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**EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1
TESTS S-28-7, S-28-9, and S-28-12
(STEAM GENERATOR TUBE RUPTURE TESTS)**

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February 1978

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IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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

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(STEAM GENERATOR TUBE RUPTURE TESTS)

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by

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EG&G IDAHO, INC.

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AND THE
DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. EY-76-C-07-1570

ABSTRACT

Recorded test data are presented for Tests S-28-7, S-28-9, and S-28-12 of the Semiscale Mod-1 steam generator tube rupture test series. These tests are among several Semiscale Mod-1 experiments conducted to investigate the thermal and hydraulic phenomena accompanying a hypothesized loss-of-coolant accident in a pressurized water reactor (PWR) system.

Tests S-28-7, S-28-9, and S-28-12 were conducted from initial conditions of 15 736 kPa and 557 K, 15 754 kPa and 556 K, and 15 704 kPa and 559 K, respectively, 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. The specific objective of these tests was to refine the definition of the upper limit of steam generator tube ruptures at which high peak cladding temperatures occur, as set by Test S-28-1. During these tests, cooling water was injected into the cold leg of the intact and broken loops to simulate emergency core coolant in a PWR. Thirty (Test S-28-7), 34 (Test S-28-9), and 20 (Test S-28-12) steam generator tube ruptures were simulated by a controlled injection from a heated accumulator into the intact loop hot leg.

The purpose of this report is to make available the uninterpreted data from Tests S-28-7, S-28-9, and S-28-12 for future data analysis and test reporting activities. The data, presented in the form of graphs in engineering units, have been analyzed only to the extent necessary to ensure that they are reasonable and consistent.

SUMMARY

Tests S-28-7, S-28-9, and S-28-12 were performed as part of the Semiscale Mod-1 portion of the Semiscale Program conducted by EG&G Idaho, Inc., for the United States Government. These tests are part of the steam generator tube rupture test series (Test Series 28) performed to investigate the response of the Mod-1 system to steam generator tube ruptures during a hypothesized loss-of-coolant accident (LOCA). The test objective specific to Tests S-28-7, S-28-9, and S-28-12 was to refine the definition of the upper limit of steam generator tube ruptures at which high peak cladding temperatures occur, as set by Test S-28-1. Hardware configuration and test parameters were selected to yield a system response that simulates the response of a pressurized water reactor during a hypothesized LOCA with subsequent refill and reflood.

These tests utilized the Semiscale Mod-1 system equipped with a pressure vessel with a 40-rod electrically heated core; an intact loop with pump, steam generator, and pressurizer; a broken loop with simulated pump, simulated steam generator, and rupture assemblies; and a pressure suppression system with header, pressure suppression tank, and heated steam supply system. High and low pressure coolant injection pumps and a coolant injection accumulator were provided for each system loop. An additional injection accumulator was provided for the intact loop hot leg. The intact loop hot leg injection flow rate was set to simulate the rupture of 30 (Test S-28-7), 34 (Test S-28-9), and 20 (Test S-28-12) steam generator tubes. For Tests S-28-7, S-28-9, and S-28-12, four heater rods were intentionally unpowered to simulate the effects of control rod guide tubes and the power in three heater rods was increased to produce a slightly peaked power profile.

Tests S-28-7, S-28-9, and S-28-12 were conducted from initial conditions of 15 736 kPa and 557 K, 15 754 kPa and 556 K, and 15 704 kPa and 559 K (temperatures taken at the intact loop cold leg vessel inlet), respectively, with a simulated full size (200%) double-ended offset shear of the broken loop cold leg piping at initial core power levels of 1.43 MW (Test S-28-7) and 1.42 MW (Tests S-28-9 and S-28-12), and initial core inlet flow rates of 9.2 l/s (Test S-28-7), 8.8 l/s (Test S-28-9), and 9.2 l/s (Test S-28-12). The instantaneous offset shear of the broken loop cold leg piping was simulated by simultaneous (within 10 ms) actuation of the rupture assemblies. After initiation of blowdown, power to the heated core was reduced to simulate the predicted heat flux response of nuclear fuel rods during a LOCA. Blowdown was accompanied by simulated emergency core coolant injected into the cold leg piping of the intact and broken loops. This injection was followed by a controlled injection from a heated accumulator into the intact loop hot leg to simulate steam generator tube ruptures.

Tests S-28-7, S-28-9, and S-28-12 were 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 221 measurements taken for Tests S-28-7 and S-28-9, 218 and 219, respectively, produced usable data. Of 206 measurements taken for Test S-28-12, 202 produced usable data.

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TESTS S-28-7, S-28-9, and S-28-12

(STEAM GENERATOR TUBE RUPTURE TESTS)

I. INTRODUCTION

The Semiscale Mod-1 experiments represent the current phase of the Semiscale program conducted by EG&G Idaho, Inc., for the United States Government. The program, which is sponsored by the Nuclear Regulatory Commission through the Department of Energy, is part of the overall program designed to investigate the response of a pressurized water reactor (PWR) 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.

Tests S-28-7, S-28-9, and S-28-12 were conducted August 2, 3, and 23, 1977, respectively, in the Semiscale Mod-1 system as part of the steam generator tube rupture test series (Test Series 28). This series was designed to obtain thermal-hydraulic response data from blowdown, refill, and reflood transients in a simulated nuclear reactor with an electrically heated core to study system response during a LOCA with steam generator tube ruptures. The specific objective of these tests was to refine the definition of the upper limit of steam generator tube ruptures at which high peak cladding temperatures occur, as set by Test S-28-1. Hardware configuration and test parameters were selected to yield a system response that simulates the response of a PWR to a hypothesized LOCA with subsequent refill and reflood.

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 Tests S-28-7, S-28-9, and S-28-12; Section III presents the data graphs and provides comments and supporting information necessary for interpretation of the data. A description of the overall Semiscale Program and test series, a more detailed description of the Semiscale Mod-1 system, and a description of the measurement and data processing techniques and uncertainties can be found in Reference 1. Appendix A also provides additional information on the data acquisition system capabilities.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TESTS

S-28-7, S-28-9, AND S-28-12

The following system configuration, procedures, initial test conditions, and events are specific to Tests S-28-7, S-28-9, and S-28-12 as indicated:

1. SYSTEM CONFIGURATION AND TEST PROCEDURES

The Semiscale Mod-1 system used for these tests consisted of a pressure vessel with internals, including a 40-rod core with 36 electrically heated rods; an intact loop with steam generator, pump, and pressurizer; a broken loop with simulated steam generator, simulated pump, and two rupture assemblies; coolant injection accumulators for the cold legs of the intact and broken loops, and a heated accumulator for the intact loop hot leg; high and low pressure injection pumps for each of the system loops; and a pressure suppression system with a suppression tank, header, and heated steam supply system. For Tests S-28-7, S-28-9, and S-28-12, the volume of the lower plenum was reduced to 0.015 m^3 by the addition of a metal filler piece. Semiscale Mod-1 experimental system configuration information is described further in Reference 1. Figures 1 and 2 show the system configuration for the tests.

For Tests S-28-7, S-28-9, and S-28-12, 33 rods of the 40-rod electrically heated core were operated at a peak power density of approximately 37.7 kW/m , three rods (D-4, E-4, and E-5) were operated at a peak power density of approximately 39.7 kW/m to yield a slightly peaked power profile, and four rods (Rods C-3, D-5, F-3, and F-6) were unpowered to simulate the effect of control rod guide tubes. The resulting total core power was approximately 1.43 MW for Test S-28-7 and 1.42 MW for Tests S-28-9 and S-28-12.

In preparation for the tests, the accumulators for the intact and broken loop cold legs were filled with treated demineralized water, drained to the specified initial levels, and pressurized with nitrogen to 4223 kPa. The steam generator rupture system accumulator for the intact loop hot leg was filled with treated demineralized water, drained to the specified initial level, heated to 541 K, and pressurized to 7584 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 set to zero. Warmup to initial test conditions was accomplished with the heaters in the vessel core. Heatup of the broken loop piping was accomplished with bypass lines which served to allow circulation through the broken loop. During warmup, the purification and sampling systems were valved into the primary system to maintain water chemistry requirements and to provide a water sample at system conditions for subsequent analysis. At 56 K temperature intervals during warmup, detector readings were sampled to allow the integrity of the measurement instrumentation and the operability of the data acquisition system to be checked.

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

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 1.43 MW (Test S-28-7) and 1.42 MW (Test S-28-9 and S-28-12), initial test conditions were held for 763, 653, and 1218 s, respectively, 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.

For Tests S-28-7, S-28-9, and S-28-12, the system was successfully subjected to a simulated double-ended cold leg break through two rupture assemblies and two blowdown nozzles, each having a break area of $0.000\ 243\ \text{m}^2$. 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 was injected from the primary system into the pressure suppression system which was vented to maintain a constant pressure of 241 kPa. At blowdown, power to the primary coolant

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

circulation pump was reduced and the pump was allowed to coast down to a speed of 1475 rpm which was maintained for the duration of the tests. During the blowdown transient, power to the electrically heated core was automatically controlled to simulate the thermal response of nuclear heated fuel rods.

For Tests S-28-7, S-28-9, and S-28-12, the coolant injection systems were arranged to discharge into both system loops at the cold leg injection points (Spool 14 and Spool 42). The high pressure coolant injection pumps were started immediately after initiation of blowdown (0 s) and continued to the end of the tests (640 s). For Tests S-28-7, S-28-9, and S-28-12, low pressure coolant injection was initiated at 25, 26, and 27 s, respectively, after blowdown at a system pressure of 1034 kPa and continued until termination of the tests (640 s). Coolant injection from the intact loop accumulator (CI-T-1) for these tests began 17 s after blowdown, nitrogen discharge began 64 s after rupture, and was terminated 88 s after blowdown. The broken loop accumulator (CI-T-2) for the tests began injection 3 s after blowdown, nitrogen discharge began 27 s after rupture and continued until the tests were terminated (640 s). During these tests, the steam generator rupture system accumulator (CI-T-3) began injection at 62 s and continued until termination of the tests (640 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

	<u>Measured^[a]</u>			<u>Specified</u>
	<u>Test S-28-7</u>	<u>Test S-28-9</u>	<u>Test S-28-12</u>	<u>Tests S-28-7, S-28-9, and S-28-12</u>
Core power (MW)	1.43	1.42	1.42	1.43 $\pm$ 0.01
Intact loop cold leg fluid temperature (K)	557	556	559	558 $\pm$ 1
Hot leg to cold leg temperature differential (K)	37	37.6	36.7	37 $\pm$ 0.5
Pressurizer pressure (kPa)	15 736	15 754	15 704	15 600 $\pm$ 35
Pressurizer liquid mass (kg) ^[b]	9.56	9.30	9.3	9.07
Steam generator feedwater temperature (K)	503	506	497	497 $\begin{smallmatrix} + 6 \\ - 17 \end{smallmatrix}$
Steam generator liquid level (from bottom of tube sheet) (cm)	259	273	247	295 $\pm$ 5
Broken loop fluid temperature (pump side) (K)	592	590	591	589 to 594
Broken loop fluid temperature (vessel side) (K)	555	554	557	Not Specified
Intact loop cold leg flow (kg/s)	9.20	8.83	9.08	[c]

TABLE I (continued)

	Measured ^[a]			Specified
	Test S-28-7	Test S-28-9	Test S-28-12	Tests S-28-7, S-28-9, and S-28-12
Pressure suppression tank water level (cm)	121	121	121	121 $\pm$ 1
Pressure suppression tank pressure (kPa)	235	240	236	241 $\pm$ 7
Pressure suppression tank water temperature (K)	291	292	294	<297

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

[b] Pressurizer liquid mass including surge line.

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

TABLE II

PRIMARY COOLANT TEMPERATURE DISTRIBUTION PRIOR TO RUPTURE^[a]

	Detector	Temperature (K)		
		Test S-28-7	Test S-28-9	Test S-28-12
Vessel lower plenum (upper portion above filler block)	TFV-LP-7	556	554	557
Intact loop hot leg (near vessel)	RBU-2	594	594	593
Intact loop cold leg (near pump inlet)	TFU-10	555	555	555
∞ Intact loop cold leg (near vessel)	RBU-14A	557	556	557
Broken loop cold leg (near nozzle)	TFB-23	555	554	554
Broken loop hot leg (near vessel)	TFB-30	592	592	591
Broken loop cold leg (near nozzle)	TFB-42	590	590	588

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

TABLE III
WATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

	<u>Test S-28-7</u>	<u>Test S-28-9</u>	<u>Test S-28-12</u>
pH	9.55	Not Available	9.90
Conductivity ($\mu\text{S}/\text{cm}$)	111		91
Lithium ($\mu\text{g}/\text{m}\ell$)	3.9		4.1
Chlorides ($\mu\text{g}/\text{m}\ell$)	0.7		0.6
Fluorides ($\mu\text{g}/\text{m}\ell$) ^[b]	<0.48		<0.4
Oxygen (cc/ℓ)	0.08		0.1
Total gas (cc/ℓ)	97.8		181.6
Suspended solids ($\mu\text{g}/\text{m}\ell$)	2.97		0.59

[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 $\mu\text{g}/\text{m}\ell$.

TABLE IV

SEQUENCE OF EVENTS DURING TESTS S-28-7, S-28-9, and S-28-12^[a]

Event	Time Relative To Rupture (s)		
	Test S-28-7	Test S-28-9	Test S-28-12
Core power level established	-763	-553	-1218
Bypass lines valved out of system	-2.5	-2.5	-2.5
Blowdown initiated	0	0	0
Pump power reduced	0	0	0
High pressure injection system pumps started ^[b]	0	0	0
ECC accumulator valved in	0	0	0
Steam generator feedwater and discharge valves closed	1	1	1
Core power decay transient started	2.6	2.6	2.6
Low pressure injection system pumps started ^[b]	30.5	31	27
Core power tripped off ^[c]	740	641	661

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

TABLE IV (continued)

-
- [b] .Injection from ECC accumulators and high and low pressure injection system pumps does not start until system pressure drops below accumulator or pump pressure, respectively.
- [c] Core power tripped manually at termination of test.
-

III. DATA PRESENTATION

The data from Semiscale Mod-1 Tests S-28-7, S-28-9, and S-28-12 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 these tests was monitored by 221 detectors for Tests S-28-7 and S-28-9, and by 206 detectors for Test S-28-12. The data obtained were recorded on both digital and analog data acquisition systems. The analog system was used to provide redundant data. The long-term data (-32 to 640 s) presented in this report were recorded at an effective sample rate of 1.369 points per second. Long-term plots are given for -20 to 600 s rather than for the full 640-s recording time to provide better resolution. Short-term data and plots (-6 to 42 s) were recorded at an effective sample rate of 19.17 points per second.

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

Figures 3 through 8 and Table V provide supporting information for interpretation of the data graphs shown in Figures 9 through 643 and provide relative locations of all detectors used during these tests. 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 643 present all the blowdown and reflood data obtained. Time zero on the graphs is the time of rupture initiation. Appendix A provides information explaining the data acquisition system capabilities. Appendix B explains posttest data processing for data conversion into engineering units and data adjustments. Presented in Appendix C is an analysis of selected data which provides a guide to the uncertainty associated with data measurements in the Semiscale Mod-1 system.

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

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

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

Distance from
cold leg ϕ (cm)

Distance from
cold leg ϕ (cm)

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

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

INEL-A-4308

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

TABLE V

DATA PRESENTATION FOR SEMISCALE MOD-1 TESTS S-28-7, S-28-9, and S-28-12

Measurement	Location and Comments [a]	Range [a]		Figure [a,c]	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	11, 12	
TFU-6	Hot leg, Spool 6, 290 cm from vessel center.			13, 14	
TFU-7	Cold Leg, Spool 7, 624 cm from vessel center.			15, 16 (Test S-28-7) 17, 18 (Test S-28-9) 19, 20 (Test S-28-12)	
TFU-10	Cold leg, Spool 10, 367 cm from vessel center.			21, 22 (Test S-28-7) 23, 24 (Test S-28-9) 25, 26 (Test S-28-12)	
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	27, 28 (Test S-28-7) 29, 30 (Test S-28-9) 31, 32 (Test S-28-12)	
TFU-14B	Cold leg, Spool 14, 99 cm from vessel center, downstream of cold leg injection port.			33, 34 (Test S-28-7) 35, 36 (Test S-28-9) 37, 38 (Test S-28-12)	
TFU-15	Cold leg, Spool 15, 54 cm from vessel center.			39, 40	
<u>Broken Loop</u>					
TFB-20	Cold leg, Spool 20, 52 cm from vessel center.	0 to 1533 K	0 to 820 K	41, 42	
TFB-23	Cold leg, Spool 23, 232 cm from vessel center, upstream of vessel-side nozzle.			43, 44	
TFB-30	Hot leg, Spool 30, 40 cm from vessel center.			45, 46	
TFB-37	Cold leg, Spool 37, 703 cm from vessel center along hot leg, discharge of simulated steam generator.			47, 48	
TFB-42	Cold leg, Spool 42, 1054 cm from vessel center along hot leg, upstream of pump-side nozzle.			49, 50 (Test S-28-7) 51, 52 (Test S-28-9) 53, 54 (Test S-28-12)	
<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°.			55, 56	Detector failed for test S-28-12.
TFV-ANN-4M	180°.			57, 58	
<u>Downcomer Annulus</u>					
	Centered in annulus, Type J iron-constantan thermocouples.	0 to 1033 K	0 to 701 K		
TFV-ANN-35A	89 cm below cold leg centerline, 0°.			59, 60	
TFV-ANN-70A	178 cm below cold leg centerline, 0°.			61, 62	
TFV-ANN-115A	292 cm below cold leg centerline, 0°.			63, 64	
TFV-ANN-156A	396 cm below cold leg centerline, 0°.			65, 66	Tests S-28-7 & S-28-9 only.

