) above bottom of core.			109, 110	
TH-F2-01 TH-F2-22 TH-F2-25	Heater at Column F, Row 2. Thermo- couples 18 cm (255°), 56 cm (105°), and 64 cm (0°) above bottom of core.			111, 112	
TH-F3-06 TH-F3-22 TH-F3-25	Heater at Column F, Row 3. Thermo- couples 15 cm (315°), 56 cm (105°), and 64 cm (30°) above bottom of core.			113, 114	
TH-F4-14 TH-F4-29 TH-F4-44	Heater at Column F, Row 4. Thermo- couples 36 cm (90°), 74 cm (165°), and 112 cm (210°) above bottom of core.			115, 116	
TH-F5-20 TH-F5-26	Heater at Column F, Row 5. Thermo- couples 51 cm (255°) and 66 cm (165°) above bottom of core.			117, 118	
TH-F6-08 TH-F6-28	Heater at Column F, Row 6. Thermo- couples 20 cm (60°) and 71 cm (210°) above bottom of core.			119, 120	
TH-G3-13	Heater at Column G, Row 3. Thermo- couples 33 cm (150°) above bottom of core.			121, 122	
TH-G4-29 TH-G4-33 TH-G4-38	Heater at Column G, Row 4. Thermo- couples 74 cm (300°), 84 cm (225°), and 97 cm (30°) above bottom of core.			123, 124	
TH-G5-14 TH-G5-24	Heater at Column G, Row 5. Thermo- couples 36 cm (45°) and 61 cm (330°) above bottom of core.			125, 126	
TH-H5-32	Heater at Column H, Row 5. Thermo- couple 81 cm (45°) above bottom of core.			127, 128	

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 31 614 kPa	129, 130	
PU-15L	Cold leg, Spool 15, 55 cm from vessel center, to atmosphere (low range).	0 to 3447 kPa	0 to 3561 kPa	129, 130	Detector saturated to t=20 s.
<u>Broken Loop</u>		0 to 17 237 kPa			
PB-21	Cold leg, Spool 21, 112 cm from vessel center.		0 to 20 654 kPa	131, 132	
PB-23	Cold leg, Spool 23, 235 cm from vessel center, upstream of nozzle (tee off DP tap).		0 to 21 476 kPa	131, 132	
PB-24	Cold leg, Spool 24, 264 cm from vessel center, downstream of nozzle.			131, 132	
PB-30	Hot leg, Spool 30, 45 cm from vessel center (tee off DP tap).		0 to 21 667 kPa	133, 134	
PB-42	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, upstream of pump-side nozzle (tee off DP tap).		0 to 20 321 kPa	133, 134	
PB-43	Cold leg, Spool 43, 1086 cm from vessel center along hot leg, upstream of rupture discs.	0 to 20 684 kPa	0 to 33 924 kPa	133, 134	
PB-CN1	Vessel-side nozzle, nozzle throat, 245 cm from vessel center, (tee off DP tap).			135, 136	
<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 21 268 kPa	137, 138	
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 34 499 kPa	137, 138	
<u>ECC System</u>		0 to 6895 kPa			
PU-ACC	In intact loop accumulator.		0 to 8368 kPa	139, 140	
<u>Steam Generator</u>					
PU-SGSD	Secondary side steam dome.	0 to 20 684 kPa	0 to 13 367 kPa	141, 142	
<u>Pressurizer</u>					
PU-PRIZE	Pressurizer steam dome.	0 to 17 237 kPa	0 to 22 009 kPa	143, 144	
<u>Pressure Suppression System</u>					
P-PSS	Suppression tank top.	0 to 1724 kPa	0 to 2173 kPa	145, 146	
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, 159 cm from vessel center. Upper plenum tap is approximately 5 cm above Spool 3 tap.	+127 cm water	+16.8 kPa	147, 148	
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	149, 150	
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	+170 kPa	151, 152	

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	+167 kPa	153, 154	
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 crifice. Spool 7 tap is 89 cm below SGOP tap.	+1270 cm water	+169 kPa	155, 156	
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	157, 158	
DPU-12-10	Pump outlet to pump inlet, cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center. Spool 10 tap is 25 cm below Spool 12 tap.	+345 kPa	+343 kPa	159, 160	
DPU-12-10L	Pump outlet to pump inlet, cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center. Spool 10 tap is 25 cm below Spool 12 tap (low range).	+254 cm water	+33.8 kPa	161, 162	Data acquisition system saturated to t=6 s.
DPU-12-15	Cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 13, 55 cm from vessel center.	+254 cm water	+34.5 kPa	163, 164	
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	165, 166	
DPU-15-3L	Cold leg to hot leg, cold leg Spool 15, 55 cm from vessel center, to hot leg Spool 3, 158 cm from vessel center. Spool 15 tap is 22 cm below Spool 3 tap (low range).	+254 cm water	+33.5 kPa	167, 168	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	+33.6 kPa	169, 170	
DPU PRESSLL	Pressurizer water level. Elevation difference between taps is 135 cm. Lower tap is 9 cm above pressurizer exit.	+127 cm water	+17.1 kPa	171, 172	
DPU-PR-4	Pressurizer bottom to Spool 4. Elevation difference between taps is 167 cm. Spool 4 tap is 140 cm below pressurizer exit.	+3447 kPa	+3456 kPa	173, 174	Data acquisition system saturated from t=0 s to t=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	+33.2 kPa	175, 176	
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	177, 178	
DPB-23-CN1	Cold leg, Spool 23, 235 cm from vessel center to vessel-side nozzle throat, 245 cm from vessel center.	+10 342 kPa	+13 843 kPa	179, 180	
DPB-23-24	Across vessel-side nozzle, Spool 23, 235 cm from vessel center to Spool 24, 264 cm from vessel center.	+10 342 kPa	+13 043 kPa	181, 182	
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	+3487 kPa	183, 184	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Broken Loop (continued)					
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	185, 186	
DPB-32U-36L	Across simulated steam generator orifice assembly, hot leg Spool 32 upper tap, 109 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	+3480 kPa	187, 188	
DPB-38-40	Across simulated pump, cold leg Spool 38, 776 cm from vessel center along hot leg, to cold leg Spool 40, 929 cm from vessel center along hot leg.	+6895 kPa	+9227 kPa	189, 190	
DPB-40-42	Across elbow leading to spool upstream of pump-side nozzle. Cold leg Spool 40, 929 cm from vessel center along hot leg, to Spool 42, 1057 cm from vessel center along hot leg. Spool 40 tap is 102 cm below Spool 42 tap.	+127 cm water	+16.2 kPa	191, 192	Data acquisition system saturated from t=0 s to t=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	+9232 kPa	193, 194	Data acquisition system saturated from t=0 s to t=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	195, 196	
DPV-0-96Q	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	197, 198	
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	199, 200	
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	+100 kPa	201, 202	
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	203, 204	
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	+33.7 kPa	205, 206	
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	207, 208	
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	209, 210	
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	211, 212	
DPV-173-180QQ	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	213, 214	
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	215, 216	