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a,c]	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	0 to 820 K	67, 68 (Test S-28-7) 69, 70 (Test S-28-9) 71, 72 (Test S-28-12)	
<u>Lower Plenum</u>					
TFV-LP-2	On fluid thermocouple rack, 2.54 cm from vessel center, 45°.	0 to 1533 K	0 to 820 K		
TFV-LP-4	5 cm above top of lower plenum filler block.			73, 74	
TFV-LP-7	10 cm above top of lower plenum filler block.			75, 76	
	18 cm above top of lower plenum filler block.			77, 78	
<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	79, 80	
<u>Core Grid Spacers</u>					
<u>Grid Spacer 5</u>					
TFG-SCD-45	140 cm below cold leg centerline, 54.6 cm above top of heated length. Thermocouple in space defined by Columns C and D, Rows 4 and 5.	0 to 1533 K	0 to 1579 K	81, 82	
<u>Grid Spacer 6</u>					
TFG-6CD-45	193 cm below cold leg centerline, 1.3 cm above top of heated length. Thermocouple in space defined by Columns C and D, Rows 4 and 5.			83, 84	
<u>Grid Spacer 10</u>					
TFG-10AB-45	363 cm below cold centerline at bottom of heated length. Thermocouple in space defined by Columns A and B, Rows 4 and 5.			85, 86	
		0 to 1533 K	0 to 584 K		
<u>ECC System</u>					
TFU-ECC-14	In ECC line leading to intact loop Spool 14.			87, 88	
TFB-ECC-42	In ECC line leading to broken loop Spool 42.			89, 90	
<u>Steam Generator</u>					
TFU-SGFW	In feedwater line leading to steam generator.	0 to 1533 K	0 to 584 K	91, 92 (Test S-28-7) 93, 94 (Test S-28-9) 95, 96 (Test S-28-12)	
TFU-SGSD	In steam dome, 329 cm above bottom of tube sheet.			97, 98	
TFU-SG1	Secondary side, 30 cm above bottom of tube sheet.			99, 100	
TFU-SG2	Secondary side, 61 cm above bottom of tube sheet.			101, 102	
TFU-SG3	Secondary side, 122 cm above bottom of tube sheet.			103, 104	
<u>Steam Generator Inerting System</u>					
TFU-SGS3	In bottom of Accumulator Tank T-3.	0 to 1533 K	0 to 584 K	105, 106	
TFU-SGS	In injection line leading from Accumulator Tank T-3 just upstream of junction with Spool 6.			107, 108	
TFU-SGS-D	In drain of injection line leading from Accumulator Tank T-3.			109, 110	
<u>Pressurizer</u>					
TFU-PRIZE	In surge line, near pressurizer exit, between turbine flowmeter and pressurizer.	0 to 1533 K	0 to 820 K	111, 112	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Pressure Suppression System</u>		0 to 1533 K	0 to 584 K		
TF-PSS-33	84 cm from bottom of tank.			113, 114 (Test S-28-7) 115, 116 (Test S-28-9) 117, 118 (Test S-28-12)	
TF-PSS-130	330 cm from bottom of tank.			119, 120	Tests S-28-7 and S-28-9 only.
<u>MATERIAL TEMPERATURE</u>	Chromel-Alumel thermocouples unless specified otherwise.				
<u>Intact Loop</u>		0 to 1533 K	0 to 820 K		
TMU-1T1G	Hot leg, Spool 1, top, 1.6 mm from pipe ID, 54 cm from vessel center.			121, 122	
<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.			123, 124	Tests S-28-7 and S-28-9 only.
<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°.			125, 126	
TMV-FI-156A	396 cm below cold leg centerline; 1.6 mm from filler ID 0°.			127, 128	Tests S-28-7 and S-28-9 only.
TMV-FD-156A	396 cm below cold leg centerline; 1.65 cm from filler ID 0°.			129, 130	
<u>Vessel Filler Insulator</u>		0 to 1033 K	0 to 701 K		
TIV-FD-35A	89 cm below cold leg centerline, 0°.			131, 132	
TIV-FD-115A	292 cm below cold leg centerline, 0°.			133, 134	
<u>Core Barrel</u>	Type J iron-constantan thermocouples	0 to 1033 K	0 to 701 K		
TMV-CI-70A	178 cm below cold leg centerline; 1.6 mm from core barrel ID, 0°.			135, 136	Tests S-28-7 and S-28-9 only.
TMV-CO-70A	178 cm below cold leg centerline; 1.6 mm from core barrel OD, 0°.			137, 138	Tests S-28-7 and S-28-9 only.
TMV-CO-115A	292 cm below cold leg centerline; 1.6 mm from core barrel OD, 0°.			139, 140	
<u>Core Housing Filler</u>		0 to 1533 K	0 to 820 K		
TMV-HF-115W	On core housing filler, 292 cm below cold leg centerline, 5 mm from outer surface, 315°.			141, 142	
TMV-HF-127W	On core housing filler, 323 cm below cold leg centerline, 5 mm from outer surface, 315°.			143, 144	Tests S-28-7 and S-28-9 only.
TMV-HF-138W	On core housing filler, 351 cm below cold leg centerline, 5 mm from outer surface, 315°.			145, 146	Tests S-28-7 and S-28-9 only.
<u>Steam Generator</u>		0 to 1533 K	0 to 584 K		
TMU-SG1	On a steam generator tube, 30 cm above bottom of tube sheet, on OD of tube.			147, 148	
TMU-SG2	On a steam generator tube, 61 cm above bottom of tube sheet, on OD of tube.			149, 150	
TMU-SG3	On a steam generator tube, 122 cm above bottom of tube sheet, on OD of tube.			151, 152	

TABLE V. (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
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.			153, 154 155, 156	
TH-D5-29	Heater at Column D, Row 5. Thermocouple 74 cm (225°) above bottom of core.			157, 158	
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.			169, 160 161, 162 163, 164	
TH-E5-20 TH-E5-25	Heater at Column E, Row 5. Thermocouples 53 cm (180°) and 64 cm (90°) above bottom of core.			165, 166 167, 168	
<u>Low Power Heaters</u>		0 to 1533 K	0 to 1579 K		
TH-A4-09 TH-A4-29 TH-A4-39	Heater at Column A, Row 4. Thermocouples 23 cm (105°), 74 cm (240°), and 99 cm (300°) above bottom of core.			169, 170 171, 172 173, 174	
TH-A5-29 TH-A5-45	Heater at Column A, Row 5. Thermocouples 74 cm (180°) and 114 cm (255°) above bottom of core.			175, 176 177, 178	
TH-B3-32	Heater at Column B, Row 3. Thermocouple 81 cm (135°) above bottom of core.			179, 180	
TH-B5-29 TH-B5-33	Heater at Column B, Row 5. Thermocouples 74 cm (150°) and 85 cm (45°) above bottom of core.			181, 182 182, 184	
TH-B6-29	Heater at Column B, Row 6. Thermocouple 74 cm (45°) above bottom of core.			185, 186	
TH-C2-38	Heater at Column C, Row 2. Thermocouple 97 cm (225°) above bottom of core.			187, 188	
TH-C4-20 TH-C4-26 TH-C4-53	Heater at Column C, Row 4. Thermocouples 51 cm (150°), 66 cm (75°), and 135 cm (300°) above bottom of core.			189, 190 191, 192 193, 194	
TH-C5-28	Heater at Column C, Row 5. Thermocouple 71 cm (315°) above bottom of core.			195, 196	
TH-C6-53	Heater at Column C, Row 6. Thermocouple 135 cm (270°) above bottom of core.			197, 198	
TH-C7-07 TH-C7-15	Heater at Column C, Row 7. Thermocouples 18 cm (345°) and 38 cm (255°) above bottom of core.			199, 200 201, 202	
TH-D1-21	Heater at Column D, Row 1. Thermocouple 53 cm (330°) above bottom of core.			203, 204	
TH-D2-14 TH-D2-61	Heater at Column D, Row 2. Thermocouples 36 cm (0°) and 166 cm (270°) above bottom of core.			205, 206 207, 208	
TH-D3-29 TH-D3-39	Heater at Column D, Row 3. Thermocouples 74 cm (150°) and 99 cm (210°) above bottom of core.			209, 210 211, 212	
TH-D6-25	Heater at Column D, Row 6. Thermocouple 64 cm (255°) above bottom of core.			213, 214	
TH-D7-20	Heater at Column D, Row 7. Thermocouple 51 cm (60°) above bottom of core.			215, 216	
TH-D8-26	Heater at Column D, Row 8. Thermocouple 69 cm (180°) above bottom of core.			217, 218	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Low Power Heaters (continued)					
TH-E1-33	Heater at Column 4, Row 1. Thermo-couple 84 cm (60°) above bottom of core.			219, 220	
TH-E2-33	Heater at Column E, Row 2. Thermo-couple 84 cm (315°) above bottom of core.			221, 222	
TH-E3-05 TH-E3-20 TH-E3-24	Heater at Column E, Row 3. Thermo-couples 13 cm (15°), 51 cm (165°) and 61 cm (75°) above bottom of core.			223, 224 225, 226 227, 228	
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.			229, 230 231, 232 233, 234	
TH-E7-44	Heater at Column E, Row 7. Thermo-couple 112 cm (195°) above bottom of core.			235, 236	
TH-E8-14 TH-E8-29	Heater at Column E, Row 8. Thermo-couples 36 cm (150°) and 74 cm (225°) above bottom of core.			237, 238 239, 240	
TH-F2-07 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.			241, 242 243, 244 245, 246	
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.			247, 248 249, 250 251, 252	
TH-F5-20 TH-F5-26 TH-F5-33 TH-F5-53	Heater at Column F, Row 5. Thermo-couples 51 cm (255°), 66 cm (165°), 84 cm (315°), and 135 cm (30°) above bottom of core.			253, 254 255, 256 257, 258 259, 260	
TH-G3-13	Heater at Column G, Row 3. Thermo-couples 33 cm (150°) above bottom of core.			261, 262	
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.			263, 264 265, 266 267, 268	
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.			269, 270 271, 272	
TH-H5-32	Heater at Column H, Row 5. Thermo-couple 81 cm (45°) above bottom of core.			273, 274	
PRESSURE					
Intact Loop		0 to 20 684 kPa			
PU-13	Cold leg, Spool 13, 138 cm from vessel center.		0 to 21 092 kPa	275, 276	
PU-15L	Cold leg, Spool 15, 55 cm from vessel center, to atmosphere (low range).	0 to 3447 kPa	0 to 3561 kPa	277, 278	Detector saturated to t=18 s.
Broken Loop		0 to 17 237 kPa			
PB-21	Cold leg, Spool 21, 112 cm from vessel center.	0 to 20 684 kPa	0 to 29 666 kPa 0 to 2 939 kPa (Test S-28-12)	279, 280	
PR-23	Cold leg, Spool 23, 235 cm from vessel center, upstream of nozzle (tee off DP tap).		0 to 21 440 kPa	281, 282	
PB-CN1	Cold leg, Spool 23, vessel-side nozzle, nozzle throat, 244 cm from vessel center along cold leg, 45°.	0 to 20 684 kPa	0 to 30 336 kPa	283, 284	Tests S-28-7 and S-28-9 only.
PB-37	Cold leg, Spool 37, 718 cm from vessel center along hot leg.		0 to 21 675 kPa	285, 286	
PB-42	Cold leg, Spool 47, 1057 cm from vessel center along hot leg, upstream of pump-side nozzle (tee off DP tap).		0 to 20 359 kPa 0 to 20 569 kPa (Test S-28-12)	287, 288	
PB-HN1	Pump-side nozzle, nozzle throat, 1066 cm from vessel center along hot leg (tee off DP tap)		0 to 20 654 kPa 0 to 20 831 kPa (Test S-28-12)	289, 290	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>PRESSURE (continued)</u>					
<u>Vessel</u>					
PV-UP+10	In upper plenum, 25 cm above cold leg centerline, mounted on standoff, 30°.	0 to 17 237 kPa	0 to 21 261 kPa	291, 292	
PV-LP-166	In upper part of lower plenum, 422 cm below cold leg centerline, mounted on standoff, 225°.	0 to 20 684 kPa	0 to 34 226 kPa	293, 294	
<u>ECC System</u>					
PU-ACC1	In intact loop accumulator	0 to 6894 kPa	0 to 8629 kPa	295, 296	
PU-ACC2	In broken loop accumulator.		0 to 8368 kPa	297, 298	
<u>Steam Generator</u>					
PU-SGSD	Secondary side steam dome.	0 to 20 684 kPa	0 to 14 018 kPa	299, 300	
<u>Steam Generator Rupture System</u>					
PU-SGS3	In vessel simulating steam generator tube rupture. (Vessel accumulator.)	0 to 6895 kPa	0 to 8368 kPa	301, 302	
<u>Pressurizer</u>					
PU-PRIZE	Pressurizer steam dome.	0 to 17 237 kPa	0 to 22 330 kPa	303, 304	
<u>Pressure Suppression System</u>					
P-PSS	Suppression tank top.	0 to 1724 kPa	0 to 2173 kPa	305, 306	Pressure suppression system pressure was affected by a malfunction of the rupture disc pressurization valve from t=0 to t=6 s for Test S-28-7 and from t=0 to t=20 s for Test S-28-9.
<u>DIFFERENTIAL PRESSURE</u>					
<u>Intact Loop</u>					
DPU-3-7	Hot leg Spool 3, 158 cm from vessel center to cold leg Spool 7, 587 cm from vessel center. Spool 3 tap is 46 cm above Spool 7 tap.	+1270 cm water	+170 kPa	307, 308	
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	309, 310 (Test S-28-7) 311, 312 (Test S-28-9) 313, 314 (Test S-28-12)	
DPU-SGOP-7	From steam generator outlet plenum 683 cm from vessel center along from vessel center, including orifice. Spool 7 tap is 89 cm below SGOP tap.	+1270 cm water	+169 kPa	315, 316	Data acquisition system saturated at t=63 s.
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	317, 318 (Test S-28-7) 319, 320 (Test S-28-9) 321, 322 (Test S-28-12)	Data acquisition system saturated intermittently from t=0 to t=3 s for Tests S-28-9 and S-28-12.
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	323, 324	Detector failed for Test S-28-7.
DPU-12-10L	Pump outlet to pump inlet, cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 10, 359 cm from vessel center. Spool 10 tap is 25 cm below Spool 12 tap (low range).	+254 cm water	+33.2 kPa	325, 326	Data acquisition system saturated until t=7 s.

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Intact Loop (continued)</u>					
DPU-12-15	Cold leg Spool 12, 192 cm from vessel center, to cold leg Spool 15, 55 cm from vessel center.	+254 cm water	+33.5 kPa	327, 328 (Test S-28-7) 329, 330 (Test S-28-9) 331, 332 (Test S-28-12)	
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	333, 334	Tests S-28-7 and S-28-9 only.
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	335, 336 (Test S-28-7) 337, 338 (Test S-28-9) 339, 340 (Test S-28-12)	Data acquisition system saturated until t=0 s.
DPU-PRESLL	Pressurizer water level. Elevation difference between taps is 135 cm. Lower tap is 9 cm above pressurizer exit.	+127 cm water	+17.1 kPa	341, 342	
UPU-PR-4	Pressurizer bottom to Spool 4. Elevation difference between taps is 157 cm. Spool 4 tap is 140 cm below pressurizer exit.	+3447 kPa	+3456 kPa	343, 344	Tests S-28-7 and S-28-9 only. Detector saturated from t=0 to t=12 s.
<u>Broken Loop</u>					
DPB-21-1ANN	Cold leg Spool 21, 112 cm from vessel center, to vessel inlet annulus, 23 cm below cold leg centerline at 225°. Inlet annulus tap is 23 cm below Spool 21 tap.	+254 cm water	+33.6 kPa	345, 346 (Test S-28-7) 347, 348 (Test S-28-9) 349, 350 (Test S-28-12)	
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	351, 352	
DPB-CN1-24	Vessel-side nozzle throat, 245 cm from vessel center to Spool 24, 264 cm from vessel center.	+3447 kPa	+6961 kPa	353, 354	Tests S-28-7 and S-28-9 only.
DPB-30-43	Across entire broken loop hot leg including rupture assembly; hot leg Spool 30, 45 cm from vessel to cold leg Spool 43, 1006 cm from vessel center along hot leg.	+3447 kPa	+6973 kPa	355, 356	Overranged from t=0 to t=16 s.
DPB-32U-36L	Across simulated steam generator orifice assembly, hot leg Spool 32 upper tap, 189 cm from vessel center, to Spool 36 lower tap, 617 cm from vessel center. Spool 32 upper tap is 41 cm above Spool 36 lower tap.	+1379 kPa	+1388 kPa	357, 358	
DPB-36L-37	Across nozzle assembly. Spool 36 lower tap, 617 cm from vessel center along hot leg to Spool 37, 718 cm from vessel center along hot leg. Spool 37 tap is 102 cm below Spool 36 lower tap.	+345 kPa	+346 kPa	359, 360	
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	361, 362	
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	363, 364 365, 366 367, 368	Data acquisition system saturated from t=0 to t=1 s and intermittently from t=23 to t=30 s.
DPB-42-HN1	Spool 42 upstream of pump-side nozzle, 1057 cm from vessel center along hot leg to nozzle throat, 1066 cm from vessel center along hot leg.	+10 342 kPa	+13 843 kPa	369, 370	Tests S-28-7 and S-28-9 only.

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a,c]	Measurement Comments [b]
		Detector	Data Acquisition System		
Broken Loop (continued)					
DPB-HN1-43	Pump-side nozzle, nozzle throat 1066 cm from vessel center along hot leg to Spool 43, 1086 cm from vessel center along hot leg.	+3447 kPa	+6932 kPa	371, 372	Tests S-28-7 and S-28-9 only.
Vessel					
DPV-UP-1ANN	Upper plenum, 27 cm above cold leg centerline at 30° to inlet annulus, 22 cm below cold leg centerline at 225°. Elevation difference between taps is 40 cm.	+762 cm water	+102 kPa	373, 374 (Test S-28-7) 375, 376 (Test S-28-9) 377, 378 (Test S-28-12)	
DPV-0-9GQ	Inlet annulus cold leg centerline at 90°. Inlet annulus cold leg centerline at 225°. Elevation difference between taps is 23 cm.	+127 cm water	+18.4 kPa	379, 380 (Test S-28-7) 381, 382 (Test S-28-9) 383, 384 (Test S-28-12)	
DPV-9-26GQ	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	385, 386 (Test S-28-7) 387, 388 (Test S-28-9) 389, 390 (Test S-28-12)	
DPV-9-166Q	Inlet annulus, 23 cm below cold leg centerline at 225°, to lower plenum, 422 cm below cold leg centerline at 225°. Elevation difference between taps is 399 cm.	+762 cm water +1270 cm water	+101 kPa +167 kPa (Test S-28-12)	391, 392 (Test S-28-7) 393, 394 (Test S-28-9) 395, 396 (Test S-28-12)	
DPV-26-66QM	Across part of downcomer, 66 cm (225°) to 140 cm (180°), below cold leg centerline. Elevation difference between taps is 74 cm.	+127 cm water	+21.3 kPa	397, 398 (Test S-28-7) 399, 400 (Test S-28-9) 401, 402 (Test S-28-12)	
DPV-55-110MM	Across part of downcomer, 140 cm (180°) to 279 cm (180°), below cold leg centerline. Elevation difference between taps is 140 cm.	+254 cm water	+33.8 kPa	403, 404 (Test S-28-7) 405, 406 (Test S-28-9) 407, 408 (Test S-28-12)	
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	409, 410 (Test S-28-7) 411, 412 (Test S-28-9) 413, 414 (Test S-28-12)	
DPV-156-173QQ	Across part of lower plenum, 396 cm (225°) to 439 cm (225°), below cold leg centerline. Elevation difference between taps is 43 cm.	+51 cm water	+6.47 kPa	415, 416 (Test S-28-7) 417, 418 (Test S-28-9) 419, 420 (Test S-28-12)	
DPV-166Q+10	Lower plenum, 422 cm below cold leg centerline at 225° to upper plenum, 27 cm above cold leg centerline at 30°. Elevation difference between taps is 395 cm.	+762 cm water	+101 kPa	421, 422	
ECC SYSTEM					
DPV-ACC1-TB	Top to bottom of intact loop accumulator. Elevation difference between taps is 274 cm.	+762 cm water	+104 kPa	423, 424	
DPB-ACC2-TB	Top to bottom of broken loop accumulator. Elevation difference between taps is 213 cm.	+127 cm water	+17.35 kPa	425, 426	

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a,c]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Steam Generator</u>					
DPU-SG-SEC	Secondary side, differential pressure taps at 114 cm and 320 cm above bottom of tube sheet. Elevation difference between taps is 206 cm.	+254 cm water	+33.7 kPa	427, 428	
DPU-SG-DISC	Across venturi tube, 168 cm downstream from steam generator discharge.	+1270 cm water	+170 kPa	429, 430	
<u>Steam Generator Rupture System</u>					
DPU-SGS-6	From instrumented spool piece in simulated tube rupture injection line to hot leg Spool 6, 318 cm from vessel center.	+6895 kPa	+9230 kPa	431, 432	
DPU-SGS-TB	Top to bottom of steam generator rupture system accumulator tank.	+1270 cm water	+108 kPa	433, 434	
<u>Pressure Suppression System</u>					
DP-PSS-TB	Top to bottom of pressure suppression tank. Elevation difference between taps is 338 cm.	+762 cm water	+103 kPa (Test S-28-7) +115 kPa (Test S-28-9)	435, 436	Tests S-28-7 and S-28-9 only.
VOLUMETRIC FLOW RATE	Turbine flowmeter, bidirectional.				Data acquisition system range may exceed rated detector range; however, turbine response is linear to flow rates well beyond the rated range.
<u>Intact Loop</u>					
FTU-1	Hot leg, Spool 1, 42 cm from vessel center.	+1.26 to +25.2 ϵ/s	+0 to 75.7 ϵ/s	437, 438	Detector failed for Test S-28-12.
FTU-9	Cold leg, Spool 9, 393 cm from vessel center.	+5.05 to +50.5 ϵ/s	+75.7 ϵ/s	439, 440 (Test S-28-7) 441, 442 (Test S-28-9) 443, 444 (Test S-28-12)	
FTU-13	Cold leg, Spool 13, 163 cm from vessel center.	+1.26 to +50.5 ϵ/s	+75.7 ϵ/s	445, 446	Test S-28-12 only.
FTU-15	Cold leg, Spool 15, 42 cm from vessel center.	+1.26 to +50.5 ϵ/s	+63.1 ϵ/s	447, 448 (Test S-28-7) 449, 450 (Test S-28-9) 451, 452 (Test S-28-12)	
<u>Broken Loop</u>					
FTB-21	Cold leg, Spool 21, 146 cm from vessel center; 3-in. pipe.	+1.26 to +25.2 ϵ/s	+75.7 ϵ/s	453, 454 (Test S-28-7) 455, 456 (Test S-28-9) 457, 458 (Test S-28-12)	
FTB-30	Hot leg, Spool 30, 63 cm from vessel center; 3-in. pipe.	+1.26 to +25.2 ϵ/s	+50.5 ϵ/s	459, 460	
FTB-37	Cold leg, Spool 37, 739 cm from vessel center along hot leg; 2-in. pipe.	+1.26 to +12.6 ϵ/s	+50.5 ϵ/s	461, 462	
<u>Core</u>					
FTV-CORE-IN	Entrance to core, 401 cm below cold leg centerline.	+1.26 to +12.6 ϵ/s	+69.4 ϵ/s	463, 464 (Test S-28-7) 465, 466 (Test S-28-9) 467, 468 (Test S-28-12)	Data acquisition system saturated near t=65 s for Tests S-28-9 and S-28-12.
<u>ECU System</u>					
FTU-HPIS	In line immediately after HPIS pump for intact loop, 1/2-in. line.	+0.047 to +0.47 ϵ/s	+0.315 ϵ/s	469, 470	Detector failed for Test S-28-12.

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>ECC System (continued)</u>					
FTB-HPIS	In line immediately after HPIS pump for broken loop, 1/2-in. line.	+0.0126 to +0.63 t/s	+0.315 t/s	471, 472 (Test S-28-7) 473, 474 (Test S-28-9) 475, 476 (Test S-28-12)	
FTU-LPIS	In line leading from LPIS pump for intact loop, 1/2-in.	+0.047 to +0.47 t/s	+0.0315 t/s	477, 478	Data acquisition system saturated at t=0 s, t=2.5 s, t=11 s, and t=26 s for Test S-28-7. Data acquisition system saturated at t=3 s and t=26 s for Test S-28-9. Data acquisition system saturated at t=0 s, t=12 s and t=26 s for Test S-28-12.
FTU-LPIS	In line leading from LPIS pump for broken loop, 3/4-in. line.	+0.047 to +0.47 t/s	+0.126 t/s	479, 480	
FTU-ACC1	In line leading from intact loop accumulator, 1-in. line.	+0.315 to +3.15 t/s	+4.42 t/s	481, 482	Data acquisition system saturated intermittently from t=70 to t=90 s.
FTB-ACC2	In line leading from broken loop accumulator, 1-in. line.	+0.126 to +1.26 t/s	+1.39 t/s	483, 484	Data acquisition system saturated from t=30 to t=50 s.
<u>Steam Generator</u>					
FTU-SGFW	Steam generator feedwater line.	+0.126 to +1.26 t/s	+1.26 t/s	485, 486	Test S-28-7 only. Detector failed for Test S-28-9.
<u>Steam Generator Rupture System</u>					
FTU-SGS	In simulated tube rupture injection line.	+0.126 to +0.631 t/s	+1.89 t/s	487, 488	Data acquisition system saturated from t=445 to t=460 s for Test S-28-9.
<u>Pressurizer</u>					
FTU-PRIZE	Surge line.	+0.315 to +3.15 t/s	+6.31 t/s	489, 490	Detector failed for Test S-28-12.
FLUID VELOCITY	Turbine flowmeter, bidirectional.				Detector failed for Test S-28-7.
<u>Downcomer</u>					
FTV-40A	102 cm below cold leg centerline, 0°.	+0.762 to +15.24 m/s	+15.24 m/s	491, 492 (Test S-28-9) 493, 494 (Test S-28-12)	Data acquisition system saturated intermittently from t=27 to t=38 s for Test S-28-9, and from t=26 to t=65 s for Test S-28-12.
FTV-40M	102 cm below cold leg centerline,	+0.762 to +15.24 m/s	+15.24 m/s	495, 496 (Test S-28-7) 497, 498 (Test S-28-9) 499, 500 (Test S-28-12)	Data acquisition system saturated intermittently from t=27 to t=38 s for Test S-28-7, and near t=28 s for Test S-28-9.
MOMENTUM FLUX	Drag disc, bidirectional.				Momentum flux reported only for -6 to 42 s, except as noted. Drag disc data may exhibit significant temperature dependence. Drag disc should be used only for short-term transient response.
<u>Intact Loop</u>					
FDU-1	Hot leg, Spool 1, 60 cm from vessel center; target size 2.22 cm.	+298 to +117 113 kg/m-s ²	+176 090 kg/m-s ²	501	Detector failed for Test S-28-9.
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	502	Detector saturated to t=15 s.
FDU-10	Cold leg, Spool 10, 240 cm from vessel center; target size 2.22 cm.	+298 to +161 760 kg/m-s ²	+16 740 kg/m-s ²	503	
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	504	
<u>Broken Loop</u>					
FDB-21	Cold leg, Spool 21, 134 cm from vessel center, 3-in. pipe; target size 1.67 cm.	+298 to +104 915 kg/m-s ²	+66 774 kg/m-s ²	505	
FDB-23	Cold leg, Spool 23, 238 cm from vessel center, upstream of vessel side nozzle, 2-in. pipe; target size 1.03 cm.	+298 to +180 067 kg/m-s ²	+155 319 kg/m-s ²	506	Detector saturated from t=0 to t=2 s.

TABLE V (continued)

Measurement	Location and Comments [a]	Range [a]		Figure [a,c]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Broken Loop (continued)</u>					
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	507	Questionable data, transducer was mounted horizontally and possibly 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	508 509 510	Questionable data, transducer was mounted horizontally and possibly 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	+165 320 kg/m-s ²	511	
<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	512	
<u>DENSITY</u>					
<u>Intact Loop</u>					
		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GU-1T GU-1B GU-1C	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.			513, 514 515, 516 517, 518	
GU-5VR	Hot leg, Spool 5, 246 cm from vessel center, vertical.			519, 520	
GU-10VR	Cold leg, Spool 10, 359 cm from vessel center, vertical.			521, 522	
GU-13VR	Cold leg, Spool 13, 142 cm from vessel center, vertical.			523, 524 (Test S-28-7) 525, 526 (Test S-28-9) 527, 528 (Test S-28-12)	
GU-15T GU-15B GU-15C	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.			529, 530 (Test S-28-7) 531, 532 (Test S-28-9) 533, 534 (Test S-28-12) 535, 536 (Test S-28-7) 537, 538 (Test S-28-9) 539, 540 (Test S-28-12) 541, 542 (Test S-28-7) 543, 544 (Test S-28-9) 545, 546 (Test S-28-12)	Data values above 1000 kg/m ³ do not reflect actual system density and were the result of detector photo-multiplier tube nonlinearity.
<u>Broken Loop</u>					
		1.6 to 1600 kg/m ³	0 to 1600 kg/m ³		
GB-21T GB-21B GB-21C	Cold leg, Spool 21, 123 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.			547, 548 (Test S-28-7) 549, 550 (Test S-28-9) 551, 552 (Test S-28-12) 553, 554 (Test S-28-7) 555, 556 (Test S-28-9) 557, 558 (Test S-28-12) 559, 560 (Test S-28-7) 561, 562 (Test S-28-9) 563, 564 (Test S-28-12)	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
Broken Loop (continued)					
GB-23VR	Cold leg, Spool 23, 235 cm from vessel center, vertical.			565, 566 (Test S-28-9) 567, 568 (Test S-28-12)	Detector failed for Test S-28-7.
GB-30T GB-30B GB-30C	Hot leg, Spool 30, 49 cm from vessel center. T (top) ranges 270 to 360°. B (bottom) ranges 30 to 330°. C, mathematical composite of T and B.			569, 570 571, 572 573, 574	
GB-37HZ	Cold leg, Spool 37, 711 cm from vessel center along hot leg, across vertical pipe, simulated steam generator discharge.			575, 576	
GB-42VR	Cold leg, Spool 42, 1057 cm from vessel center along hot leg, vertical.			577, 578	
Vessel		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°.			579, 580	
GVLP-165HZ	Upper part of lower plenum, 419 cm below cold leg centerline, 4.379 cm below downcomer exit, horizontal 0 to 180°.			581, 582 (Test S-28-7) 583, 584 (Test S-28-9) 585, 586 (Test S-28-12)	Data values above 1000 kg/m ³ do not reflect actual system density and were the result of detector photomultiplier tube nonlinearity.
GVLP-172HZ	Lower Plenum, 437 cm below cold leg centerline, 22 cm below downcomer exit, horizontal, 90 to 270°.			587, 588 (Test S-28-7) 589, 590 (Test S-28-9) 591, 592 (Test S-28-12)	
Pressurizer					
GU-PRIZE	Surge line.	1.6 to 1600 kg/m ³	0 to 1600 kg/m ³	593, 594 (Test S-28-7) 595, 596 (Test S-28-9) 597, 598 (Test S-28-12)	
MASS FLOW RATE	Mass flow rate obtained by combining density (gamma attenuation technique) with volumetric flow rate (turbine flowmeter) or momentum flux (drag disc).	Range for mass flow is determined from range of individual detectors used in calculation.			Mass flow rate reported only for -6 to 42 s, except as noted; see comments on individual detectors.
Intact Loop					
FDU-1, GU-1C FTU-1, GU-1C	Hot leg, Spool 1.			599 600, 601	Detector FDU-1 failed for Test S-28-9. Detector FTU-1 failed for Test S-28-12.
FDU-5, GU-5VR	Hot leg, Spool 5.			602	Data acquisition system saturated to t=1.5 s.
FTU-9, GU-10VR	Cold leg, Spool 9.			603, 604	
FTU-10, GU-10VR	Cold leg, Spool 10.			605	
FDU-13, GU-13VR FTU-13, GU-13VR	Cold leg, Spool 13.			606 607, 608	
FTU-15, GU-15C	Cold leg, Spool 15.			609, 610	Data values above 1000 kg/m ³ for GU-15C do not reflect actual system density and were the result of detector photomultiplier tube nonlinearity.
Broken Loop					
FDB-21, GB-21C FTB-21, GB-21C	Cold leg, Spool 21.			611 612, 613	
FDB-23, GB-23VR	Cold leg, Spool 23.			614	FDB-23 saturated from t=0 to t=2 s. GB-23VR failed for Test S-28-7.
FDB-30, GB-30C FTB-30, GB-30C	Hot leg, Spool 30.			615 616, 617	Questionable data for FDB-30, transducer was mounted horizontally and possibly filled with cold water.
FDB-37, GB-37HZ FTB-37, GB-37HZ	Cold leg, Spool 37.			618 619, 620	Questionable data for FDB-37, transducer was mounted horizontally and possibly filled with cold water.
FDB-42, GB-42VR	Cold leg, Spool 42.			621	

TABLE V (continued)

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a,c]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
<u>Vessel</u>					
FDV-CORE-IN GV-COR-150HZ	Entrance to core.			622, 623 624, 625 626, 627	
FTV-CORE-IN GV-COR-150HZ	Entrance to core.			628, 629	Data acquisition system saturated near t=65 s for Tests S-28-9 and S-28-12.
<u>Pressurizer</u>					
FTU-PRIZE GU-PRIZE	Pressurizer surge line.			630, 631 632, 633	FTU-PRIZE failed for Test S-28-12.
CORE CHARACTERISTICS					
PWRCOR T-1	Core power.	0 to 1600 kW	0 to 2047 kW	634, 635	
PWRCOR T-2	Core power.	0 to 1600 kW	0 to 2563 kW	636, 637	
VOLTCOR-T	Core voltage.		0 to 200 Vdc	638, 639	
AMPCOR-t	Core current.	0 to 10 000 A	0 to 9645 A	640, 641	
PUMP CHARACTERISTICS					
PUMPU-RPM	Pump speed.	0 to 3600 rpm	0 to 3600 rpm	642, 643	

[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.

[c] Data on figures generally apply to all three tests (S-28-7, S-28-9, and S-28-12) except as noted.

Fig. 9 Fluid temperature in intact loop hot leg (TFU-1), from -20 to 600 s.

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

Fig. 11 Fluid temperature in intact loop hot leg (RBU-2), from -20 to 600 s.