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
ECC SYSTEM					
DPU-ACC-TB	Top to bottom of intact loop accumulator. Elevation difference between taps is 274 cm.	+1270 cm water	+108 kPa	217, 218	
Steam Generator:					
DPU-SGFW	In steam generator feedwater line.	+762 cm water	+762 cm water	219, 220	
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	221, 222	
DPU-SG-DISC	Across venturi tube, 168 cm downstream from steam generator discharge.	+1270 cm water	+170 kPa	223, 224	
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	225, 226	
VOLUMETRIC FLOW RATE	Turbine flowmeter, bidirectional.				Data acquisition system range may exceed rated detection 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 +25.24 l/s	+75.71 l/s	227, 228	The detector is a unidirectional flow device and the electronics only registered positive values.
FTU-9	Cold leg, Spool 9, 393 cm from vessel center.	+5.05 to +50.47 l/s	+75.71 l/s	227, 228	
FTU-13	Cold leg, Spool 13, 163 cm from vessel center.	+1.26 to +50.47 l/s	+75.71 l/s	229, 230	
FTU-15	Cold leg, Spool 15, 42 cm from vessel center.	+1.26 to +50.47 l/s	+75.71 l/s	229, 230	
Broken Loop					
FTB-21	Cold leg, Spool 21, 146 cm from vessel center; 3-in. pipe.	+1.26 to +25.24 l/s	+75.71 l/s	231, 232	
FTB-30	Hot leg, Spool 30, 63 cm from vessel center; 3-in. pipe.	+1.26 to +25.24 l/s	+50.47 l/s	233, 234	
FTB-37	Cold leg, Spool 37, 739 cm from vessel center along hot leg; 2-in. pipe.	+1.26 to +50.47 l/s	+50.47 l/s	233, 234	
Core					
FTV-CORE-IN	Entrance to core, 401 cm below cold leg centerline.	+1.26 to +12.62 l/s	+56.78 l/s	235, 236	
ECC System					
FTU-IIPIS	In line immediately after IIPIS pump for intact loop, 1/2-in. line.	+0.017 to +0.47 l/s	+0.315 l/s	237, 238	
FTU-LPIS	In line leading from LPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 l/s	+0.631 l/s	239, 240	
FTU-ACC	In line leading from intact loop accumulator, 1-in. line.	+0.315 to +3.15 l/s	+4.42 l/s	241, 242	Data acquisition system saturated from t=68 to t=86 s.
Pressurizer					
FTU-PRIZE	Surge line.	+0.315 to +3.15 l/s	+6.31 l/s	243, 244	
FLUID VELOCITY					
Downcomer					
FTV-40A	102 cm below cold leg centerline, 0°.	+0.762 to +15.24 m/s	+15.24 m/s	245, 246	
FTV-40M	102 cm below cold leg centerline, 180°.	+0.762 to +15.24 m/s	+15.24 m/s	245, 246	
MOMENTUM FLUX					
	Drag disc, bidirectional.				Drag disc data may exhibit significant temperature dependence. Drag disc data should be used only for short-term transient response.

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Intact Loop</u>					
FDU-1	3-in. pipe. Hot leg, Spool 1, 60 cm from vessel center; target size 2.22 cm.	+298 to +17 113 kg/m-s ²	+76 090 kg/m-s ²	247, 248	
FDU-5	Hot leg, Spool 5, 256 cm from vessel center; target size 2.54 cm.	+1.49 to +2976 kg/m-s ²	+6994 kg/m-s ²	249, 250	
FDU-10	Cold leg, Spool 10, 349 cm from vessel center; target size 2.22 cm.	+298 to +154 769 kg/m-s ²	+35 344 kg/m-s ²	251, 252	
FDU-13	Cold leg, Spool 13, 138 cm from vessel center; target size 2.22 cm.	+298 to +22 025 kg/m-s ²	+28 528 kg/m-s ²	253, 254	
FDU-15	Cold leg, Spool 15, 60 cm from vessel center; target size 2.22 cm.	+298 to +21 578 kg/m-s ²	+39 124 kg/m-s ²	255, 256	
<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	257, 258	
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	+228 730 kg/m-s ²	259, 260	
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	261, 262	Questionable data, drag disc mounted horizontally and filled with cold 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	263, 264	Questionable data, drag disc mounted horizontally and filled with cold 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	+219 191 kg/m-s ²	265, 266	
<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	267, 268	
<u>DENSITY</u>					
<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.			269, 270	
GU-1B				271, 272	
GU-1C					
GU-5VR	Hot leg, Spool 5, 246 cm from vessel center, vertical.			273, 274	
GU-10VR	Cold leg, Spool 10, 355 cm from vessel center, vertical.			273, 274	
GU-13VR	Cold leg, Spool 13, 142 cm from vessel center, vertical.			275, 276	
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.			277, 278	
GU-15B				279, 280	
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.			281, 282	
GB-21B				283, 284	
GB-21C					
GB-23VR	Cold leg, Spool 23, 235 cm from vessel center, vertical.			285, 286	
GB-30T	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.			287, 288	
GB-30B				289, 290	
GB-30C					
GB-37	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, vertical.			291, 292	
GB-42VR					

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<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°.			293, 294	
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.			295, 296	
GVLP-165HZ	Upper part of lower plenum, 419 cm below cold leg centerline, 4.379 cm below downcomer exit, horizontal 0 to 180°.			297, 298	
GVLP-172HZ	Lower plenum, 437 cm below cold leg centerline, 22 cm below downcomer exit, horizontal, 90 to 270°.			297, 298	
<u>Pressurizer</u>					
GU-PRIZE	Surge line.	1.6 to 1600 kg/m ³	0 to 1600 kg/m ³	299, 300	
MASS FLOW RATE	Mass flow rate obtained by combining density (gamma attenuation technique) with volumetric flow rate (turbine flowmeter) or momentum flux (dray disc).	Range for mass flow is determined from range of individual detectors used in calculation.			
<u>Intact Loop</u>					
FDU-1, GU-1C FTU-1, GU-1C	Hot leg, Spool 1.			301, 302 303, 304	
FDU-5, GU-5VR	Hot leg, Spool 5.			305, 306	
FTU-9, GU-10VR	Cold leg, Spool 9.			307, 308	
FDU-10, GU-10VR	Cold leg, Spool 10.			309, 310	
FDU-13, GU-13VR FTU-13, GU-13VR	Cold leg, Spool 13.			311, 312 313, 314	
FDU-15, GU-15C FTU-15, GU-15C	Cold leg, Spool 15.			315, 316 317, 318	
<u>Broken Loop</u>					
FDB-21, GB-21C FTB-21, GB-21C	Cold leg, Spool 21.			319, 320 321, 322	
FDB-23, GB-23VR	Cold leg, Spool 23.			323, 324	
FDB-30, GB-30C FTB-30, GB-30C	Hot leg, Spool 30.			325, 326 327, 328	
FDB-37, GB-37 FTB-37, GB-37	Hot leg, Spool 37.			329, 330 331, 332	
FDB-42, GB-42VR	Cold leg, Spool 42.			333, 334	
<u>Vessel</u>					
FDV-CORE-IN GV-COR-150HZ	Entrance to core.			335, 336	
FTV-CORE-IN GV-COR-150HZ	Entrance to core.			337, 338	
<u>Pressurizer</u>					
FTU-PRIZE GU-PRIZE	Pressurizer surge line.			339, 340	
CORE CHARACTERISTICS					
PWRCOR T-1	Core power.		1600 kW	341, 342	
PWRCOR T-2	Core power.		1600 kW	341, 342	
VOLTCOR-T	Core voltage.		0 to 200 Vdc	343, 344	
AMPCOR-T	Core current.		0 to 10 000 A	345, 346	
PUMP CHARACTERISTICS					
PUMPU-CUR	Pump current.		0 to 44 A	347, 348	
PUMPU-RPM	Pump speed.		0 to 3600 rpm	349, 350	

[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 200 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 200 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 200 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 200 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 200 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, reflood bypass simulators (TFB-RFB-C and TFB-RFB-H), from -20 to 200 s.

Fig. 20 Fluid temperature in broken loop, reflood bypass simulators (TFB-RFB-C and TFB-RFB-H), from -6 to 42 s.

Fig. 21 Fluid temperature in inlet annulus (TFV-ANN-4A and TFV-ANN-4M), from -20 to 200 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-15T, TFV-ANN-35A, TFV-ANN-35T and TFV-ANN-70A), from -20 to 200 s.