Fig. 12 Fluid temperature in intact loop hot leg (RBU-2), from -6 to 42 s.

Fig. 13 Fluid temperature in intact loop hot leg (TFU-6), from -20 to 600 s.

Fig. 14 Fluid temperature in intact loop hot leg (TFU-6), from -6 to 42 s.

Fig. 15 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-7), from -20 to 600 s.

Fig. 16 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-7), from -6 to 42 s.

Fig. 17 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-7), from -20 to 600 s.

Fig. 18 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-7), from -6 to 42 s.

Fig. 19 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-7), from -20 to 600 s.

Fig. 20 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-7), from -6 to 42 s.

Fig. 21 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-10), from -20 to 600 s.

Fig. 22 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-10), from -6 to 42 s.

Fig. 23 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-10), from -20 to 600 s.

Fig. 24 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-10), from -6 to 42 s.

Fig. 25 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-10), from -20 to 600 s.

Fig. 26 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-10), from -6 to 42 s.

Fig. 27 Fluid temperature in intact loop cold leg, Test S-28-7 (RBU-14A), from -20 to 600 s.

Fig. 28 Fluid temperature in intact loop cold leg, Test S-28-7 (RBU-14A), from -6 to 42 s.

Fig. 29 Fluid temperature in intact loop cold leg, Test S-28-9 (RBU-14A), from -20 to 600 s.

Fig. 30 Fluid temperature in intact loop cold leg, Test S-28-9 (RBU-14A), from -6 to 42 s.

Fig. 31 Fluid temperature in intact loop cold leg, Test S-28-12 (RBU-14A), from -20 to 600 s.

Fig. 32 Fluid temperature in intact loop cold leg, Test S-28-12 (RBU-14A), from -6 to 42 s:

Fig. 33 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-14B), from -20 to 600 s.

Fig. 34 Fluid temperature in intact loop cold leg, Test S-28-7 (TFU-14B), from -6 to 42 s.

Fig. 35 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-14B), from -20 to 600 s.

Fig. 36 Fluid temperature in intact loop cold leg, Test S-28-9 (TFU-14B), from -6 to 42 s.

Fig. 37 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-14B), from -20 to 600 s.

Fig. 38 Fluid temperature in intact loop cold leg, Test S-28-12 (TFU-14B), from -6 to 42 s.

Fig. 39 Fluid temperature in intact loop (TFU-15), from -20 to 600 s.

Fig. 40 Fluid temperature in intact loop (TFU-15), from -6 to 42 s.

Fig. 41 Fluid temperature in broken loop, vessel side (TFB-20), from -20 to 600 s.

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

Fig. 43 Fluid temperature in broken loop cold-leg (TFB-23), from -20 to 600 s.

Fig. 44 Fluid temperature in broken loop cold leg (TFB-23), from -6 to 42 s.

Fig. 45 Fluid temperature in broken loop, pump side (TFB-30) from -20 to 600 s.

Fig. 46 Fluid temperature in broken loop, pump side (TFB-30), from -6 to 42 s.

Fig. 47 Fluid temperature in broken loop, pump side (TFB-37), from -20 to 600 s.

Fig. 48 Fluid temperature in broken loop, pump side (TFB-37), from -6 to 42 s.

Fig. 49 Fluid temperature in broken loop, pump side, Test S-28-7 (TFB-42), from -20 to 600 s.

Fig. 50 Fluid temperature in broken loop, pump side, Test S-28-7 (TFB-42), from -6 to 42 s.

Fig. 51 Fluid temperature in broken loop, pump side, Test S-28-9 (TFB-42), from -20 to 600 s.

Fig. 52 Fluid temperature in broken loop, pump side, Test S-28-9 (TFB-42), from -6 to 42 s.

Fig. 53 Fluid temperature in broken loop, pump side, Test S-28-12 (TFB-42), from -20 to 600 s.

Fig. 54 Fluid temperature in broken loop, pump side, Test S-28-12 (TFB-42), from -6 to 42 s.

Fig. 55 Fluid temperature in inlet annulus, Tests S-28-7 and S-28-9 (TFV-ANN-4A), from -20 to 600 s.

Fig. 56 Fluid temperature in inlet annulus, Tests S-28-7 and S-28-9 (TFV-ANN-4A), from -6 to 42 s.

Fig. 57 Fluid temperature in inlet annulus (TFV-ANN-4M), from -20 to 600 s.

Fig. 58 Fluid temperature in inlet annulus (TFV-ANN-4M), from -6 to 42 s.

Fig. 59 Fluid temperature in downcomer annulus (TFV-ANN-35A), from -20 to 600 s.

Fig. 60 Fluid temperature in downcomer annulus (TFV-ANN-35A), from -6 to 42 s.

Fig. 61 Fluid temperature in downcomer annulus (TFV-ANN-70A), from -20 to 600 s.

Fig. 62 Fluid temperature in downcomer annulus (TFV-ANN-70A), from -6 to 42 s.

Fig. 63 Fluid temperature in downcomer annulus (TFV-ANN-115A), from -20 to 600 s.

Fig. 64 Fluid temperature in downcomer annulus (TFV-ANN-115A), from -6 to 42 s.

Fig. 65 Fluid temperature in downcomer annulus, Tests S-28-7 and S-28-9 (TFV-ANN-156A), from -20 to 600 s.

Fig. 66 Fluid temperature in downcomer annulus, Tests S-28-7 and S-28-9 (TFV-ANN-156A), from -6 to 42 s.

Fig. 67 Fluid temperature in upper plenum, Test S-28-7 (TFV-UP+13), from -20 to 600 s.

Fig. 68 Fluid temperature in upper plenum, Test S-28-7 (TFV-UP+13), from -6 to 42 s.

Fig. 69 Fluid temperature in upper plenum, Test S-28-9 (TFV-UP+13), from -20 to 600 s.

Fig. 70 Fluid temperature in upper plenum, Test S-28-9 (TFV-UP+13), from -6 to 42 s.

Fig 71 Fluid temperature in upper plenum, Test S-28-12 (TFV-UP+13), from -20 to 600 s.

Fig. 72 Fluid temperature in upper plenum, Test S-28-12 (TFV-UP+13), from -6 to 42 s.

Fig. 73 Fluid temperature in lower plenum (TFV-LP-2), from -20 to 600 s.

Fig. 74 Fluid temperature in lower plenum (TFV-LP-2), from -6 to 42 s.

Fig. 75 Fluid temperature in lower plenum (TFV-LP-4), from -20 to 600 s.

Fig. 76 Fluid temperature in lower plenum (TFV-LP-4), from -6 to 42 s.

Fig. 77 Fluid temperature in lower plenum (TFV-LP-7), from -20 to 600 s.

Fig. 78 Fluid temperature in lower plenum (TFV-LP-7), from -6 to 42 s.

Fig. 79 Fluid temperature in core inlet (TFV-CORE-IN), from -20 to 600 s.

Fig. 80 Fluid temperature in core inlet (TFV-CORE-IN), from -6 to 42 s.

Fig. 81 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45), from -20 to 600 s.

Fig. 82 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45), from -6 to 42 s.

Fig. 83 Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45), from -20 to 600 s.

Fig. 84 Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45), from -6 to 42 s.

Fig. 85 Fluid temperature in core, Grid Spacer 10 (TFG-10AB-45), from -20 to 600 s.

Fig. 86 Fluid temperature in core, Grid Spacer 10 (TFG-10AB-45), from -6 to 42 s.

Fig. 87 Fluid temperature in intact loop coolant injection line (TFU-ECC-14), from -20 to 600 s.

Fig. 88 Fluid temperature in intact loop coolant injection line (TFU-ECC-14), from -6 to 42 s.

Fig. 89 Fluid temperature in broken loop coolant injection line (TFB-ECC-42), from -20 to 600 s.

Fig. 90 Fluid temperature in broken loop coolant injection line (TFB-ECC-42), from -6 to 42 s.

Fig. 91 Fluid temperature in steam generator feedwater line, Test S-28-7 (TFU-SGFW), from -20 to 600 s.

Fig. 92 Fluid temperature in steam generator feedwater line, Test S-28-7 (TFU-SGFW), from -6 to 42 s.

Fig. 93 Fluid temperature in steam generator feedwater line, Test S-28-9 (TFU-SGFW), from -20 to 600 s.

Fig. 94 Fluid temperature in steam generator feedwater line, Test S-28-9 (TFU-SGFW), from -6 to 42 s.

Fig. 95 Fluid temperature in steam generator feedwater line, Test S-28-12 (TFU-SGFW), from -20 to 600 s.

Fig. 96 Fluid temperature in steam generator feedwater line, Test S-28-12 (TFU-SGFW), from -6 to 42 s.

Fig. 97 Fluid temperature in steam generator steam dome (TFU-SGSD), from -20 to 600 s.

Fig. 98 Fluid temperature in steam generator steam dome (TFU-SGSD), from -6 to 42 s.

Fig. 99 Fluid temperature in steam generator secondary side (TFU-SG1), from -20 to 600 s.

Fig. 100 Fluid temperature in steam generator secondary side (TFU-SG1), from -6 to 42 s.

Fig. 101 Fluid temperature in steam generator secondary side (TFU-SG2), from -20 to 600 s.

Fig. 102 Fluid temperature in steam generator secondary side (TFU-SG2), from -6 to 42 s.

Fig. 103 Fluid temperature in steam generator secondary side (TFU-SG3), from -20 to 600 s.

Fig. 104 Fluid temperature in steam generator secondary side (TFU-SG3), from -6 to 42 s.

Fig. 105 Fluid temperature in tube rupture simulation accumulator (TFU-SGS3), from -20 to 600 s.

Fig. 106 Fluid temperature in tube rupture simulation accumulator (TFU-SGS3), from -6 to 42 s.

Fig. 107 Fluid temperature in steam generator (TFU-SGS), from -20 to 600 s.

Fig. 108 Fluid temperature in steam generator (TFU-SGS), from -6 to 42 s.

Fig. 109 Fluid temperature in steam generator (TFU-SGS-D), from -20 to 600 s.

Fig. 110 Fluid temperature in steam generator (TFU-SGS-D), from -6 to 42 s.

Fig. 111 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -20 to 600 s.

Fig. 112 Fluid temperature in pressurizer surge line (TFU-PRIZE), from -6 to 42 s.

Fig. 113 Fluid temperature in pressure suppression tank, Test S-28-7 (TF-PSS-33), from -20 to 600 s.

Fig. 114 Fluid temperature in pressure suppression tank, Test S-28-7 (TF-PSS-33), from -6 to 42 s.

Fig. 115 Fluid temperature in pressure suppression tank, Test S-28-9 (TF-PSS-33), from -20 to 600 s.

Fig. 116 Fluid temperature in pressure suppression tank, Test S-28-9 (TF-PSS-33), from -6 to 42 s.

Fig. 117 Fluid temperature in pressure suppression tank, Test S-28-12 (TF-PSS-33), from -20 to 600 s.

Fig. 118 Fluid temperature in pressure suppression tank, Test S-28-12 (TF-PSS-33), from -6 to 42 s.

Fig. 119 Fluid temperature in pressure suppression tank, Tests S-28-7 and S-28-9 (TF-PSS-130), from -20 to 600 s.

Fig. 120 Fluid temperature in pressure suppression tank, Tests S-28-7 and S-28-9 (TF-PSS-130), from -6 to 42 s.

Fig. 121 Material temperature in intact loop (TMU-1T16), from -20 to 600 s.

Fig. 122 Material temperature in intact loop (TMU-1T16), from -6 to 42 s.

Fig. 123 Material temperature in intact loop, Tests S-28-7 and S-28-9 (TMB-20B16), from -20 to 600 s.

Fig. 124 Material temperature in intact loop, Tests S-28-7 and S-28-9 (TMB-20B16), from -6 to 42 s.

Fig. 125 Material temperature in vessel filler (TMV-FI-115A), from -20 to 600 s.

Fig. 126 Material temperature in vessel filler (TMV-FI-115A), from -6 to 42 s.

Fig. 127 Material temperature in vessel filler (TMV-FI-156A), from -20 to 600 s.

Fig. 128 Material temperature in vessel filler (TMV-FI-156A), from -6 to 42 s.

Fig. 129 Material temperature in vessel filler (TMV-F0-156A), from -20 to 600 s.

Fig. 130 Material temperature in vessel filler (TMV-F0-156A), from -6 to 42 s.

Fig. 131 Material temperature in vessel filler insulator (TIV-FO-35A), from -20 to 600 s.

Fig. 132 Material temperature in vessel filler insulator (TIV-FO-35A), from -6 to 42 s.

Fig. 133 Material temperature in vessel filler insulator (TIV-F0-115A), from -20 to 600 s.

Fig. 134 Material temperature in vessel filler insulator (TIV-F0-115A), from -6 to 42 s.

Fig. 135 Material temperature in core barrel inner diameter, Tests S-28-7 and S-28-9 (TMV-CI-70A), from -20 to 600 s.

Fig. 136 Material temperature in core barrel inner diameter, Tests S-28-7 and S-28-9 (TMV-CI-70A), from -6 to 42 s.

Fig. 137 Material temperature in core barrel outer diameter, Tests S-28-7 and S-28-9 (TMV-CO-70A), from -20 to 600 s.

Fig. 138 Material temperature in core barrel outer diameter, Tests S-28-7 and S-28-9 (TMV-CO-70A), from -6 to 42 s.

Fig. 139 Material temperature in core barrel outer diameter (TMV-CO-115A), from -20 to 600 s.

Fig. 140 Material temperature in core barrel outer diameter (TMV-CO-115A), from -6 to 42 s.

Fig. 141 Material temperature in core housing filler (TMV-HF-115W), from -20 to 600 s.

Fig. 142 Material temperature in core housing filler (TMV-HF-115W), from -6 to 42 s.

Fig. 143 Material temperature in core housing filler, Tests S-28-7 and S-28-9 (TMV-HF-127W), from -20 to 600 s.

Fig. 144 Material temperature in core housing filler, Tests S-28-7 and S-28-9 (TMV-HF-127W), from -6 to 42 s.

Fig. 145 Material temperature in core housing filler, Tests S-28-7 and S-28-9 (TMV-HF-138W), from -20 to 600 s.

Fig. 146 Material temperature in core housing filler, Tests S-28-7 and S-28-9 (TMV-HF-138W), from -6 to 42 s.

Fig. 147 Material temperature in steam generator (TMU-SG1), from -20 to 600 s.

Fig. 148 Material temperature in steam generator (TMU-SG1), from -6 to 42 s.

Fig. 149 Material temperature in steam generator (TMU-SG2), from -20 to 600 s.

Fig. 150 Material temperature in steam generator (TMU-SG2), from -6 to 42 s.

Fig. 151 Material temperature in steam generator (TMU-SG3), from -20 to 600 s.

Fig. 152 Material temperature in steam generator (TMU-SG3), from -6 to 42 s.

Fig. 153 Core heater temperature, Rod D-4 (TH-D4-14), from -20 to 600 s.

Fig. 154 Core heater temperature, Rod D-4 (TH-D4-14), from -6 to 42 s.

Fig. 155 Core heater temperature, Rod D-4 (TH-D4-29), from -20 to 600 s.

Fig. 156 Core heater temperature, Rod D-4 (TH-D4-29), from -6 to 42 s.

Fig. 157 Core heater temperature, Rod D-5 (TH-D5-29), from -20 to 600 s.

Fig. 158 Core heater temperature, Rod D-5 (TH-D5-29), from -6 to 42 s.

Fig. 159 Core heater temperature, Rod E-4 (TH-E4-09), from -20 to 600 s.

Fig. 160 Core heater temperature, Rod E-4 (TH-E4-09), from -6 to 42 s.

Fig. 161 Core heater temperature, Rod E-4 (TH-E4-27), from -20 to 600 s.

Fig. 162 Core heater temperature, Rod E-4 (TH-E4-27), from -6 to 42 s.

Fig. 163 Core heater temperature, Rod E-4 (TH-E4-55), from -20 to 600 s.

Fig. 164 Core heater temperature, Rod E-4 (TH-E4-55), from -6 to 42 s.

Fig. 165 Core heater temperature, Rod E-5 (TH-E5-20), from -20 to 600 s.

Fig. 166 Core heater temperature, Rod E-5 (TH-E5-20), from -6 to 42 s.

Fig. 167 Core heater temperature, Rod E-5 (TH-E5-25), from -20 to 600 s.

Fig. 168 Core heater temperature, Rod E-5 (TH-E5-25), from -6 to 42 s.

Fig. 169 Core heater temperature, Rod A-4 (TH-A4-09), from -20 to 600 s.

Fig. 170 Core heater temperature, Rod A-4 (TH-A4-09), from -6 to 42 s.

Fig. 171 Core heater temperature, Rod A-4 (TH-A4-29), from -20 to 600 s.

Fig. 172 Core heater temperature, Rod A-4 (TH-A4-29), from -6 to 42 s.

Fig. 173 Core heater temperature, Rod A-4 (TH-A4-39), from -20 to 600 s.

Fig. 174 Core heater temperature, Rod A-4 (TH-A4-39), from -6 to 42 s.

Fig. 175 Core heater temperature, Rod A-5 (TH-A5-29), from -20 to 600 s.

Fig. 176 Core heater temperature, Rod A-5 (TH-A5-29), from -6 to 42 s.

Fig. 177 Core heater temperature, Rod A-5 (TH-A5-45), from -20 to 600 s.

Fig. 178 Core heater temperature, Rod A-5 (TH-A5-45), from -6 to 42 s.