Fig. 24 Fluid temperature in downcomer annulus (TFV-ANN-15T, 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, TFV-ANN-115M, and TFV-ANN-156A), from -20 to 200 s.

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

Fig. 27 Fluid temperature in upper plenum (TFV-UP+13), from -20 to 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 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 200 s.

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

Fig. 57 Material temperature in core barrel inner diameter (TMV-CI-35A), from -20 to 200 s.

Fig. 58 Material temperature in core barrel inner diameter (TMV-CI-35A), from -6 to 42 s.

Fig. 59 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -20 to 200 s.

Fig. 60 Core heater temperature, Rod D-4 (TH-D4-14 and TH-D4-29), from -6 to 42 s.

Fig. 61 Core heater temperature, Rod D-5 (TH-D5-09, TH-D5-29, and TH-D5-39), from -20 to 200 s.

Fig. 62 Core heater temperature, Rod D-5 (TH-D5-09, TH-D5-29, and TH-D5-39), from -6 to 42 s.

Fig. 63 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -20 to 200 s.

Fig. 64 Core heater temperature, Rod E-4 (TH-E4-09, TH-E4-27, and TH-E4-55), from -6 to 42 s.

Fig. 65 Core heater temperature, Rod E-5 (TH-E5-21), from -20 to 200 s.

Fig. 66 Core heater temperature, Rod E-5 (TH-E5-21), from -6 to 42 s.

Fig. 67 Core heater temperature, Rod A-4 (TH-A4-09 and TH-A4-29), from -20 to 200 s.

Fig. 68 Core heater temperature, Rod A-4 (TH-A4-09 and TH-A4-29), from -6 to 42 s.

Fig. 69 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -20 to 200 s.

Fig. 70 Core heater temperature, Rod A-5 (TH-A5-29 and TH-A5-45), from -6 to 42 s.

Fig. 71 Core heater temperature, Rod B-3 (TH-B3-32), from -20 to 200 s.

Fig. 72 Core heater temperature, Rod B-3 (TH-B3-32), from -6 to 42 s.

Fig. 73 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -20 to 200 s.

Fig. 74 Core heater temperature, Rod B-5 (TH-B5-29 and TH-B5-33), from -6 to 42 s.

Fig. 75 Core heater temperature, Rod B-6 (TH-B6-14 and TH-B6-29), from -20 to 200 s.

Fig. 76 Core heater temperature, Rod B-6 (TH-B6-14 and TH-B6-29), from -6 to 42 s.

Fig. 77 Core heater temperature, Rod C-2 (TH-C2-28 and TH-C2-38), from -20 to 200 s.

Fig. 78 Core heater temperature, Rod C-2 (TH-C2-28 and TH-C2-38), from -6 to 42 s.

Fig. 79 Core heater temperature, Rod C-3 (TH-C3-60), from -20 to 200 s.

Fig. 80 Core heater temperature, Rod C-3 (TH-C3-60), from -6 to 42 s.

Fig. 81 Core heater temperature, Rod C-4 (TH-C4-20 and TH-C4-26), from -20 to 200 s.

Fig. 82 Core heater temperature, Rod C-4 (TH-C4-20 and TH-C4-26), from -6 to 42 s.

Fig. 83 Core heater temperature, Rod C-5 (TH-C5-28), from -20 to 200 s.

Fig. 84 Core heater temperature, Rod C-5 (TH-C5-28), from -6 to 42 s.

Fig. 85 Core heater temperature, Rod C-6 (TH-C6-32 and TH-C6-53), from -20 to 200 s.

Fig. 86 Core heater temperature, Rod C-6 (TH-C6-32 and TH-C6-53), from -6 to 42 s.

Fig. 87 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -20 to 200 s.

Fig. 88 Core heater temperature, Rod C-7 (TH-C7-07 and TH-C7-15), from -6 to 42 s.

Fig. 89 Core heater temperature, Rod D-1 (TH-D1-21), from -20 to 200 s.

Fig. 90 Core heater temperature, Rod D-1 (TH-D1-21), from -6 to 42 s.

Fig. 91 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -20 to 200 s.

Fig. 92 Core heater temperature, Rod D-2 (TH-D2-14 and TH-D2-61), from -6 to 42 s.

Fig. 93 Core heater temperature, Rod D-3 (TH-D3-29, TH-D3-33, and TH-D3-39), from -20 to 200 s.

Fig. 94 Core heater temperature, Rod D-3 (TH-D3-29, TH-D3-33, and TH-D3-39), from -6 to 42 s.

Fig. 95 Core heater temperature, Rod D-7 (TH-D7-20), from -20 to 200 s.

Fig. 96 Core heater temperature, Rod D-7 (TH-D7-20), from -6 to 42 s.

Fig. 97 Core heater temperature, Rod D-8 (TH-D8-57), from -20 to 200 s.

Fig. 98 Core heater temperature, Rod D-8 (TH-D8-57), from -6 to 42 s.

Fig. 99 Core heater temperature, Rod E-1 (TH-E1-33), from -20 to 200 s.

Fig. 100 Core heater temperature, Rod E-1 (TH-E1-33), from -6 to 42 s.

Fig. 101 Core heater temperature, Rod E-2 (TH-E2-20 and TH-E2-33), from -20 to 200 s.

Fig. 102 Core heater temperature, Rod E-2 (TH-E2-20 and TH-E2-33), from -6 to 42 s.

Fig. 103 Core heater temperature, Rod E-3 (TH-E3-24), from -20 to 200 s.

Fig. 104 Core heater temperature, Rod E-3 (TH-E3-24), from -6 to 42 s.

Fig. 105 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -20 to 200 s.

Fig. 106 Core heater temperature, Rod E-6 (TH-E6-08, TH-E6-28, and TH-E6-37), from -6 to 42 s.

Fig. 107 Core heater temperature, Rod E-7 (TH-E7-13 and TH-E7-44), from -20 to 200 s.

Fig. 108 Core heater temperature, Rod E-7 (TH-E7-13 and TH-E7-44), from -6 to 42 s.

Fig. 109 Core heater temperature, Rod E-8 (TH-E8-14, TH-E8-29, and TH-E8-45), from -20 to 200 s.

Fig. 110 Core heater temperature, Rod E-8 (TH-E8-14, TH-E8-29, and TH-E8-45), from -6 to 42 s.

Fig. 111 Core heater temperature, Rod F-2 (TH-F2-07, TH-F2-22, and TH-F2-25), from -20 to 200 s.

Fig. 112 Core heater temperature, Rod F-2 (TH-F2-07, TH-F2-22, and TH-F2-25), from -6 to 42 s.

Fig. 113 Core heater temperature, Rod F-3 (TH-F3-06, TH-F3-22, and TH-F3-25), from -20 to 200 s.

Fig. 114 Core heater temperature, Rod F-3 (TH-F3-06, TH-F3-22, and TH-F3-25), from -6 to 42 s.

Fig. 115 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -20 to 200 s.

Fig. 116 Core heater temperature, Rod F-4 (TH-F4-14, TH-F4-29, and TH-F4-44), from -6 to 42 s.

Fig. 117 Core heater temperature, Rod F-5 (TH-F5-20 and TH-F5-26), from -20 to 200 s.

Fig. 118 Core heater temperature, Rod F-5 (TH-F5-20 and TH-F5-26), from -6 to 42 s.

Fig. 119 Core heater temperature, Rod F-6 (TH-F6-08 and TH-F6-28), from -20 to 200 s.

Fig. 120 Core heater temperature, Rod F-6 (TH-F6-08 and TH-F6-28), from -6 to 42 s.

Fig. 121 Core heater temperature, Rod G-3 (TH-G3-13), from -20 to 200 s.

Fig. 122 Core heater temperature, Rod G-3 (TH-G3-13), from -6 to 42 s.

Fig. 123 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -20 to 200 s.

Fig. 124 Core heater temperature, Rod G-4 (TH-G4-29, TH-G4-33, and TH-G4-38), from -6 to 42 s.

Fig. 125 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -20 to 200 s.

Fig. 126 Core heater temperature, Rod G-5 (TH-G5-14 and TH-G5-24), from -6 to 42 s.

Fig. 127 Core heater temperature, Rod H-5 (TH-H5-32), from -20 to 200 s.

Fig. 128 Core heater temperature, Rod H-5 (TH-H5-32), from -6 to 42 s.

Fig. 129 Pressure in intact loop (PU-13 and PU-15L), from -20 to 200 s.

Fig. 130 Pressure in intact loop (PU-13 and PU-15L), from -6 to 42 s.

Fig. 131 Pressure in broken loop, vessel side (PB-21, PB-23, and PB-24), from -20 to 200 s.

Fig. 132 Pressure in broken loop, vessel side (PB-21, PB-23, and PB-24), from -6 to 42 s.

Fig. 133 Pressure in broken loop, pump side (PB-30, PB-42, and PB-43), from -20 to 200 s.

Fig. 134 Pressure in broken loop, pump side (PB-30, PB-42, and PB-43), from -6 to 42 s.

Fig. 135 Pressure in broken loop, vessel side (PB-CN1), from -20 to 200 s.

Fig. 136 Pressure in broken loop, vessel side (PB-CN1), from -6 to 42 s.

Fig. 137 Pressure in vessel (PV-UP+10 and PV-LP-180), from -20 to 200 s.

Fig. 138 Pressure in vessel (PV-UP+10 and PV-LP-180), from -6 to 42 s.

Fig. 139 Pressure in intact loop accumulator (PU-ACC), from -20 to 200 s.

Fig. 140 Pressure in intact loop accumulator (PU-ACC), from -6 to 42 s.

Fig. 141 Pressure in steam generator, secondary side (PU-SGSD), from -20 to 200 s.

Fig. 142 Pressure in steam generator, secondary side (PU-SGSD), from -6 to 42 s.

Fig. 143 Pressure in pressurizer (PU-PRIZE), from -20 to 200 s.

Fig. 144 Pressure in pressurizer (PU-PRIZE), from -6 to 42 s.

Fig. 145 Pressure in pressure suppression tank (P-PSS), from -20 to 200 s.

Fig. 146 Pressure in pressure suppression tank (P-PSS), from -6 to 42 s.

Fig. 147 Differential pressure in intact loop (DPU-UP-3), from -20 to 200 s.

Fig. 148 Differential pressure in intact loop (DPU-UP-3), from -6 to 42 s.

Fig. 149 Differential pressure in intact loop (DPU-3-6), from -20 to 200 s.

Fig. 150 Differential pressure in intact loop (DPU-3-6), from -6 to 42 s.

Fig. 151 Differential pressure in intact loop (DPU-6-SGIP), from -20 to 200 s.

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

Fig. 153 Differential pressure in intact loop (DPU-6-7), from -20 to 200 s.

Fig. 154 Differential pressure in intact loop (DPU-6-7), from -6 to 42 s.

Fig. 155 Differential pressure in intact loop (DPU-SGOP-7), from -20 to 200 s.

Fig. 156 Differential pressure in intact loop (DPU-SGOP-7), from -6 to 42 s.

Fig. 157 Differential pressure in intact loop (DPU-7-10), from -20 to 200 s.

Fig. 158 Differential pressure in intact loop (DPU-7-10), from -6 to 42 s.

Fig. 159 Differential pressure in intact loop (DPU-12-10), from -20 to 200 s.

Fig. 160 Differential pressure in intact loop (DPU-12-10), from -6 to 42 s.

Fig. 161 Differential pressure in intact loop, low range (DPU-12-10L), from -20 to 200 s.

Fig. 162 Differential pressure in intact loop, low range (DPU-12-10L), from -6 to 42 s.

Fig. 163 Differential pressure in intact loop (DPU-12-15), from -20 to 200 s.

Fig. 164 Differential pressure in intact loop (DPU-12-15), from -6 to 42 s.

Fig. 165 Differential pressure in intact loop (DPU-15-3), from -20 to 200 s.

Fig. 166 Differential pressure in intact loop (DPU-15-3), from -6 to 42 s.

Fig. 167 Differential pressure in intact loop, low range (DPU-15-3L), from -20 to 200 s.

Fig. 168 Differential pressure in intact loop, low range (DPU-15-3L), from -6 to 42 s.

Fig. 169 Differential pressure in intact loop (DPU-15-IANN), from -20 to 200 s.

Fig. 170 Differential pressure in intact loop (DPU-15-IANN), from -6 to 42 s.

Fig. 171 Differential pressure in intact loop (DPU-PRESLL), from -20 to 200 s.

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

Fig. 173 Differential pressure in intact loop (DPU-PR-4), from -20. to 200 s.

Fig. 174 Differential pressure in intact loop (DPU-PR-4), from -6 to 42 s.

Fig. 175 Differential pressure in broken loop (DPB-21-IANN), from -20 to 200 s.

Fig. 176 Differential pressure in broken loop (DPB-21-IANN), from -6 to 42 s.

Fig. 177 Differential pressure in broken loop (DPB-21-23), from -20 to 200 s.

Fig. 178 Differential pressure in broken loop (DPB-21-23), from -6 to 42 s.

Fig. 179 Differential pressure in broken loop (DPB-23-CN1), from -20 to 200 s.

Fig. 180 Differential pressure in broken loop (DPB-23-CN1), from -6 to 42 s.

Fig. 181 Differential pressure in broken loop (DPB-23-24), from -20 to 200 s.

Fig. 182 Differential pressure in broken loop (DPB-23-24), from -6 to 42 s.

Fig. 183 Differential pressure in broken loop (DPB-30-36L), from -20 to 200 s.

Fig. 184 Differential pressure in broken loop (DPB-30-36L), from -6 to 42 s.

Fig. 185 Differential pressure in broken loop (DPB-30-38), from -20 to 200 s.

Fig. 186 Differential pressure in broken loop (DPB-30-38), from -6 to 42 s.

Fig. 187 Differential pressure in broken loop (DPB-32U-36L), from -20 to 200 s.

Fig. 188 Differential pressure in broken loop (DPB-32U-36L), from -6 to 42 s.

Fig. 189 Differential pressure in broken loop (DPB-38-40), from -20 to 200 s.

Fig. 190 Differential pressure in broken loop (DPB-38-40), from -6 to 42 s.

Fig. 191 Differential pressure in broken loop (DPB-40-42), from -20 to 200 s.

Fig. 192 Differential pressure in broken loop (DPB-40-42), from -6 to 42 s.

Fig. 193 Differential pressure in broken loop (DPB-42-43), from -20 to 200 s.

Fig. 194 Differential pressure in broken loop (DPB-42-43), from -6 to 42 s.

Fig. 195 Differential pressure in vessel (DPV-UP-IANN), from -20 to 200 s.

Fig. 196 Differential pressure in vessel (DPV-UP-IANN), from -6 to 42 s.

Fig. 197 Differential pressure in vessel (DPV-0-9GQ), from -20 to 200 s.

Fig. 198 Differential pressure in vessel (DPV-0-9GQ), from -6 to 42 s.

Fig. 199 Differential pressure in vessel (DPV-9-26QQ), from -20 to 200 s.

Fig. 200 Differential pressure in vessel (DPV-9-26QQ), from -6 to 42 s.

Fig. 201 Differential pressure in vessel (DPV-9-180QQ), from -20 to 200 s.

Fig. 202 Differential pressure in vessel (DPV-9-180QQ), from -6 to 42 s.