Fig. 179 Core heater temperature, Rod B-3 (TH-B3-32), from -20 to 600 s.

Fig. 180 Core heater temperature, Rod B-3 (TH-B3-32), from -6 to 42 s.

Fig. 181 Core heater temperature, Rod B-5 (TH-B5-29), from -20 to 600 s.

Fig. 182 Core heater temperature, Rod B-5 (TH-B5-29), from -6 to 42 s.

Fig. 183 Core heater temperature, Rod B-5 (TH-B5-33), from -20 to 600 s.

Fig. 184 Core heater temperature, Rod B-5 (TH-B5-33), from -6 to 42 s.

Fig. 185 Core heater temperature, Rod B-6 (TH-B6-29), from -20 to 600 s.

Fig. 186 Core heater temperature, Rod B-6 (TH-B6-29), from -6 to 42 s.

Fig. 187 Core heater temperature, Rod C-2 (TH-C2-38), from -20 to 600 s.

Fig. 188 Core heater temperature, Rod C-2 (TH-C2-38), from -6 to 42 s.

Fig. 189 Core heater temperature, Rod C-4 (TH-C4-20), from -20 to 600 s.

Fig. 190 Core heater temperature, Rod C-4 (TH-C4-20), from -6 to 42 s.

Fig. 191 Core heater temperature, Rod C-4 (TH-C4-26), from -20 to 600 s.

Fig. 192 Core heater temperature, Rod C-4 (TH-C4-26), from -6 to 42 s.

Fig. 193 Core heater temperature, Rod C-4 (TH-C4-53), from -20 to 600 s.

Fig. 194 Core heater temperature, Rod C-4 (TH-C4-53), from -6 to 42 s.

Fig. 195 Core heater temperature, Rod C-5 (TH-C5-28), from -20 to 600 s.

Fig. 196 Core heater temperature, Rod C-5 (TH-C5-28), from -6 to 42 s.

Fig. 197 Core heater temperature, Rod C-6 (TH-C6-53), from -20 to 600 s.

Fig. 198 Core heater temperature, Rod C-6 (TH-C6-53), from -6 to 42 s.

Fig. 199 Core heater temperature, Rod C-7 (TH-C7-07), from -20 to 600 s.

Fig. 200 Core heater temperature, Rod C-7 (TH-C7-07), from -6 to 42 s.

Fig. 201 Core heater temperature, Rod C-7 (TH-C7-15), from -20 to 600 s.

Fig. 202 Core heater temperature, Rod C-7 (TH-C7-15), from -6 to 42 s.

Fig. 203 Core heater temperature, Rod D-1 (TH-D1-21), from -20 to 600 s.

Fig. 204 Core heater temperature, Rod D-1 (TH-D1-21), from -6 to 42 s.

Fig. 205 Core heater temperature, Rod D-2 (TH-D2-14), from -20 to 600 s.

Fig. 206 Core heater temperature, Rod D-2 (TH-D2-14), from -6 to 42 s.

Fig. 207 Core heater temperature, Rod D-2 (TH-D2-61), from -20 to 600 s.

Fig. 208 Core heater temperature, Rod D-2 (TH-D2-61), from -6 to 42 s.

Fig. 209 Core heater temperature, Rod D-3 (TH-D3-29), from -20 to 600 s.

Fig. 210 Core heater temperature, Rod D-3 (TH-D3-29), from -6 to 42 s.

Fig. 211 Core heater temperature, Rod D-3 (TH-D3-39), from -20 to 600 s.

Fig. 212 Core heater temperature, Rod D-3 (TH-D3-39), from -6 to 42 s.

Fig. 213 Core heater temperature, Rod D-6 (TH-D6-25), from -20 to 600 s.

Fig. 214 Core heater temperature, Rod D-6 (TH-D6-25), from -6 to 42 s.

Fig. 215 Core heater temperature, Rod D-7 (TH-D7-20), from -20 to 600 s.

Fig. 216 Core heater temperature, Rod D-7 (TH-D7-20), from -6 to 42 s.

Fig. 217 Core heater temperature, Rod D-8 (TH-D8-26), from -20 to 600 s.

Fig. 218 Core heater temperature, Rod D-8 (TH-D8-26), from -6 to 42 s.

Fig. 219 Core heater temperature, Rod E-1 (TH-E1-33), from -20 to 600 s.

Fig. 220 Core heater temperature, Rod E-1 (TH-E1-33), from -6 to 42 s.

Fig. 221 Core heater temperature, Rod E-2 (TH-E2-33), from -20 to 600 s.

Fig. 222 Core heater temperature, Rod E-2 (TH-E2-33), from -6 to 42 s.

Fig. 223 Core heater temperature, Rod E-3 (TH-E3-05), from -20 to 600 s.

Fig. 224 Core heater temperature, Rod E-3 (TH-E3-05), from -6 to 42 s.

Fig. 225 Core heater temperature, Rod E-3 (TH-E3-20), from -20 to 600 s.

Fig. 226 Core heater temperature, Rod E-3 (TH-E3-20), from -6 to 43 s.

Fig. 227 Core heater temperature, Rod E-3 (TH-E3-24), from -20 to 600 s.

Fig. 228 Core heater temperature, Rod E-3 (TH-E3-24), from -6 to 42 s.

Fig. 229 Core heater temperature, Rod E-6 (TH-E6-08), from -20 to 600 s.

Fig. 230 Core heater temperature, Rod E-6 (TH-E6-08), from -6 to 42 s.

Fig. 231 Core heater temperature, Rod E-6 (TH-E6-28), from -20 to 600 s.

Fig. 232 Core heater temperature, Rod E-6 (TH-E6-28), from -6 to 42 s.

Fig. 233 Core heater temperature, Rod E-6 (TH-E6-37), from -20 to 600 s.

Fig. 234 Core heater temperature, Rod E-6 (TH-E6-37), from -6 to 42 s.

Fig. 235 Core heater temperature, Rod E-7 (TH-E7-44), from -20 to 600 s.

Fig. 236 Core heater temperature, Rod E-7 (TH-E7-44), from -6 to 42 s.

Fig. 237 Core heater temperature, Rod E-8 (TH-E8-14), from -20 to 600 s.

Fig. 238 Core heater temperature, Rod E-8 (TH-E8-14), from -6 to 42 s.

Fig. 239 Core heater temperature, Rod E-8 (TH-E8-29), from -20 to 600 s.

Fig. 240 Core heater temperature, Rod E-8 (TH-E8-29), from -6 to 42 s.

Fig. 241 Core heater temperature, Rod F-2 (TH-F2-07), from -20 to 600 s.

Fig. 242 Core heater temperature, Rod F-2 (TH-F2-07), from -6 to 42 s.

Fig. 243 Core heater temperature, Rod F-2 (TH-F2-22), from -20 to 600 s.

Fig. 244 Core heater temperature, Rod F-2 (TH-F2-22), from -6 to 42 s.

Fig. 245 Core heater temperature, Rod F-2 (TH-F2-25), from -20 to 600 s.

Fig. 246 Core heater temperature, Rod F-2 (TH-F2-25), from -6 to 42 s.

Fig. 247 Core heater temperature, Rod F-4 (TH-F4-14), from -20 to 600 s.

Fig. 248 Core heater temperature, Rod F-4 (TH-F4-14), from -6 to 42 s.

Fig. 249 Core heater temperature, Rod F-4 (TH-F4-29), from -20 to 600 s.

Fig. 250 Core heater temperature, Rod F-4 (TH-F4-29), from -6 to 42 s.

Fig. 251 Core heater temperature, Rod F-4 (TH-F4-44), from -20 to 600 s.

Fig. 252 Core heater temperature, Rod F-4 (TH-F4-44), from -6 to 42 s.

Fig. 253 Core heater temperature, Rod F-5 (TH-F5-20), from -20 to 600 s.

Fig. 254 Core heater temperature, Rod F-5 (TH-F5-20), from -6 to 42 s.

Fig. 255 Core heater temperature, Rod F-5 (TH-F5-26), from -20 to 600 s.

Fig. 256 Core heater temperature, Rod F-5 (TH-F5-26), from -6 to 42 s.

Fig. 257 Core heater temperature, Rod F-5 (TH-F5-33), from -20 to 600 s.

Fig. 258 Core heater temperature, Rod F-5 (TH-F5-33), from -6 to 42 s.

Fig. 259 Core heater temperature, Rod F-5 (TH-F5-53), from -20 to 600 s.

Fig. 260 Core heater temperature, Rod F-5 (TH-F5-53), from -6 to 42 s.

Fig. 261 Core heater temperature, Rod G-3 (TH-G3-13), from -20 to 600 s.

Fig. 262 Core heater temperature, Rod G-3 (TH-G3-13), from -6 to 42 s.

Fig. 263 Core heater temperature, Rod G-4 (TH-G4-29), from -20 to 600 s.

Fig. 264 Core heater temperature, Rod G-4 (TH-G4-29), from -6 to 42 s.

Fig. 265 Core heater temperature, Rod G-4 (TH-G4-33), from -20 to 600 s.

Fig. 266 Core heater temperature, Rod G-4 (TH-G4-33), from -6 to 42 s.

Fig. 267 Core heater temperature, Rod G-4 (TH-G4-38), from -20 to 600 s.

Fig. 268 Core heater temperature, Rod G-4 (TH-G4-38), from -6 to 42 s.

Fig. 269 Core heater temperature, Rod G-5 (TH-G5-14), from -20 to 600 s.

Fig. 270 Core heater temperature, Rod G-5 (TH-G5-14), from -6 to 42 s.

Fig. 271 Core heater temperature, Rod G-5 (TH-G5-24), from -20 to 600 s.

Fig. 272 Core heater temperature, Rod G-5 (TH-G5-24), from -6 to 42 s.

Fig. 273 Core heater temperature, Rod H-5, (TH-H5-32), from -20 to 600 s.

Fig. 274 Core heater temperature, Rod H-5, (TH-H5-32), from -6 to 42 s.

Fig. 275 Pressure in intact loop (PU-13), from -20 to 600 s.

Fig. 276 Pressure in intact loop (PU-13), from -6 to 42 s.

Fig. 277 Pressure in intact loop (PU-15L), from -20 to 600 s.

Fig. 278 Pressure in intact loop (PU-15L), from -6 to 42 s.

Fig. 279 Pressure in broken loop, vessel side (PB-21), from -20 to 600 s.

Fig. 280 Pressure in broken loop, vessel side (PB-21), from -6 to 42 s.

Fig. 281 Pressure in broken loop, vessel side (PB-23), from -20 to 600 s.

Fig. 282 Pressure in broken loop, vessel side (PB-23), from -6 to 42 s.

Fig. 283 Pressure in broken loop, vessel side, Tests S-28-7 and S-28-9 (PB-CN1), from -20 to 600 s.

Fig. 284 Pressure in broken loop, vessel side, Tests S-28-7 and S-28-9 (PB-CN1), from -6 to 42 s.

Fig. 285 Pressure in broken loop, pump side (PB-37), from -20 to 600 s.

Fig. 286 Pressure in broken loop, pump side (PB-37), from -6 to 42 s.

Fig. 287 Pressure in broken loop, pump side (PB-42), from -20 to 600 s.

Fig. 288 Pressure in broken loop, pump side (PB-42), from -6 to 42 s.

Fig. 289 Pressure in broken loop, vessel side (PB-HN1), from -20 to 600 s.

Fig. 290 Pressure in broken loop, vessel side (PB-HN1), from -6 to 42 s.

Fig. 291 Pressure in vessel (PV-UP+10), from -20 to 600 s.

Fig. 292 Pressure in vessel (PV-UP+10), from -6 to 42 s.

Fig. 293 Pressure in vessel (PV-LP-166), from -20 to 600 s.

Fig. 294 Pressure in vessel (PV-LP-166), from -6 to 42 s.

Fig. 295 Pressure in intact loop accumulator (PU-ACC1), from -20 to 600 s.

Fig. 296 Pressure in intact loop accumulator (PU-ACC1), from -6 to 42 s.

Fig. 297 Pressure in intact loop accumulator (PB-ACC2), from -20 to 600 s.

Fig. 298 Pressure in intact loop accumulator (PB-ACC2), from -6 to 42 s.

Fig. 299 Pressure in steam generator, tube rupture simulation accumulator (PU-SGSD), from -20 to 600 s.

Fig. 300 Pressure in steam generator, tube rupture simulation accumulator (PU-SGSD), from -6 to 42 s.

Fig. 301 Pressure in steam generator, secondary side (PU-SGS3), from -20 to 600 s.

Fig. 302 Pressure in steam generator, secondary side (PU-SGS3), from -6 to 42 s.

Fig. 303 Pressure in pressurizer (PU-PRIZE), from -20 to 600 s.

Fig. 304 Pressure in pressurizer (PU-PRIZE), from -6 to 42 s.

Fig. 305 Pressure in pressure suppression tank (P-PSS), from -20 to 600 s.

Fig. 306 Pressure in pressure suppression tank (P-PSS), from -6 to 42 s.

Fig. 307 Differential pressure in intact loop (DPU-3-7), from -20 to 600 s.

Fig. 308 Differential pressure in intact loop (DPU-3-7), from -6 to 42 s.

Fig. 309 Differential pressure in intact loop, Test S-28-7 (DPU-6-SGIP), from -20 to 600 s.

Fig. 310 Differential pressure in intact loop, Test S-28-7 (DPU-6-SGIP), from -20 to 600 s.

Fig. 311 Differential pressure in intact loop, Test S-28-9 (DPU-6-SGIP), from -20 to 600 s.

Fig. 312 Differential pressure in intact loop, Test S-28-9 (DPU-6-SGIP), from -6 to 42 s.

Fig. 313 Differential pressure in intact loop, Test S-28-12 (DPU-6-SGIP), from -20 to 600 s.

Fig. 314 Differential pressure in intact loop, Test S-28-12 (DPU-6-SGIP), from -6 to 42 s.

Fig. 315 Differential pressure in intact loop (DPU-SGOP-7), from -20 to 600 s.

Fig. 316 Differential pressure in intact loop (DPU-SGOP-7), from -6 to 42 s.

Fig. 317 Differential pressure in intact loop, Test S-28-7 (DPU-7-10), from -20 to 600 s.

Fig. 318 Differential pressure in intact loop, Test S-28-7 (DPU-7-10), from -6 to 42 s.

Fig. 319 Differential pressure in intact loop, Test S-28-9 (DPU-7-10), from -20 to 600 s.

Fig. 320 Differential pressure in intact loop, Test S-28-9 (DPU-7-10), from -6 to 42 s.

Fig. 321 Differential pressure in intact loop, Test S-28-12 (DPU-7-10), from -20 to 600 s.

Fig. 322 Differential pressure in intact loop, Test S-28-12 (DPU-7-10), from -6 to 42 s.

Fig. 323 Differential pressure in intact loop, Tests S-28-9 and S-28-12 (DPU-12-10), from -20 to 600 s.

Fig. 324 Differential pressure in intact loop, Tests S-28-9 and S-28-12 (DPU-12-10), from -6 to 42 s.

Fig. 325 Differential pressure in intact loop, low range (DPU-12-10L), from -20 to 600 s.

Fig. 326 Differential pressure in intact loop, low range (DPU-12-10L), from -6 to 42 s.

Fig. 327 Differential pressure in intact loop, Test S-28-7 (DPU-12-15), from -20 to 600 s.

Fig. 328 Differential pressure in intact loop, Test S-28-7 (DPU-12-15), from -6 to 42 s.

Fig. 329 Differential pressure in intact loop, Test S-28-9 (DPU-12-15), from -20 to 600 s.

Fig. 330 Differential pressure in intact loop, Test S-28-9 (DPU-12-15), from -6 to 42 s.

Fig. 331 Differential pressure in intact loop, Test S-28-12 (DPU-12-15), from -20 to 600 s.

Fig. 332 Differential pressure in intact loop, Test S-28-12 (DPU-12-15), from -6 to 42 s.

Fig. 333 Differential pressure in intact loop, Test S-28-7 and S-28-9 (DPU-15-3), from -20 to 600 s.

Fig. 334 Differential pressure in intact loop, Test S-28-7 and S-28-9 (DPU-15-3), from -6 to 42 s.

Fig. 335 Differential pressure in intact loop, low range, Test S-28-7 (DPU-15-3L), from -20 to 600 s.

Fig. 336 Differential pressure in intact loop, low range, Test S-28-7 (DPU-15-3L), from -6 to 42 s.

Fig. 337 Differential pressure in intact loop, low range, Test S-28-9 (DPU-15-3L), from -20 to 600 s.

Fig. 338 Differential pressure in intact loop, low range, Test S-28-9 (DPU-15-3L), from -6 to 42 s.

Fig. 339 Differential pressure in intact loop, low range, Test S-28-12 (DPU-15-3L), from -20 to 600 s.

Fig. 340 Differential pressure in intact loop, low range, Test S-28-12 (DPU-15-3L), from -6 to 42 s.

Fig. 341 Differential pressure in pressurizer (DPU-PRESLL), from -20 to 600 s.

Fig. 342 Differential pressure in pressurizer (DPU-PRESLL), from -6 to 42 s.

Fig. 343 Differential pressure in intact loop, Test S-28-7 and S-28-9 (DPU-PR-4), from -20 to 600 s.

Fig. 344 Differential pressure in intact loop, Tests S-28-7 and S-28-9 (DPU-PR-4), from -6 to 42 s.

Fig. 345 Differential pressure in broken loop, Test S-28-7 (DPB-21-IANN), from -20 to 600 s.

Fig. 346 Differential pressure in broken loop, Test S-28-7 (DPB-21-IANN), from -6 to 42 s.