Fig. 203 Differential pressure in vessel (DPV-26-55QM), from -20 to 200 s.

Fig. 204 Differential pressure in vessel (DPV-26-55QM), from -6 to 42 s.

Fig. 205 Differential pressure in vessel (DPV-55-110MM), from -20 to 200 s.

Fig. 206 Differential pressure in vessel (DPV-55-110MM), from -6 to 42 s.

Fig. 207 Differential pressure in vessel (DPV-110-156MQ), from -20 to 200 s.

Fig. 208 Differential pressure in vessel (DPV-110-156MQ), from -6 to 42 s.

Fig. 209 Differential pressure in vessel (DPV-156-173QQ), from -20 to 200 s.

Fig. 210 Differential pressure in vessel (DPV-156-173QQ), from -6 to 42 s.

Fig. 211 Differential pressure in vessel (DPV-166-192QT), from -20 to 200 s.

Fig. 212 Differential pressure in vessel (DPV-166-192QT), from -6 to 42 s.

Fig. 213 Differential pressure in vessel (DPV-173-180QQ), from -20 to 200 s.

Fig. 214 Differential pressure in vessel (DPV-173-180QQ), from -6 to 42 s.

Fig. 215 Differential pressure in vessel (DPV-LP-UP), from -20 to 200 s.

Fig. 216 Differential pressure in vessel (DPV-LP-UP), from -6 to 42 s.

Fig. 217 Differential pressure in intact loop accumulator (DPU-ACC-TB), from -20 to 200 s.

Fig. 218 Differential pressure in intact loop accumulator (DPU-ACC-TB), from -6 to 42 s.

Fig. 219 Differential pressure across steam generator feedwater orifice (DPU-SGFW), from -20 to 200 s.

Fig. 220 Differential pressure across steam generator feedwater orifice (DPU-SGFW), from -6 to 42 s.

Fig. 221 Differential pressure in steam generator secondary (DPU-SG-SEC), from -20 to 200 s.

Fig. 222 Differential pressure in steam generator secondary (DPU-SG-SEC), from -6 to 42 s.

Fig. 223 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -20 to 200 s.

Fig. 224 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -6 to 42 s.

Fig. 225 Differential pressure in pressure suppression tank (DP-PSS-TB), from -20 to 200 s.

Fig. 226 Differential pressure in pressure suppression tank (DP-PSS-TB), from -6 to 42 s.

Fig. 227 Volumetric flow in intact loop (FTU-1 and FTU-9), from -20 to 200 s.

Fig. 228 Volumetric flow in intact loop (FTU-1 and FTU-9), from -6 to 42 s.

Fig. 229 Volumetric flow in intact loop (FTU-13 and FTU-15), from -20 to 200 s.

Fig. 230 Volumetric flow in intact loop (FTU-13 and FTU-15), from -6 to 42 s.

Fig. 231 Volumetric flow in broken loop (FTB-21), from -20 to 200 s.

Fig. 232 Volumetric flow in broken loop (FTB-21), from -6 to 42 s.

Fig. 233 Volumetric flow in broken loop (FTB-30 and FTB-37), from -20 to 200 s.

Fig. 234 Volumetric flow in broken loop (FTB-30 and FTB-37), from -6 to 42 s.

Fig. 235 Volumetric flow in core entrance (FTV-CORE-IN), from -20 to 200 s.

Fig. 236 Volumetric flow in core entrance (FTV-CORE-IN), from -6 to 42 s.

Fig. 237 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -20 to 200 s.

Fig. 238 Volumetric flow in intact loop high pressure injection line (FTU-HPIS), from -6 to 42 s.

Fig. 239 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -20 to 200 s.

Fig. 240 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -6 to 42 s.

Fig. 241 Volumetric flow in intact loop accumulator discharge line (FTU-ACC), from -20 to 200 s.

Fig. 242 Volumetric flow in intact loop accumulator discharge line (FTU-ACC), from -6 to 42 s.

Fig. 243 Volumetric flow from pressurizer (FTU-PRIZE), from -20 to 200 s.

Fig. 244 Volumetric flow from pressurizer (FTU-PRIZE), from -6 to 42 s.

Fig. 245 Fluid velocity in vessel (FTV-40A and FTV-40M), from -20 to 200 s.

Fig. 246 Fluid velocity in vessel (FTV-40A and FTV-40M), from -6 to 42 s.

Fig. 247 Momentum flux in intact loop (FDU-1), from -20 to 200 s.

Fig. 248 Momentum flux in intact loop (FDU-1), from -6 to 42 s.

Fig. 249 Momentum flux in intact loop (FDU-5), from -20 to 200 s.

Fig. 250 Momentum flux in intact loop (FDU-5), from -6 to 42 s.

Fig. 251 Momentum flux in intact loop (FDU-10), from -20 to 200 s.

Fig. 252 Momentum flux in intact loop (FDU-10), from -6 to 42 s.

Fig. 253 Momentum flux in intact loop (FDU-13), from -20 to 200 s.

Fig. 254 Momentum flux in intact loop (FDU-13), from -6 to 42 s.

Fig. 255 Momentum flux in intact loop (FDU-15), from -20 to 200 s.

Fig. 256 Momentum flux in intact loop (FDU-15), from -6 to 42 s.

Fig. 257 Momentum flux in broken loop (FDB-21), from -20 to 200 s.

Fig. 258 Momentum flux in broken loop (FDB-21), from -6 to 42 s.

Fig. 259 Momentum flux in broken loop (FDB-23), from -20 to 200 s.

Fig. 260 Momentum flux in broken loop (FDB-23), from -6 to 42 s.

Fig. 261 Momentum flux in broken loop (FDB-30), from -20 to 200 s.

Fig. 262 Momentum flux in broken loop (FDB-30), from -6 to 42 s.

Fig. 263 Momentum flux in broken loop (FDB-37), from -20 to 200 s.

Fig. 264 Momentum flux in broken loop (FDB-37), from -6 to 42 s.

Fig. 265 Momentum flux in broken loop (FDB-42), from -20 to 200 s.

Fig. 266 Momentum flux in broken loop (FDB-42), from -6 to 42 s.

Fig. 267 Momentum flux in core entrance (FDV-CORE-IN), from -20 to 200 s.

Fig. 268 Momentum flux in core entrance (FDV-CORE-IN), from -6 to 42 s.

Fig. 269 Density in intact loop (GU-1T and GU-1B), from -20 to 200 s.

Fig. 270 Density in intact loop (GU-1T and GU-1B), from -6 to 42 s.

Fig. 271 Density in intact loop (GU-1C), from -20 to 200 s.

Fig. 272 Density in intact loop (GU-1C), from -6 to 42 s.

Fig. 273 Density in intact loop (GU-5VR and GU-10VR), from -20 to 200 s.

Fig. 274 Density in intact loop (GU-5VR and GU-10VR), from -6 to 42 s.

Fig. 275 Density in intact loop (GU-13VR), from -20 to 200 s.

Fig. 276 Density in intact loop (GU-13VR), from -6 to 42 s.

Fig. 277 Density in intact loop (GU-15T and GU-15B), from -20 to 200 s.

Fig. 278 Density in intact loop (GU-15T and GU-15B), from -6 to 42 s.

Fig. 279 Density in intact loop (GU-15C), from -20 to 200 s.

Fig. 280 Density in intact loop (GU-15C), from -6 to 42 s.

Fig. 281 Density in broken loop (GB-21T and GB-21B), from -20 to 200 s.

Fig. 282 Density in broken loop (GB-21T and GB-21B), from -6 to 42 s.

Fig. 283 Density in broken loop (GB-21C), from -20 to 200 s.

Fig. 284 Density in broken loop (GB-21C), from -6 to 42 s.

Fig. 285 Density in broken loop (GB-23VR), from -20 to 200 s.