Fig. 347 Differential pressure in broken loop, Test S-28-9 (DPB-21-IANN), from -20 to 600 s.

Fig. 348 Differential pressure in broken loop, Test S-28-9 (DPB-21-IANN), from -6 to 42 s.

Fig. 349 Differential pressure in broken loop, Test S-28-12 (DPB-21-IANN), from -20 to 600 s.

Fig. 350 Differential pressure in broken loop, Test S-28-12 (DPB-21-IANN), from -6 to 42 s.

Fig. 351 Differential pressure in broken loop (DPB-23-CN1), from -20 to 600 s.

Fig. 352 Differential pressure in broken loop (DPB-23-CN1), from -6 to 42 s.

Fig. 353 Differential pressure in broken loop, Tests S-28-7 and S-28-9 (DPB-CN1-24), from -20 to 600 s.

Fig. 354 Differential pressure in broken loop, Tests S-28-7 and S-28-9 (DPB-CN1-24), from -6 to 42 s.

Fig. 355 Differential pressure in broken loop (DPB-30-43), from -20 to 600 s.

Fig. 356 Differential pressure in broken loop (DPB-30-43), from -6 to 42 s.

Fig. 357 Differential pressure in broken loop (DPB-32U-36L), from -20 to 600 s.

Fig. 358 Differential pressure in broken loop (DPB-32U-36L), from -6 to 42 s.

Fig. 359 Differential pressure in broken loop (DPB-36L-37), from -20 to 600 s.

Fig. 360 Differential pressure in broken loop (DPB-36L-37), from -6 to 42 s.

Fig. 361 Differential pressure in broken loop (DPB-38-40), from -20 to 600 s.

Fig. 362 Differential pressure in broken loop (DPB-38-40), from -6 to 42 s.

Fig. 363 Differential pressure in broken loop, Test S-28-7 (DPB-40-42), from -20 to 600 s.

Fig. 364 Differential pressure in broken loop, Test S-28-7 (DPB-40-42), from -6 to 42 s.

Fig. 365 Differential pressure in broken loop, Test S-28-9 (DPB-40-42), from -20 to 600 s.

Fig. 366 Differential pressure in broken loop, Test S-28-9 (DPB-40-42), from -6 to 42 s.

Fig. 367 Differential pressure in broken loop, Test S-28-12 (DPB-40-42), from -20 to 600 s.

Fig. 368 Differential pressure in broken loop, Test S-28-12 (DPB-40-42), from -6 to 42 s.

Fig. 369 Differential pressure in broken loop, Tests S-28-7 and S-28-9 (DPB-42-HN1), from -20 to 600 s.

Fig. 370 Differential pressure in broken loop, Tests S-28-7 and S-28-9 (DPB-42-HN1), from -6 to 42 s.

Fig. 371 Differential pressure in broken loop, Tests S-28-7 and S-28-9 (DPB-HN1-43), from -20 to 600 s.

Fig. 372 Differential pressure in broken loop, Test S-28-7 and S-28-9 (DPB-HN1-43), from -6 to 42 s.

Fig. 373 Differential pressure in vessel, Test S-28-7 (DPV-UP-IANN), from -20 to 600 s.

Fig. 374 Differential pressure in vessel, Test S-28-7 (DPV-UP-IANN), from -6 to 42 s.

Fig. 375 Differential pressure in vessel, Test S-28-9 (DPV-UP-IANN), from -20 to 600 s

Fig. 376 Differential pressure in vessel, Test S-28-9 (DPV-UP-IANN), from -6 to 42 s.

Fig. 377 Differential pressure in vessel, Test S-28-12 (DPV-UP-IANN), from -20 to 600 s.

Fig. 378 Differential pressure in vessel, Test S-28-12 (DPV-UP-IANN), from -6 to 42 s.

Fig. 379 Differential pressure in vessel, Test S-28-7 (DPV-0-9GQ), from -20 to 600 s.

Fig. 380 Differential pressure in vessel, Test S-28-7 (DPV-0-9GQ), from -6 to 42 s.

Fig. 381 Differential pressure in vessel, Test S-28-9 (DPV-0-9GQ), from -20 to 600 s.

Fig. 382 Differential pressure in vessel, Test S-28-9 (DPV-0-9GQ), from -6 to 42 s.

Fig. 383 Differential pressure in vessel, Test S-28-12 (DPV-0-9GQ), from -20 to 600 s.

Fig. 384 Differential pressure in vessel, Test S-28-12 (DPV-0-9GQ), from -6 to 42 s.

Fig. 385 Differential pressure in vessel, Test S-28-7 (DPV-9-260Q), from -20 to 600 s.

Fig. 386 Differential pressure in vessel, Test S-28-7 (DPV-9-260Q), from -6 to 42 s.

Fig. 387 Differential pressure in vessel, Test S-28-9 (DPV-9-26QQ), from -20 to 600 s.

Fig. 388 Differential pressure in vessel, Test S-28-9 (DPV-9-26QQ), from -6 to 42 s.

Fig. 389 Differential pressure in vessel, Test S-28-12 (DPV-9-26QQ), from -20 to 600 s.

Fig. 390 Differential pressure in vessel, Test S-28-12 (DPV-9-26QQ), from -6 to 42 s.

Fig. 391 Differential pressure in vessel, Test S-28-7 (DPV-9-166QQ), from -20 to 600 s.

Fig. 392 Differential pressure in vessel, Test S-28-7 (DPV-9-166QQ), from -6 to 42 s.

Fig. 393 Differential pressure in vessel, Test S-28-9 (DPV-9-166QQ), from -20 to 600 s.

Fig. 394 Differential pressure in vessel, Test S-28-9 (DPV-9-166QQ), from -6 to 42 s.

Fig. 395 Differential pressure in vessel, Test S-28-12 (DPV-9-166QQ), from -20 to 600 s.

Fig. 396 Differential pressure in vessel, Test S-28-12 (DPV-9-166QQ), from -6 to 42 s.

Fig. 397 Differential pressure in vessel, Test S-28-7 (DPV-26-55QM), from -20 to 600 s.

Fig. 398 Differential pressure in vessel, Test S-28-7 (DPV-26-55QM), from -6 to 42 s.

Fig. 399 Differential pressure in vessel, Test S-28-9 (DPV-26-55QM), from -20 to 600 s.

Fig. 400 Differential pressure in vessel, Test S-28-9 (DPV-26-55QM), from -6 to 42 s.

Fig. 401 Differential pressure in vessel, Test S-28-12 (DPV-26-55QM), from -20 to 600 s.

Fig. 402 Differential pressure in vessel, Test S-28-12 (DPV-26-55QM), from -6 to 42 s.

Fig. 403 Differential pressure in vessel (DPV-55-110MM), from -20 to 600 s.

Fig. 404 Differential pressure in vessel (DPV-55-110MM), from -6 to 42 s.

Fig. 405 Differential pressure in vessel, Test S-28-9 (DPV-55-110MM), from -20 to 600 s.

Fig. 406 Differential pressure in vessel, Test S-28-9 (DPV-55-110MM), from -6 to 42 s.

Fig. 407 Differential pressure in vessel, Test S-28-12 (DPV-55-110MM), from -20 to 600 s.

Fig. 408 Differential pressure in vessel, Test S-28-12 (DPV-55-110MM), from -6 to 42 s.

Fig. 409 Differential pressure in vessel, Test S-28-7 (DPV-110-156MQ), from -20 to 600 s.

Fig. 410 Differential pressure in vessel, Test S-28-7 (DPV-110-156MQ), from -6 to 42 s.

Fig. 411 Differential pressure in vessel, Test S-28-9 (DPV-110-156MQ), from -20 to 600 s.

Fig. 412 Differential pressure in vessel, Test S-28-9 (DPV-110-156MQ), from -6 to 42 s.

Fig. 413 Differential pressure in vessel, Test S-28-12 (DPV-110-156MQ), from -20 to 600 s.

Fig. 414 Differential pressure in vessel, Test S-28-12 (DPV-110-156MQ), from -6 to 42 s.

Fig. 415 Differential pressure in vessel, Test S-28-7 (DPV-156-173QQ), from -20 to 600 s.

Fig. 416 Differential pressure in vessel, Test S-28-7 (DPV-156-173QQ), from -6 to 42 s.

Fig. 417 Differential pressure in vessel, Test S-28-9 (DPV-156-173QQ), from -20 to 600 s.

Fig. 418 Differential pressure in vessel, Test S-28-9 (DPV-156-173QQ), from -6 to 42 s.

Fig. 419 Differential pressure in vessel, Test S-28-12 (DPV-156-173QQ), from -20 to 600 s.

Fig. 420 Differential pressure in vessel, Test S-28-12 (DPV-156-173QQ), from -6 to 42 s.

Fig. 421 Differential pressure in vessel (DPV-166Q+10), from -20 to 600 s.

Fig. 422 Differential pressure in vessel (DPV-166Q+10), from -6 to 42 s.

Fig. 423 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -20 to 600 s.

Fig. 424 Differential pressure in intact loop accumulator (DPU-ACC1-TB), from -6 to 42 s.

Fig. 425 Differential pressure in broken loop accumulator (DPB-ACC2-TB), from -20 to 600 s.

Fig. 426 Differential pressure in broken loop accumulator (DPB-ACC2-TB), from -6 to 42 s.

Fig. 427 Differential pressure in steam generator secondary side (DPU-SG-SEC), from -20 to 600 s.

Fig. 428 Differential pressure in steam generator secondary side (DPU-SG-SEC), from -6 to 42 s.

Fig. 429 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -20 to 600 s.

Fig. 430 Differential pressure across steam generator outlet orifice (DPU-SG-DISC), from -6 to 42 s.

Fig. 431 Differential pressure between simulation rupture injection line and Spool 6 (DPU-SGS-6), from -20 to 600 s.

Fig. 432 Differential pressure between simulation rupture injection line and Spool 6 (DPU-SGS-6), from -6 to 42 s.

Fig. 433 Differential pressure in intact loop tube rupture simulation accumulator (DPU-SGS3-TB), from -20 to 600 s.

Fig. 434 Differential pressure in intact loop tube rupture simulation accumulator (DPU-SGS3 TB), from -6 to 42 s.

Fig. 435 Differential pressure in pressure suppression tank, Tests S-28-7 and S-28-9 (DP-PSS-TB), from -20 to 600 s.

Fig. 436 Differential pressure in pressure suppression tank, Tests S-28-7 and S-28-9 (DP-PSS-TB), from -6 to 42 s.

Fig. 437 Volumetric flow in intact loop, Tests S-28-7 and S-28-9 (FTU-1) from -20 to 600 s.

Fig. 438 Volumetric flow in intact loop, Tests S-28-7 and S-28-9 (FTU-1) from -6 to 42 s.

Fig. 439 Volumetric flow in intact loop, Test S-28-7 (FTU-9), from -20 to 600 s.

Fig. 440 Volumetric flow in intact loop, Test S-28-7 (FTU-9), from -6 to 42 s.

Fig. 441 Volumetric flow in intact loop, Test S-28-9 (FTU-9), from -20 to 600 s.

Fig. 442 Volumetric flow in intact loop, Test S-28-9 (FTU-9), from -6 to 42 s.

Fig. 443 Volumetric flow in intact loop, Test S-28-12 (FTU-9), from -20 to 600 s.

Fig. 444 Volumetric flow in intact loop, Test S-28-12 (FTU-9), from -6 to 42 s.

Fig. 445 Volumetric flow in intact loop, Test S-28-12 (FTU-13) from -20 to 600 s.

Fig. 446 Volumetric flow in intact loop, Test S-28-12 (FTU-13) from -6 to 42 s.

Fig. 447 Volumetric flow in intact loop, Test S-28-7 (FTU-15), from -20 to 600 s.

Fig. 448 Volumetric flow in intact loop, Test S-28-7 (FTU-15), from -6 to 42 s.

Fig. 449 Volumetric flow in intact loop, Test S-28-9 (FTU-15), from -20 to 600 s.

Fig. 450 Volumetric flow in intact loop, Test S-28-9 (FTU-15), from -6 to 42 s.

Fig. 451 Volumetric flow in intact loop, Test S-28-12 (FTU-15), from -20 to 600 s.

Fig. 452 Volumetric flow in intact loop, Test S-28-12 (FTU-15), from -6 to 42 s.

Fig. 453 Volumetric flow in broken loop, Test S-28-7 (FTB-21), from -20 to 600 s.

Fig. 454 Volumetric flow in broken loop, Test S-28-7 (FTB-21), from -6 to 42 s.

Fig. 455 Volumetric flow in broken loop, Test S-28-9 (FTB-21), from -20 to 600 s.

Fig. 456 Volumetric flow in broken loop, Test S-28-9 (FTB-21), from -6 to 42 s.

Fig. 457 Volumetric flow in broken loop, Test S-28-12 (FTB-21), from -20 to 600 s.

Fig. 458 Volumetric flow in broken loop, Test S-28-12 (FTB-21), from -6 to 42 s.

Fig. 459 Volumetric flow in broken loop (FTB-30), from -20 to 600 s.

Fig. 460 Volumetric flow in broken loop (FTB-30), from -6 to 42 s.

Fig. 461 Volumetric flow in broken loop (FTB-37), from -20 to 600 s.

Fig. 462 Volumetric flow in broken loop (FTB-37), from -6 to 42 s.

Fig. 463 Volumetric flow in core entrance, Test S-28-7 (FTV-CORE-IN), from -20 to 600 s.

Fig. 464 Volumetric flow in core entrance, Test S-28-7 (FTV-CORE-IN), from -6 to 42 s.

Fig. 465 Volumetric flow in core entrance, Test S-28-9 (FTV-CORE-IN), from -20 to 600 s.

Fig. 466 Volumetric flow in core entrance, Test S-28-9 (FTV-CORE-IN), from -6 to 42 s.

Fig. 467 Volumetric flow in core entrance, Test S-28-12 (FTV-CORE-IN), from -20 to 600 s.

Fig. 468 Volumetric flow in core entrance, Test S-28-12 (FTV-CORE-IN), from -6 to 42 s.

Fig. 469 Volumetric flow in intact loop high pressure injection line, Tests S-28-7 and S-28-9 (FTU-HPIS), from -20 to 600 s.

Fig. 470 Volumetric flow in intact loop high pressure injection line, Tests S-28-7 and S-28-9 (FTU-HPIS), from -6 to 42 s.

Fig. 471 Volumetric flow in broken loop high pressure injection line, Test S-28-7 (FTB-HPIS), from -20 to 600 s.

Fig. 472 Volumetric flow in broken loop high pressure injection line, Test S-28-7 (FTB-HPIS), from -6 to 42 s.

Fig. 473 Volumetric flow in broken loop high pressure injection line, Test S-28-9 (FTB-HPIS), from -20 to 600 s.

Fig. 474 Volumetric flow in broken loop high pressure injection line, Test S-28-9 (FTB-HPIS), from -6 to 42 s.

Fig. 475 Volumetric flow in broken loop high pressure injection line, Test S-28-12 (FTB-HPIS), from -20 to 600 s.

Fig. 476 Volumetric flow in broken loop high pressure injection line, Test S-28-12 (FTB-HPIS), from -6 to 42 s.

Fig. 477 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -20 to 600 s.

Fig. 478 Volumetric flow in intact loop low pressure injection line (FTU-LPIS), from -6 to 42 s.

Fig. 479 Volumetric flow in broken loop low pressure injection line (FTB-LPIS), from -20 to 600 s.

Fig. 480 Volumetric flow in broken loop low pressure injection line (FTB-LPIS), from -6 to 42 s.

Fig. 481 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -20 to 600 s.

Fig. 482 Volumetric flow in intact loop accumulator discharge line (FTU-ACC1), from -6 to 42 s.

Fig. 483 Volumetric flow in broken loop accumulator discharge line (FTB-ACC2), from -20 to 600 s.

Fig. 484 Volumetric flow in broken loop accumulator discharge line (FTB-ACC2), from -6 to 42 s.

Fig. 485 Volumetric flow in intact loop steam generator feedwater line, Test S-28-7 (FTU-SGFW), from -20 to 600 s.

Fig. 486 Volumetric flow in intact loop steam generator feedwater line, Test S-28-7 (FTU-SGFW), from -6 to 42 s.

Fig. 487 Volumetric flow from intact loop steam generator tube rupture simulation accumulator (FTU-SGS), from -20 to 600 s.

Fig. 488 Volumetric flow from intact loop steam generator tube rupture simulation accumulator (FTU-SGS), from -6 to 42 s.

Fig. 489 Volumetric flow from pressurizer, Tests S-28-7 and S-28-9 (FTU-PRIZE), from -20 to 600 s.

Fig. 490 Volumetric flow from pressurizer, Tests S-28-7 and S-28-9 (FTU-PRIZE), from -6 to 42 s.

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Fig. 491 Fluid velocity in vessel, Test S-28-9 (FTV-40A), from -20 to 600 s.

Fig. 492 Fluid velocity in vessel, Test S-28-9 (FTV-40A), from -6 to 42 s.

Fig. 493 Fluid velocity in vessel, Test S-28-12 (FTV-40A), from -20 to 600 s.

Fig. 494 Fluid velocity in vessel, Test S-28-12 (FTV-40A), from -6 to 42 s.

Fig. 495 Fluid velocity in vessel, Test S-28-7 (FTV-40M), from -20 to 600 s.

Fig. 496 Fluid velocity in vessel, Test S-28-7 (FTV-40M), from -6 to 42 s.

Fig. 497 Fluid velocity in vessel, Test S-28-9 (FTV-40M), from -20 to 600 s.