Fig. 286 Density in broken loop (GB-23VR), from -6 to 42 s.

Fig. 287 Density in broken loop (GB-30T and GB-30B), from -20 to 200 s.

Fig. 288 Density in broken loop (GB-30T and GB-30B), from -6 to 42 s.

Fig. 289 Density in broken loop (GB-30C), from -20 to 200 s.

Fig. 290 Density in broken loop (GB-30C), from -6 to 42 s.

Fig. 291 Density in broken loop (GB-37 and GB-42VR), from -20 to 200 s.

Fig. 292 Density in broken loop (GB-37 and GB-42VR), from -6 to 42 s.

Fig. 293 Density in vessel (GV-COR-150HZ), from -20 to 200 s.

Fig. 294 Density in vessel (GV-COR-150HZ), from -6 to 42 s.

Fig. 295 Density in vessel (GV-162/192D), from -20 to 200 s.

Fig. 296 Density in vessel (GV-162/192D), from -6 to 42 s.

Fig. 297 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -20 to 200 s.

Fig. 298 Density in vessel (GVLP-165HZ and GVLP-172HZ), from -6 to 42 s.

Fig. 299 Density in pressurizer (GU-PRIZE), from -20 to 200 s.

Fig. 300 Density in pressurizer (GU-PRIZE), from -6 to 42 s.

Fig. 301 Mass flow in intact loop (FDU-1, GU-1C), from -20 to 200 s.

Fig. 302 Mass flow in intact loop (FDU-1, GU-1C), from -6 to 42 s.

Fig. 303 Mass flow in intact loop (FTU-1, GU-1C), from -20 to 200 s.

Fig. 304 Mass flow in intact loop (FTU-1, GU-1C), from -6 to 42 s.

Fig. 305 Mass flow in intact loop (FDU-5, GU-5VR), from -20 to 200 s.

Fig. 306 Mass flow in intact loop (FDU-5, GU-5VR), from -6 to 42 s.

Fig. 307 Mass flow in intact loop (FTU-9, GU-10VR), from -20 to 200 s.

Fig. 308 Mass flow in intact loop (FTU-9, GU-10VR), from -6 to 42 s.

Fig. 309 Mass flow in intact loop (FDU-10, GU-10VR), from -20 to 200 s.

Fig. 310 Mass flow in intact loop (FDU-10, GU-10VR), from -6 to 42 s.

Fig. 311 Mass flow in intact loop (FDU-13, GU-13VR), from -20 to 200 s.

Fig. 312 Mass flow in intact loop (FDU-13, GU-13VR), from -6 to 42 s.

Fig. 313 Mass flow in intact loop (FTU-13, GU-13VR), from -20 to 200 s.

Fig. 314 Mass flow in intact loop (FTU-13, GU-13VR), from -6 to 42 s.

Fig. 315 Mass flow in intact loop (FDU-15, GU-15C), from -20 to 200 s.

Fig. 316 Mass flow in intact loop (FDU-15, GU-15C), from -6 to 42 s.

Fig. 317 Mass flow in intact loop (FTU-15, GU-15C), from -20 to 200 s.

Fig. 318 Mass flow in intact loop (FTU-15, GU-15C), from -6 to 42 s.

Fig. 319 Mass flow in intact loop (FDB-21, GB-21C), from -20 to 200 s.

Fig. 320 Mass flow in intact loop (FDB-21, GB-21C), from -6 to 42 s.

Fig. 321 Mass flow in broken loop (FTB-21, GB-21C), from -20 to 200 s.

Fig. 322 Mass flow in broken loop (FTB-21, GB-21C), from -6 to 42 s.

Fig. 323 Mass flow in broken loop (FDB-23, GB-23VR), from -20 to 200 s.

Fig. 324 Mass flow in broken loop (FDB-23, GB-23VR), from -6 to 42 s.

Fig. 325 Mass flow in broken loop (FDB-30, GB-30C), from -20 to 200 s.

Fig. 326 Mass flow in broken loop (FDB-30, GB-30C), from -6 to 42 s.

Fig. 327 Mass flow in broken loop (FTB-30, GB-30C), from -20 to 200 s.

Fig. 328 Mass flow in broken loop (FTB-30, GB-30C), from -6 to 42 s.

Fig. 329 Mass flow in broken loop (FDB-37, GB-37), from -20 to 200 s.

Fig. 330 Mass flow in broken loop (FDB-37, GB-37), from -6 to 42 s.

Fig. 331 Mass flow in broken loop (FTB-37, GB-37), from -20 to 200 s.

Fig. 332 Mass flow in broken loop (FTB-37, GB-37), from -6 to 42 s.

Fig. 333 Mass flow in broken loop (FDB-42, GB-42VR), from -20 to 200 s.

Fig. 334 Mass flow in broken loop (FDB-42, GB-42VR), from -6 to 42 s.

Fig. 335 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ), from -20 to 200 s.

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

Fig. 337 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -20 to 200 s.

Fig. 338 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 339 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -20 to 200 s.

Fig. 340 Mass flow in pressurizer (FTU-PRIZE, GU-PRIZE), from -6 to 42 s.

Fig. 341 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -20 to 200 s.

Fig. 342 Core heater rod total power (PWRCOR T-1 and PWRCOR T-2), from -6 to 42 s.

Fig. 343 Core heater voltage (VOLT COR-T), from -20 to 200 s.

Fig. 344 Core heater voltage (VOLT COR-T), from -6 to 42 s.

Fig. 345 Core heater total current (AMPCOR-T), from -20 to 200 s.

Fig. 346 Core heater total current (AMPCOR-T), from -6 to 42 s.

Fig. 347 Primary pump current (PUMPU-CUR), from -20 to 200 s.

Fig. 348 Primary pump current (PUMPU-CUR), from -6 to 42 s.

Fig. 349 Primary pump speed (PUMPU-RPM), from -20 to 200 s.

Fig. 350 Primary pump speed (PUMPU-RPM), from -6 to 42 s.

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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).
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APPENDIX A

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1 TEST S-06-6

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APPENDIX A

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1 TEST S-06-6

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-06-6 are presented in the following paragraphs and tables.

1. PRESSURE MEASUREMENTS

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

Correction of the steam generator secondary pressure (PU-SGSD) measurement is done in the same manner as for the main loop pressures using Heise gauges installed expressly for this purpose.

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

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

where

$F'(t)$ = corrected data

$F(t)$ = raw data

C_0 = offset

C_1 = scaling factor.

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

TABLE A-I

CONSTANTS FOR PRESSURE MEASUREMENT
CORRECTIONS (TEST S-06-6)

<u>Detector Identification</u>	<u>C_0</u>	<u>C_1</u>
PU-SGSD	-12.9	1.029 4
PB-CN1	-27.5	1.015 5
PB-42	2.0	1.014 6
PB-24	-42.7	1.013 3
PV-LP-180	16.6	0.990 7

2. DIFFERENTIAL PRESSURE MEASUREMENTS

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

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

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

For some differential pressure measurements, the data scan at 533 K cannot be used as a reference for thermal drift, so other references are used. For these detectors, and those having nonlinear pressure sensitivities, the corrections are performed according to the following equations:

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

where $t_1 \leq t \leq t_n$

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

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

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

where

t = time

$F'(t)$ = corrected data

$F(t)$ = raw data

K = scaling factor

C_1 and t_i = corrections and time points.

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

TABLE A-II
CONSTANTS FOR DIFFERENTIAL PRESSURE
MEASUREMENT CORRECTIONS (TEST S-06-6)

<u>Detector Identification</u>	<u>K</u>	<u>C₁</u>	<u>t₁</u>	<u>C₂</u>	<u>t₂</u>	<u>C₃</u>	<u>t₃</u>
DPU-ACC-TB	1	-1.41	0				
DPV-0-9G0	1	0.287	0	0.528	0.01	0.942	35.0
DPU-3-6	1	-0.389	0	-0.748	0.01	-1.437	35.0
DPU-6-7	1	0.784	0	0.163	0.01	-0.870	35.0
DPU-UP-3	1	-1.999	0		0.01		35.0
DPU-PRSELL	1	0.137	0		0.01		35.0
DPU-12-10	1	-3.34	0	-0.998	0.01	3.69	35.0
DPV-26-55QM	1	0.234	0	1.29	0.01	1.74	35.0
DPV-LP-UP	1	-0.496	0	-1.116	0.01	-2.35	35.0

3. MOMENTUM FLUX MEASUREMENT

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 sensitivity is removed before the data are converted to momentum flux. The temperature of each transducer is taken from the signal of a nearby fluid or metal temperature thermocouple. Slight corrections for errors in setting the transducer output to zero at ambient conditions are also made at this time. Corrections are made using the following equation:

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

where

$F'(t)$ = corrected data

$F(t)$ = raw data

T_i = temperature sensitivity

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

C_o = ambient sensitivity

P_1 = pressure sensitivity

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

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

TABLE A-III
CONSTANTS FOR MOMENTUM FLUX
MEASUREMENT CORRECTIONS (TEST S-06-6)

Detector Identification	C_o	T_i	$T(t)$ [a]	P_1	$P(t)$ [c]
FDU-5	0	-0.000 414	RBU-2	0.000 001 72	PV-UP+10
FDV-CORE-IN	0	-0.000 190	TFV-LP-22		
FDU-10	0	0.000 383	TFU-10	0.000 006 74	PU-PRIZE
FDU-13	0	0.001 564	RBU-14A		
FDB-30 ^[b]	0	-0.001 336	TFB-30	0.000 001 06	PB-30
FDB-21	0	-0.001 521	TFB-20	-0.000 004 15	PB-21
FDB-23	0	0.001 112	TFB-23	-0.000 003 38	PB-23
FDB-42	0	-0.001 339	TFB-42		
FDB-37 ^[b]	0	0.000 685 8	TFB-37		
FDU-1	0.30	-0.000 036 0	RBU-2	-0.000 002 10	PV-UP+10
FDU-15	0	-0.002 412 0	RBU-14A	-0.000 002 83	PU-13

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

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

[c] $P(t)$ is the pressure data from the indicated transducer used for pressure correction sensitivity.

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:

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

where

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

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

The density measurements GVLP-172HZ, GV-COR-150HZ, and GV-162/192D which precalculate the logarithm function, and hence have a simpler conversion formula:

$$\text{GVLP-172HZ} \quad \rho = -40.39 F(t) - 2338.6$$

$$\text{GV-COR-150HZ} \quad \rho = -58.07 F(t) - 2787.2$$

$$\text{GV-162/192D} \quad \rho = -8.746 F(t)$$

where F(t) is the transducer voltage output.

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 A-1.

TABLE A-IV
 CONSTANTS FOR DENSITY MEASUREMENT
 CONVERSIONS TO ENGINEERING UNITS (TEST S-06-6)

<u>ID</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-5VR	1.161	-0.687	0.000 6	5.48
GU-10VR	1.099	-0.452	0.000 6	6.89
GU-13VR	1.686	-2.137	0.000 6	3.43
GB-42VR	1.018	+0.147	0.000 4	8.25
GB-37	2.057	-4.310	0.000 6	4.41
GB-23VR	1.133	-0.644	0.000 6	7.00
GVLP-165HZ	1.043	-0.206	0.000 6	6.84
GU-PRIZE	1.118	-0.098	0.000 6	1.195
GB-21B	1.092	-0.469	0.000 5	8.27
GB-21T	1.093	-0.367	0.000 4	6.92
GB-30B	1.053	-0.154	0.000 5	8.24
GB-30T	1.200	-0.999	0.000 4	6.48
GU-1B	1.036		0.000 5	8.49
GU-1T	1.047	-0.061	0.000 4	7.19
GII-15B	1.028	+0.043	0.000 5	8.88
GU-15T	1.121	-0.631	0.000 4	7.87

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

In the Semiscale Mod-1 system, two-beam gamma densitometers provide added information which allows the calculation of a better average density than that obtained from a single beam. A mathematical model is used for processing the two-beam data to

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

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 A-1 and by applying the froth-water model is given by:

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

where

- $\bar{\rho}$ = average cross-sectional density
- ρ_1 = average density measured by the upper gamma beam (measures the froth density)
- ρ_w = density of liquid water (at local system conditions)
- α_f = $1 + (1/2\pi) (\sin\beta - \beta)$ = froth fraction.

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

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

where

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

where

- H = $\ell_w \cos\theta$ (ℓ_w and θ are defined in Figure A-1)
- D = piping inside diameter
- ρ_2 = the average density measured by the lower gamma beam.

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

APPENDIX B

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TEST S-06-6

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APPENDIX B

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TEST S-06-6

Analysis has been performed on selected data from Test S-06-6 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 B-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 B-I.

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 B-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 B-2. Table B-II provides a summary of engineering error values obtained from current analysis techniques as applied to the data presented herein.

TABLE B-I

RANDOM ERROR VARIANCE TEST (S-06-6)

Measurement	Random Error Variance σ_F	Period of Application (s)	Figure	Comments
TFB-23	2.085	0 to 29	B-1	The error bands should be smaller than what is represented from 88 to 91 s ^[c] .
	9.375	29 to 91		
	0.858	91 to 200		
TFV-ANN-35A	2.614	0 to 25	B-2	
	7.908	25 to 80		
	0.470	80 to 200		
TFV-LP-15	3.766	0 to 72	B-3	
	0.311	72 to 200		
TFG-6DE-67	1.428	0 to 34	B-4	
	5.754	34 to 87		
	38.779	87 to 159		
	13.195	159 to 200		
TFU-SG4	0.062	0 to 36	B-5	
	0.028	36 to 200		
TFU-PRIZE	3.947	0 to 30	B-6	
	1.478	30 to 106		
	0.099	106 to 200		
TMU-15T16	0.322	0 to 200	B-7	
TMV-CI-35A	0.596	0 to 49	B-8	
	2.535	49 to 80		
	0.473	80 to 102		
	0.094	102 to 200		

TABLE B-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TH-E4-09	2.466 1.006 27.420 0.263	0 to 24 24 to 154 154 to 164 164 to 200	B-9	The error bands should be smaller than what is represented from 161 to 164 s ^[c] .
TH-E4-27	4.649 1.127	0 to 24 24 to 261	B-10	
TH-E4-55	5.966 0.544	0 to 22 22 to 200	B-11	
PU-13	3.910 0.754	0 to 77 77 to 200	B-12	
PB-23	4.031 0.707	0 to 77 77 to 200	B-13	
DPU-6-7	0.237 0.389 0.060 0.213	0 to 27 27 to 72 72 to 106 106 to 200	B-14	
DPU-7-10	0.121 0.191 0.023 0.104	0 to 31 31 to 73 73 to 105 105 to 200	B-15	The error bands should be smaller than what is represented from 0 to 73 ^[a] and from 105 to 200 s ^[a] .
DPU-12-10	0.426 0.601 0.125 0.187	0 to 39 39 to 57 57 to 140 140 to 200	B-16	

TABLE B-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
DPU-12-15	0.081 0.270 0.035 0.119	0 to 25 25 to 75 75 to 109 109 to 200	B-17	The error bands should be smaller than what is represented from 25 to 75 ^[a] and 109 to 200 ^[a] .
DPV-LP-UP	0.159 0.083 0.173	0.5 to 72 72 to 118 118 to 200	B-18	
FTU-1	8.093 62.990 0.765 40.035	0 to 47 47 to 72 72 to 87 87 to 200	B-19	The error bands should be smaller than what is represented from 47 to 72 s and 87 to 100 s ^[b] .
FTU-15	10.152 24.184 18.057 104.723	0 to 25 25 to 67 67 to 107 107 to 200	B-20	
FTU-HPIS	0.102 0.166	0 to 87 87 to 200	B-21	
FTU-LPIS	0.752 0.233 0.006	0 to 39 39 to 90 90 to 200	B-22	
FTU-ACC	0.082 0.577 3.816 0.023	0.5 to 18 18 to 65 65 to 92 92 to 200	B-23	The error bands should be smaller than what is represented from 74 to 87 s ^[b] and from 90 to 92 s ^[c] .