Fig. 498 Fluid velocity in vessel, Test S-28-9 (FTV-40M), from -6 to 42 s.

Fig. 499 Fluid velocity in vessel, Test S-28-12 (FTV-40M), from -20 to 600 s.

Fig. 500 Fluid velocity in vessel, Test S-28-12 (FTV-40M), from -6 to 42 s.

Fig. 501 Momentum flux in intact loop, Tests S-28-9 and S-28-12 (FDU-1), from -6 to 42 s.

Fig. 502 Momentum flux in intact loop (FDU-5), from -6 to 42 s.

Fig. 503 Momentum flux in intact loop (FDU-10), from -6 to 42 s.

Fig. 504 Momentum flux in intact loop (FDU-13), from -6 to 42 s.

Fig. 505 Momentum flux in broken loop (FDB-21), from -6 to 42 s.

Fig. 506 Momentum flux in broken loop (FDB-23), from -6 to 42 s.

Fig. 507 Momentum flux in broken loop (FDB-30), from -6 to 42 s.

Fig. 508 Momentum flux in broken loop, Test S-28-7 (FDB-37), from -6 to 42 s.

Fig. 509 Momentum flux in broken loop, Test S-28-9 (FDB-37), from -6 to 42 s.

Fig. 510 Momentum flux in broken loop, Test S-28-12 (FDB-37), from -6 to 42 s.

Fig. 511 Momentum flux in broken loop (FDB-42), from -6 to 42 s.

Fig. 512 Momentum flux in core entrance (FDV-CORE-IN), from -6 to 42 s.

Fig. 513 Density in intact loop (GU-1T), from -20 to 600 s.

Fig. 514 Density in intact loop (GU-1T), from -6 to 42 s.

Fig. 515 Density in intact loop (GU-1B), from -20 to 600 s.

Fig. 516 Density in intact loop (GU-1B), from -6 to 42 s.

Fig. 517 Density in intact loop (GU-1C), from -20 to 600 s..

Fig. 518 Density in intact loop (GU-1C), from -6 to 42 s.

Fig. 519 Density in intact loop (GU-5VR), from -20 to 600 s.

Fig. 520 Density in intact loop (GU-5VR), from -6 to 42 s.

Fig. 521 Density in intact loop (GU-10VR), from -20 to 600 s.

Fig. 522 Density in intact loop (GU-10VR), from -6 to 42 s.

Fig. 523 Density in intact loop, Test S-28-7 (GU-13VR), from -20 to 600 s.

Fig. 524 Density in intact loop, Test S-28-7.(GU-13VR), from -6 to 42 s.

Fig. 525 Density in intact loop, Test S-28-9 (GU-13VR), from -20 to 600 s.

Fig. 526 Density in intact loop, Test S-28-9 (GU-13VR), from -6 to 42 s.

Fig. 527 Density in intact loop, Test S-28-12 (GU-13VR), from -20 to 600 s.

Fig. 528 Density in intact loop, Test S-28-12 (GU-13VR), from -6 to 42 s.

Fig. 529 Density in intact loop, Test S-28-7 (GU-15T), from -20 to 600 s.

Fig. 530 Density in intact loop, Test S-28-7 (GU-15T), from -6 to 42 s.

Fig. 531 Density in intact loop, Test S-28-9 (GU-15T), from -20 to 600 s.

Fig. 532 Density in intact loop, Test S-28-9 (GU-15T), from -6 to 42 s.

Fig. 533 Density in intact loop, Test S-28-12 (GU-15T), from -20 to 600 s.

Fig. 534 Density in intact loop, Test S-28-12 (GU-15T), from -6 to 42 s.

Fig. 535 Density in intact loop, Test S-28-7 (GU-15B), from -20 to 600 s.

Fig. 536 Density in intact loop, Test S-28-7 (GU-15B), from -6 to 42 s.

Fig. 537 Density in intact loop, Test S-28-9 (GU-15B), from -20 to 600 s.

Fig. 538 Density in intact loop, Test S-28-9 (GU-15B), from -6 to 42 s.

Fig. 539 Density in intact loop, Test S-28-12 (GU-15B), from -20 to 600 s.

Fig. 540 Density in intact loop, Test S-28-12 (GU-15B), from -6 to 42 s.

Fig. 541 Density in intact loop, Test S-28-7 (GU-15C), from -20 to 600 s.

Fig. 542 Density in intact loop, Test S-28-7 (GU-15C), from -6 to 42 s.

Fig. 543 Density in intact loop, Test S-28-9 (GU-15C), from -20 to 600 s.

Fig. 544 Density in intact loop, Test S-28-9 (GU-15C), from -6 to 42 s.

Fig. 545 Density in intact loop, Test S-28-12 (GU-15C), from -20 to 600 s.

Fig. 546 Density in intact loop, Test S-28-12 (GU-15C), from -6 to 42 s.

Fig. 547 Density in broken loop, Test S-28-7 (GB-21T), from -20 to 600 s.

Fig. 548 Density in broken loop, Test S-28-7 (GB-21T), from -6 to 42 s.

Fig. 549 Density in broken loop, Test S-28-9 (GB-21T), from -20 to 600 s.

Fig. 550 Density in broken loop, Test S-28-9 (GB-21T), from -6 to 42 s.

Fig. 551 Density in broken loop, Test S-28-12 (GB-21T), from -20 to 600 s.

Fig. 552 Density in broken loop, Test S-28-12 (GB-21T), from -6 to 42 s.

Fig. 553 Density in broken loop, Test S-28-7 (GB-21B), from -20 to 600 s.

Fig. 554 Density in broken loop, Test S-28-7 (GB-21B), from -6 to 42 s.

Fig. 555 Density in broken loop, Test S-28-9 (GB-21B), from -20 to 600 s.

Fig. 556 Density in broken loop, Test S-28-9 (GB-21B), from -6 to 42 s.

Fig. 557 Density in broken loop, Test S-28-12 (GB-21B), from -20 to 600 s.

Fig. 558 Density in broken loop, Test S-28-12 (GB-21B), from -6 to 42 s.

Fig. 559 Density in broken loop, Test S-28-7 (GB-21C), from -20 to 600 s.

Fig. 560 Density in broken loop, Test S-28-7 (GB-21C), from -6 to 42 s.

Fig. 561 Density in broken loop, Test S-28-9 (GB-21C), from -20 to 600 s.

Fig. 562 Density in broken loop, Test S-28-9 (GB-21C), from -6 to 42 s.

Fig. 563 Density in broken loop, Test S-28-12 (GB-21C), from -20 to 600 s.

Fig. 564 Density in broken loop, Test S-28-12 (GB-21C), from -6 to 42 s.

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Fig. 565 Density in broken loop, Test S-28-9 (GB-23VR), from -20 to 600 s.

Fig. 566 Density in broken loop, Test S-28-9 (GB-23VR), from -6 to 42 s.

Fig. 567 Density in broken loop, Test S-28-12 (GB-23VR), from -20 to 600 s.

Fig. 568 Density in broken loop, Test S-28-12 (GB-23VR), from -6 to 42 s.

Fig. 569 Density in broken loop (GB-30T), from -20 to 600 s.

Fig. 570 Density in broken loop (GB-30T), from -6 to 42 s.

Fig. 571 Density in broken loop (GB-30B), from -20 to 600 s.

Fig. 572 Density in broken loop (GB-30B), from -6 to 42 s.

Fig. 573 Density in broken loop (GB-30C), from -20 to 600 s.

Fig. 574 Density in broken loop (GB-30C), from -6 to 42 s.

Fig. 575 Density in broken loop (GB-37HZ), from -20 to 600 s.

Fig. 576 Density in broken loop (GB-37HZ), from -6 to 42 s.

Fig. 577 Density in broken loop (GB-42VR), from -20 to 600 s.

Fig. 578 Density in broken loop (GB-42VR), from -6 to 42 s.

Fig. 579 Density in vessel (GV-COR-150HZ), from -20 to 600 s.

Fig. 580 Density in vessel (GV-COR-150HZ), from -6 to 42 s.

Fig. 581 Density in vessel, Test S-28-7 (GVLP-165HZ), from -20 to 600 s.

Fig. 582 Density in vessel, Test S-28-7 (GVLP-165HZ), from -6 to 42 s.

Fig. 583 Density in vessel, Test S-28-9 (GVLP-165HZ), from -20 to 600 s.

Fig. 584 Density in vessel, Test S-28-9 (GVLP-165H7), from -6 to 42 s.

Fig. 585 Density in vessel, Test S-28-12 (GVLP-165HZ), from -20 to 600 s.

Fig. 586 Density in vessel, Test S-28-12 (GVLP-165HZ), from -6 to 42 s.

Fig. 587 Density in vessel, Test S-28-7 (GVLP-172HZ), from -20 to 600 s.

Fig. 588 Density in vessel, Test S-28-7 (GVLP-172HZ), from -6 to 42 s.

Fig. 589 Density in vessel, Test S-28-9 (GVLP-172HZ), from -20 to 600 s.

Fig. 590 Density in vessel, Test S-28-9 (GVLP-172HZ), from -6 to 42 s.

Fig. 591 Density in vessel, Test S-28-12 (GVLP-172HZ), from -20 to 600 s.

Fig. 592 Density in vessel, Test S-28-12 (GVLP-172HZ), from -6 to 42 s.

Fig. 593 Density in pressurizer, Test S-28-7 (GU-PRIZE), from -20 to 600 s.

Fig. 594 Density in pressurizer, Test S-28-7 (GU-PRIZE), from -6 to 42 s.

Fig. 595 Density in pressurizer, Test S-28-9 (GU-PRIZE), from -20 to 600 s.

Fig. 596 Density in pressurizer, Test S-28-9 (GU-PRIZE), from -6 to 42 s.

Fig. 597 Density in pressurizer, Test S-28-12 (GU-PRIZE), from -20 to 600 s.

Fig. 598 Density in pressurizer, Test S-28-12 (GU-PRIZE), from -6 to 42 s.

Fig. 599 Mass flow in intact loop, Test S-28-7 and S-28-12 (FDU-1, GU-1C), from -6 to 42 s.

Fig. 600 Mass flow in intact loop, Tests S-28-7 and S-28-9 (FTU-1, GU-1C), from -20 to 600 s.

Fig. 601 Mass flow in intact loop, Test S-28-7 and S-28-9 (FTU-1, GU-1C), from -6 to 42 s.

Fig. 602 Mass flow in intact loop (FDU-5, GU-5VR), from -6 to 42 s.

Fig. 603 Mass flow in intact loop (FTU-9, GU-10VR), from -20 to 600 s.

Fig. 604 Mass flow in intact loop (FTU-9, GU-10VR), from -6 to 42 s.

Fig. 605 Mass flow in intact loop (FDU-10, GU-10VR), from -6 to 42 s.

Fig. 606 Mass flow in intact loop (FDU-13, GU-13VR), from -6 to 42 s.

Fig. 607 Mass flow in intact loop, Test S-28-12 (FTU-13, GU-13VR), from -20 to 350 s.

Fig. 608 Mass flow in intact loop, Test S-28-12 (FTU-13, GU-13VR), from -6 to 42 s.

Fig. 609 Mass flow in intact loop (FTU-15, GU-15C), from -20 to 600 s.

Fig. 610 Mass flow in intact loop (FTU-15, GU-15C), from -6 to 42 s.

Fig. 611 Mass flow in broken loop (FDB-21, GB-21C), from -6 to 42 s.

Fig. 612 Mass flow in broken loop (FTB-21, GB-21C), from -20 to 600 s.

Fig. 613 Mass flow in broken loop (FTB-21, GB-21C), from -6 to 42 s.

Fig. 614 Mass flow in broken loop, Tests S-28-9 and S-28-12 (FDB-23, GB-23VR), from -6 to 42 s.

Fig. 615 Mass flow in broken loop (FDB-30, GB-30C), from -6 to 42 s.

Fig. 616 Mass flow in broken loop (FTB-30, GB-30C), from -20 to 600 s.

Fig. 617 Mass flow in broken loop (FTB-30, GB-30C), from -6 to 42 s.

Fig. 618 Mass flow in broken loop (FDB-37, GB-37HZ), from -6 to 42 s.

Fig. 619 Mass flow in broken loop (FTB-37, GB-37HZ), from -20 to 600 s.

Fig. 620 Mass flow in broken loop (FTB-37, GB-37HZ), from -6 to 42 s.

Fig. 621 Mass flow in broken loop (FDB-42, GB-42VR), from -6 to 42 s.

Fig. 622 Mass flow in vessel, Test S-28-7 (FDV-CORE-IN, GV-COR-150HZ), from -20 to 600 s.

Fig. 623 Mass flow in vessel, Test S-28-7 (FDV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 624 Mass flow in vessel, Test S-28-9 (FDV-CORE-IN, GV-COR-150HZ), from -20 to 600 s.

Fig. 625 Mass flow in vessel, Test S-28-9 (FDV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 626 Mass flow in vessel, Test S-28-12 (FDV-CORE-IN, GV-COR-150HZ), from -20 to 600 s.

Fig. 627 Mass flow in vessel, Test S-28-12 (FDV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

Fig. 628 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -20 to 600 s.

Fig. 629 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ), from -6 to 42 s.

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Fig. 630 Mass flow in pressurizer, Test S-28-7 (FTU-PRIZE, GU-PRIZE), from -20 to 600 s.

Fig. 631 Mass flow in pressurizer, Test S-28-7 (FTU-PRIZE, GU-PRIZE), from -6 to 42 s.

Fig. 632 Mass flow in pressurizer, Test S-28-9 (FTU-PRIZE, GU-PRIZE), from -20 to 600 s.

Fig. 633 Mass flow in pressurizer, Test S-28-9 (FTU-PRIZE, GU-PRIZE), from -6 to 42 s.

Fig. 634 Core heater rod total power (PWRCOR T-1), from -20 to 600 s.

Fig. 635 Core heater rod total power (PWRCOR T-1), from -6 to 42 s.

Fig. 636 Core heater rod total power (PWRCOR T-2), from -20 to 600 s.

Fig. 637 Core heater rod total power (PWRCOR T-2), from -6 to 42 s.

Fig. 638 Core heater voltage (VOLT COR-T), from -20 to 600 s.

Fig. 639 Core heater voltage (VOLT COR-T), from -6 to 42 s.

Fig. 640 Core heater total current (AMPCOR-T), from -20 to 600 s.

Fig. 641 Core heater total current (AMPCOR-T), from -6 to 42 s.

Fig. 642 Primary pump speed (PUMPU-RPM), from -20 to 600 s.

Fig. 643 Primary pump speed (PUMPU-RPM), from -6 to 42 s.

IV. REFERENCE

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

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APPENDIX A
DATA ACQUISITION SYSTEM CAPABILITIES

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APPENDIX A

DATA ACQUISITION SYSTEM CAPABILITIES

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

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

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

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

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

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

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APPENDIX B

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1

TESTS S-28-7, S-28-9, AND S-28-12

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APPENDIX B

POSTTEST ADJUSTMENTS TO DATA FROM SEMISCALE MOD-1

TESTS S-28-7, S-28-9, AND S-28-12

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 Tests S-28-7, S-28-9, and S-28-12 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.

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, kPa

$F(t)$ = raw data, kPa

C_0 = offset, kPa

C_1 = scaling factor.

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

TABLE B-I
CONSTANTS FOR PRESSURE MEASUREMENT CORRECTIONS

Test S-28-7		
<u>Detector Identification</u>	<u>C_0</u>	<u>C_1</u>
PU-13	68.9	0.995 8
PB-42	6.9	1.010 6
PV-LP-166	100.0	1.000 9
Test S-28-9		
PB-21	13.7	0.998 0

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, 1780, 5110, 7160, 8820, 12 220, and 15 500 kPa. The output of the differential pressure cells is plotted against system pressure, with the resulting plots used to describe the pressure response of the transducers.

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

For some differential pressure measurements, other references are used. The liquid level measurements in the intact loop accumulator (DPU-ACC1-TB) and the broken loop accumulator (DPB-ACC2-TB) are referenced to calculated values based on geometrical considerations at the time when the water is depleted from the accumulators and gas flow begins. The reading from the steam generator discharge venturi (DPU-SG-DISC) is shifted to read zero after flow is stopped. For these detectors, and those having nonlinear pressure sensitivities, the corrections are performed according to the following equations:

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

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

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

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

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

where

t = time, s

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

$F(t)$ = raw data, kPa

K = scaling factor

C_i and t_i = corrections (kPa) and time points (s).