TABLE B-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FTV-40A	2.595	0 to 29	B-24	
	8.889	29 to 79		
	1.809	79 to 200		
FTV-40M	2.119	0 to 29	B-25	
	8.081	29 to 73		
	1.327	73 to 200		
GU-1T	0.981	0 to 18	B-26	The error bands are smaller than what is represented from 0 to 17 s ^[b] .
	0.230	18 to 200		
GU-1B	3.080	0 to 17	B-27	
	0.686	17 to 43		
	0.135	43 to 200		
GU-1C	1.092	0 to 18	B-28	The error bands should be smaller than what is represented from 15 to 18 s ^[c] .
	0.193	18 to 200		
GU-10VR	1.554	0 to 28	B-29	The error bands should be smaller than what is represented from 0 to 28 s ^[b] .
	0.170	28 to 200		
GU-15T	5.571	0 to 25	B-30	The error bands should be smaller than what is represented from 0 to 67 s ^[b] .
	2.526	25 to 71		
	0.488	71 to 107		
	6.932	107 to 200		
GU-15B	2.716	0 to 25	B-31	The error bands should be smaller than what is represented from 0 to 67 s ^[b] .
	3.543	25 to 71		
	1.401	71 to 107		
	7.440	107 to 200		

TABLE B-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GU-15C	4.195	0 to 25	B-32	The error bands should be smaller than what is represented from 0 to 67 s ^[b] .
	2.749	25 to 71		
	0.630	71 to 107		
	6.344	107 to 200		
GB-23VR	1.200	0 to 25	B-33	The error bands should be smaller than what is represented from 73 to 76 s ^[c] .
	10.162	25 to 76		
	0.223	76 to 115		
	0.926	115 to 200		
GV-COR-150HZ	0.445	0 to 82	B-34	
	8.169	32 to 146		
	2.906	146 to 200		
GVLP-165HZ	3.549	0 to 21	B-35	The error bands should be smaller than what is represented from 78 to 88 s ^[b] .
	0.996	21 to 77		
	5.719	77 to 183		
	2.352	184 to 200		
GVLP-172HZ	3.241	0 to 24	B-36	The error bands should be smaller than what is represented from 70 to 85 s ^[b] .
	5.779	24 to 44		
	3.152	44 to 73		
	1.088	73 to 200		
FDU-1, GU-1C	0.364	0 to 25	B-37	
	0.098	25 to 200		
FTU-1, GU-1C	0.198	0 to 101	B-38	
	0.195	101 to 200		

TABLE B-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
219 FDU-5, GU-5VR	0.640	0 to 18	B-39	
	0.284	18 to 71		
	0.064	71 to 109		
	0.077	109 to 200		
FTU-13, GU-13VR	1.011	0 to 31	B-40	
	2.967	31 to 72		
	0.175	72 to 109		
	1.105	109 to 200		
FTU-15, GU-15C	0.560	0 to 20	B-41	The error bands should be smaller than what is represented from 20 to 27 s ^[b] and from 68 to 71 s ^[c] .
	3.314	20 to 71		
	0.276	71 to 107		
	3.128	107 to 200		
FD3-21, GB-21C	1.129	0 to 24	B-42	
	3.445	24 to 72		
	0.251	72 to 200		
FTB-21, GB-21C	1.918	0 to 24	B-43	The error bands should be smaller than what is represented from 0 to 79 s ^[a] .
	2.713	24 to 72		
	0.609	72 to 200		
FTV-CORE-IN, GV-COR-150HZ	0.563	0 to 82	B-44	The error bands should be smaller than what is represented from 82 to 200 s ^[a] .
	3.751	82 to 139		
	7.635	139 to 200		

TABLE E-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
[a]	The variability in the data has two components. One is the random error and the other is the systematic error. In this region, the random component dominates the systematic component. The width of the error band is due primarily to the variance of the random underlying process. The large variability does not reflect the inability of the measuring instrument to accurately measure the process.			
[b]	The larger estimated error band occurs when there is a rapid transient change during which insufficient data are provided to allow estimation of the error. Inclusion of large transients in the estimation increases the estimated error.			
[c]	Due to present software limitations, error bands will appear larger than expected wherever segments with different size error bands are merged together.

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

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

Fig. B-3 Fluid temperature in lower plenum (TFV-LP-15).

Fig. B-4 Fluid temperature in core, Grid Spacer 6 (TFG-6DE-67).

Fig. B-5 Fluid temperature in steam generator (TFU-SG4).

Fig. B-6 Fluid temperature in pressurizer surge line (TFU-PRIZE).

Fig. B-7 Material temperature in intact loop (TMU-15T16).

Fig. B-8 Material temperature in vessel filler (TMV-CI-35A).

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

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

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

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

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

Fig. B-14 Differential pressure in intact loop (DPU-6-7).

Fig. B-15 Differential pressure in intact loop (DPU-7-10).

Fig. B-16 Differential pressure in intact loop (DPU-12-10).

Fig. B-17 Differential pressure in intact loop (DPU-12-15).

Fig. B-18 Differential pressure in vessel (DPV-LP-UP).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Fig. B-38 Mass flow in intact loop (FTU-1, GU-1C).

Fig. B-39 Mass flow in intact loop (FDU-5, GU-5VR).

Fig. B-40 Mass flow in intact loop (FTU-13, GU-13VR).

Fig. B-41 Mass flow in intact loop (FTU-15, GU-15C).

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

Fig. B-43 Mass flow in broken loop (FTB-21, GB-21C).

Fig. B-44 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ).

TABLE B-II

GENERAL MEASUREMENT ENGINEERING ERROR SOURCES AND ERROR VALUES (TEST S-06-6)

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 B-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 ±4.95 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 ±6394, ±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 B-II (continued)

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

TABLE B-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
Density (continued)	Flow regime	Gr[d] where Gr = flow regime error (kg/m ³)	[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)	
	Flow regimes	[d]	
Volumetric Flow (turbine flow-meter)	Calibration instrument reading	+0.25% of transducer full scale	[d]
	Calibration standards	+19.56 x 10 ⁻² (1/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 B-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
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 engineer 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 B-2.

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 of additional engineering error due to flow regime effects. Table B-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 B-III

TIME PERIODS WHEN FLOW REGIME ERRORS WERE APPLIED (TEST S-06-6)

<u>Transducer Identification</u>	<u>Time during which Flow Regime Errors were Applied (s)</u>	<u>Figure Number</u>
GU-1C	2 to 40	B-28
GU-10VR	10 to 25	B-29
GU-15C	13 to 20 and 57 to 100	B-32
GD-23VR	3 to 15 and 58 to 300	B-33
FDU-1, GU-1C	2 to 40	B-37
FDU-5, GU-5VR	3 to 10 and 27 to 44	B-39
FTU-13, GU-13VR	11 to 33	B-40
FTU-15, GU-15C	13 to 20 and 57 to 100	B-41
FTB-21, GB-21C	3 to 15 and 58 to 300	B-43

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,

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

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,

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

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 (B-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 (B-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.

REFERENCES

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

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