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

TABLE B-II

CONSTANTS FOR DIFFERENTIAL PRESSURE MEASUREMENT CORRECTIONS

Test S-28-7							
Detector Identification	K	C ₁	t ₁	C ₂	t ₂	C ₃	t ₃
DPU-12-10	1	54.951					
DPU-15-3L	1	-4.275					
DPB-21-IANN	1	-0.221					
DPV-UP-IANN	1	0.794					
DPV-9-26QQ	1	0.228					
DPV-26-55QM	1	-1.586	0	-1.034	0.01	0.345	36
DPV-156-173QQ	1	3.034	0	2.068	0.01	0.069	36
DPU-ACC1-TB	1	-11.928					
DPU-ACC2-TB	1	-3.489					
DPU-SG-SEC	1	-3.220					
DPU-SG-DISC	1	1.724					
DPU-SGS-6	-1						
DPU-SGS3-TB	1	4.254					

Test S-28-9							
Detector Identification	K	C ₁	t ₁	C ₂	t ₂	C ₃	t ₃
DPU-12-10	1	-12.204	0	-10.342	0.01	-6.550	36
DPU-12-10L	1	-0.145	0	-0.97	0.01	-0.034	36
DPU-15-3	1	-4.275					
DPU-15-3L	1	-4.275					
DPV-UP-IANN	1	0.737					
DPV-26-55QM	1	-1.034	0	-0.621	0.01	0.345	36

TABLE B-II (continued)

Test S-28-9							
Detector Identification	<u>K</u>	<u>C₁</u>	<u>t₁</u>	<u>C₂</u>	<u>t₂</u>	<u>C₃</u>	<u>t₃</u>
DPV-110-156MQ	1	-1.310	0	-0.758	0.01	0.276	36
DPU-ACC1-TB	1	-11.928					
DPU-ACC2-TB	1	-3.482					
DPU-SG-SEC	1	-3.213					
DPU-SG-DISC	1	1.380					
DPU-SGS-6	-1						
DPU-SGS3-TB	1	2.027					
DP-PSS-TB	1	-11.721					
Test S-28-12							
Detector Identification	<u>K</u>	<u>C₁</u>	<u>t₁</u>	<u>C₂</u>	<u>t₂</u>	<u>C₃</u>	<u>t₃</u>
DPU-15-3L	1	-4.275					
DPV-UP-IANN	1	0.714					
DPU-ACC1-TB	1	-11.928					
DPU-ACC2-TB	1	-3.475					
DPU-SG-SEC	1	-3.213					
DPU-SG-DISC	1	4.137					
DPU-SGS3-TB	1	1.820					

3. MOMENTUM FLUX MEASUREMENTS

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

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

where

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

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

T_i = temperature sensitivity, DAS volts/K

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

C_0 = ambient sensitivity, DAS volts

P_i = pressure sensitivity, DAS volts/kPa

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

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

TABLE B-III
CONSTANTS FOR MOMENTUM FLUX MEASUREMENT CORRECTIONS

Test S-28-7						
Detector Identification	C_o	T_1	$T(t)^{[a]}$	P_1	$P(t)^{[b]}$	
FDU-1	0.165	0.000 655	RBU-2	0.000 091 6	PV-UP+10	
FDU-5	0	-0.000 134	TFU-6	0.000 084 1	PV-UP+10	
FDU-10	0	0.000 126	TFU-10	0.000 036 5	PV-UP+10	
FDU-13	0	0.000 490	RBU-14A			
FDB-21	0	-0.000 372	TFB-20	-0.000 184 0	PB-21	
FDB-23	0	-0.000 447	TFB-23			
FDB-30 ^[c]	-0.132	-0.000 507	TFV-UP+13			
FDB-37 ^[c]	-0.037	0.000 281	TFB-37			
FDB-42	0.040	0.000 396	TFB-42	-0.000 076 5	PB-42	
FDV-CORE-IN	0	-0.000 010	TFV-CORE-IN			
Test S-28-9						
Detector Identification	C_o	T_1	$T(t)^{[a]}$	P_1	$P(t)^{[b]}$	
FDU-5	0	-0.000 109	TFU-6	0.000 076 5	PV-UP+10	
FDU-10	0	0.000 088	TFU-10			
FDU-13	0	0.000 457	RBU-14A			
FDB-21	-0.040	-0.000 401	TFB-20	-0.000 181 3	PB-21	
FDB-23	0	-0.000 446	TFB-23			
FDB-30 ^[c]	-0.185	-0.000 574	TFB-30	0.000 074 4	PV-UP+10	
FDB-37 ^[c]	-0.025	0.000 289	TFB-37	-0.000 024 8	PB-37	
FDB-42	0.240	-0.000 595	TFB-42			

TABLE B-III (continued)

Test S-28-12					
Detector Identification	C_0	T_1	$T(t)^{[a]}$	P_1	$P(t)^{[b]}$
FDU-1	0.250	0.000 729	RBU-2	-0.000 108 9	PV-UP+10
FDU-5	0	-0.000 077	TFU-6	0.000 073	PV-UP+10
FDU-10	-0.020	0.000 093	TFU-10		
FDU-13	0.070	0.000 499	RBU-14A	0.000 017 9	PU-13
FDB-21	0	-0.000 413	TFB-20	-0.000 074 4	PB-21
FDB-23	0.150	-0.000 414	TFB-23	-0.000 049 6	PB-23
FDB-30 ^[c]	-0.050	-0.000 507	TFB-30	0.000 096 5	PV-UP+10
FDB-37 ^[c]	-0.115	0.000 249	TFB-37		
FDB-42	-0.610	-0.000 128	TFB-42	-0.000 033 7	PB-42

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

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

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

4. DENSITY MEASUREMENTS

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

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

where

ρ = the density in kg/m^3

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

D = a theoretical voltage for zero attenuation inside the vessel

A = an amplification factor

B = a biasing factor

F(t) = the transducer voltage output.

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

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

Test S-28-7

$$\text{GVLP-172HZ} \quad \rho = -21.86 F(t) - 387.6$$

$$\text{GV-COR-150HZ} \quad \rho = -58.82 F(t) - 2851.2$$

Test S-28-9

$$\text{GVLP-172HZ} \quad \rho = -22.33 F(t) - 394.4$$

$$\text{GV-COR-150HZ} \quad \rho = -60.90 F(t) - 2973.7$$

Test S-28-12

$$\text{GVLP-172HZ} \quad \rho = -21.46 F(t) - 600.0$$

$$\text{GV-COR-150HZ} \quad \rho = -60.39 F(t) - 2878.1$$

TABLE B-IV
CONSTANTS FOR DENSITY MEASUREMENT CONVERSIONS
TO ENGINEERING UNITS

<u>Test S-28-7</u>				
<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-1T	1.070	-0.194	0.000 36	6.71
GU-1B	1.020	0.102	0.000 50	7.29
GU-5VR	1.071	-0.171	0.000 59	4.58
GU-10VR	1.097	-0.424	0.000 59	6.63
GU-13VR	0.881	0.302	0.000 59	2.12
GU-15T	1.149	-0.694	0.000 36	6.55
GU-15B	1.014	-0.135	0.000 50	7.17
GB-21T	1.064	-0.172	0.000 36	6.75
GB-21B	1.091	-0.426	0.000 50	7.82
GB-30T	1.147	-0.636	0.000 36	6.17
GB-30B	1.034	0.003	0.000 50	8.06
GB-37HZ	1.808	-3.088	0.000 59	4.17
GB-42VR	1.012	0.223	0.000 37	9.10
GVLP-165HZ	1.241	-0.194	0.001 50	0.895
GU-PRIZE	1.091	-0.054	0.000 59	0.940

<u>Test S-28-9</u>				
<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-1T	1.043	-0.240	0.000 36	6.49
GU-1B	0.972	0.265	0.000 50	7.10
GU-5VR	1.050	-0.209	0.000 59	4.80

TABLE B-IV (continued)

Test S-28-9				
<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-10VR	1.090	-0.517	0.000 59	6.52
GU-13VR	0.867	0.287	0.000 59	2.00
GU-15T	1.170	-1.027	0.000 36	6.30
GU-15B	1.013	-0.046	0.000 50	6.90
GB-21T	1.059	-0.327	0.000 36	6.50
GB-21B	1.093	-0.665	0.000 50	7.50
GB-23VR	0.949	0.348	0.000 37	6.71
GB-30T	1.116	-0.646	0.000 36	5.93
GB-30B	1.022	-0.052	0.000 50	7.83
GB-37HZ	1.754	-3.034	0.000 59	4.03
GB-42VR	0.989	0.171	0.000 37	8.75
GVLP-165HZ	1.333	-0.235	0.001 50	0.96
GU-PRIZE	1.411	-0.188	0.000 59	1.17
Test S-28-12				

<u>Detector Identification</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
GU-1T	1.024	-0.139	0.000 36	6.49
GU-1B	0.986	0.134	0.000 50	7.15
GU-5VR	1.092	-0.356	0.000 59	4.54
GU-10VR	1.139	-0.693	0.000 59	6.40
GU-13VR	0.874	0.253	0.000 59	1.96
GU-15T	1.249	-1.452	0.000 36	6.25
GU-15B	1.032	-0.105	0.000 50	6.83

TABLE B-IV (continued)

Test S-28-12				
Detector Identification	A	B	C	D
GB-21T	1.092	-0.548	0.000 36	6.47
GB-21B	1.104	-0.686	0.000 50	7.54
GB-23VR	1.012	-0.043	0.000 37	6.35
GB-30T	1.143	-0.803	0.000 36	6.00
GB-30B	1.013	-0.086	0.000 50	7.73
GB-37HZ	1.925	-3.530	0.000 59	4.123
GB-42VR	1.121	-0.955	0.000 37	8.69
GVLP-165HZ	1.014	-0.099	0.001 50	9.77
GU-PRIZE	1.229	-0.187	0.000 59	1.08

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

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

In the Semiscale Mod-1 system, two-beam gamma densitometers provide added information which allows the calculation of a better average density than that obtained from a single beam. A mathematical model is used for processing the two-beam data to obtain the improved average density information. The processing method used is based on a froth-water model coupled with information from the two individual gamma beams and related beam path and piping cross-sectional geometry. The resulting information is recorded and reported under the density measurement identification ending with a "C", for example, GU-15C.

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

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

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

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

where

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

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

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

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

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

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

where

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

where

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

D = piping inside diameter

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

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

5. CORE POWER MEASUREMENTS

Corrections to core power readings are determined from the core voltage and core current readings, with a slight adjustment for the power lost in setting the core radial peaking factor. The adjustments are as follows:

Test S-28-12

$$\text{PWRCOR T-2: } F'(t) = 1.021 F(t) - 2.0 = (\text{voltage}) (\text{current}) (0.954)$$

where

$F'(t)$ = core power in kilowatts

$F(t)$ = the raw core power reading.

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APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS

FROM SEMISCALE MOD-1 TESTS S-28-7 AND S-28-9

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APPENDIX C

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TESTS S-28-7 AND S-28-9

Analyses have been performed on selected data from Tests S-28-7 and S-28-9 to provide a guide to the uncertainty associated with data measurements in the Semiscale Mod-1 system. The end results of the analyses are 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 traces under analyses were empirically fitted with a linear difference equation, which were subject to a white noise input at each sampling time point. The objective of the empirical fitting procedure was to characterize the white noise, which was taken to represent the random error. The procedures for fitting the difference equation are discussed in depth in Reference C-1. A data trace was often segmented and different equations were fitted to each segment with statistical correlations between successive observations accounted for by the fitting procedure. The white noise input was assumed to arise from a normally distributed population. The standard deviation of the white noise, as found during the fitting procedures, was taken as an estimate of the random error standard deviation and is shown in Table C-1. The data traces of the error band analysis are shown in Figures C-1 through C-86.

TABLE C-1
RANDOM ERROR VARIANCE

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFB-23	11.644	0 to 69	C-1	Test S-28-7
	1.648	69 to 600		
	14.148	0 to 70	C-2	Test S-28-9
	1.069	70 to 600		
TFV-ANN-35A	18.953	0 to 69	C-3	Test S-28-7
	3.822	69 to 600		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TFV-ANN-35A (continued)	10.633 1.521	0 to 62 62 to 600	C-4	Test S-28-9
TFV-LP-2	2.038	0 to 600	C-5	Test S-28-7
	3.789 10.159 3.674	0 to 54 54 to 62 62 to 600	C-6	Test S-28-9
TFV-LP-4	2.120	0 to 600	C-7	Test S-28-7
	3.413 35.903 0.568	0 to 54 54 to 78 78 to 600	C-8	Test S-28-9
TFV-LP-7	2.455	0 to 600	C-9	Test S-28-7
	18.058 1.151	0 to 80 80 to 600	C-10	Test S-28-9
TFG-5CD-45	8.392 24.940 1.711	0 to 44 44 to 52 52 to 600	C-11	Test S-28-7
	7.782 54.700 1.360	0 to 48 48 to 56 56 to 600	C-12	Test S-28-9
TFU-SG3	0.177	0 to 600	C-13	Test S-28-7
	0.183	0 to 600	C-14	Test S-28-9
TFU-PRIZE	4.951 0.263	0 to 44 44 to 600	C-15	Test S-28-7
	1.063	0 to 600	C-16	Test S-28-9
TMU-1T16	0.416	0 to 600	C-17	Test S-28-7
	0.441	0 to 600	C-18	Test S-28-9
TMV-C1-70A	1.931	0 to 600	C-19	Test S-28-7
	1.657 3.235	0 to 52 52 to 140	C-20	Test S-28-9

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
TMV-C1-70A (continued)	7.226 0.211	140 to 150 150 to 600		
TH-E4-09	6.984	0 to 600	C-21	Test S-28-7
	3.079 38.326 1.935	0 to 236 236 to 245 245 to 600	C-22	Test S-28-9
TH-E4-27	15.176 68.544 3.720	0 to 240 240 to 249 249 to 600	C-23	Test S-28-7
	5.202 53.742 1.460	0 to 160 160 to 170 170 to 600	C-24	Test S-28-9
TH-E4-55	3.358 22.147 3.414 30.454 1.056	0 to 53 53 to 61 61 to 140 140 to 148 148 to 600	C-25	Test S-28-7
	1.736 32.282 1.000	0 to 105 105 to 115 115 to 600	C-26	Test S-28-9
PU-13	3.296	0 to 600	C-27	Test S-28-7
	2.861	0 to 600	C-28	Test S-28-9
PB-23	3.392	0 to 600	C-29	Test S-28-7
	2.878	0 to 600	C-30	Test S-28-9
DPU-6-SGIP	0.287 3.158 0.264	0 to 53 53 to 62 62 to 600	C-31	Test S-28-7
	0.293 3.892 0.318 0.127	0 to 53 53 to 62 62 to 446 446 to 600	C-32	Test S-28-9

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
DPU-SGOP-7	0.489	0 to 32	C-33	Test S-28-7
	2.488	32 to 68		
	0.191	68 to 600		
	0.497	0 to 54	C-34	Test S-28-9
	3.534	54 to 63		
	0.286	63 to 600		
DPU-7-10	0.227	0 to 58	C-35	Test S-28-7
	0.066	58 to 600		
	0.103	0 to 600	C-36	Test S-28-9
DPU-12-10	1.093	0 to 62	C-37	Test S-28-7
	0.214	62 to 331		
	1.207	331 to 338		
	0.222	338 to 600		
	0.438	0 to 48	C-38	Test S-28-9
	0.943	48 to 64		
	0.197	64 to 600		
DPU-12-15	0.242	0 to 78	C-39	Test S-28-7
	0.049	78 to 466		
	0.092	466 to 600		
	0.134	0 to 600	C-40	Test S-28-9
FTU-1	90.654	0 to 54	C-41	Test S-28-7
	407.489	54 to 61		
	44.395	61 to 126		
	28.602	126 to 600		
	176.861	0 to 70	C-42	Test S-28-9
	34.804	70 to 246		
	26.771	246 to 600		
FTU-15	29.450	0 to 90	C-43	Test S-28-7
	60.160	90 to 99		
	48.004	99 to 233		
	15.888	233 to 311		
	26.337	311 to 460		
	68.637	460 to 600		
	28.272	0 to 18	C-44	Test S-28-9
	11.222	18 to 61		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FTU-15 (continued)	31.881 65.640 23.790 96.737	61 to 98 98 to 206 206 to 474 475 to 600		
FTU-HPIS	0.126 0.036 0.061	0 to 62 62 to 294 294 to 600	C-45	Test S-28-7
	0.153 0.074	0 to 61 61 to 600	C-46	Test S-28-9
FTU-LPIS	0.578 0.208 0.011	0 to 54 54 to 62 62 to 600	C-47	Test S-28-7
	0.309 1.070 0.037	0 to 18 18 to 26 26 to 600	C-48	Test S-28-9
FTU-ACC1	2.531 2.670 4.360	0 to 59 59 to 67 67 to 97	C-49	Test S-28-7 Error bands are not pre- sented from t = 97 to 600 s[a].
	2.257 0.742 3.657	0 to 19 19 to 61 61 to 96	C-50	Test S-28-9 Error bands are not pre- sented from t = 96 to 600 s[a].
FTV-40A	6.337 1.711	0 to 208 208 to 600	C-51	Test S-28-9
FTV-40M	8.028 9.658 2.743 0.887	0 to 39 39 to 47 47 to 224 224 to 600	C-52	Test S-28-7
	4.611 0.968	0 to 209 209 to 600	C-53	Test S-28-9
GU-1T	0.723 2.342 0.499 2.365 0.389	0 to 312 312 to 322 322 to 359 359 to 368 368 to 600	C-54	Test S-28-7

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GU-1T (continued)	0.690 5.072 0.438	0 to 262 262 to 270	C-55	Test S-28-9
GU-1B	1.714 0.862 2.132	0 to 60 60 to 118 118 to 600	C-56	Test S-28-7
	0.690 5.072 0.438	0 to 262 262 to 270 270 to 600	C-57	Test S-28-9
GU-1C	0.851 1.498 0.882	0 to 294 294 to 394 394 to 600	C-58	Test S-28-7
	0.866 3.869 0.832	0 to 262 262 to 270 270 to 600	C-59	Test S-28-9
GU-10VR	0.636	0 to 600	C-60	Test S-28-7
	0.574	0 to 600	C-61	Test S-28-9
GU-15T	10.801 3.510 7.686 2.030 5.759 0.708 11.792	0 to 23 23 to 60 60 to 69 69 to 117 117 to 243 243 to 460 460 to 600	C-62	Test S-28-7
	10.188 2.314 10.653 0.482 6.658 0.755 9.753	0 to 23 23 to 54 54 to 70 70 to 94 94 to 205 205 to 471 471 to 600	C-63	Test S-28-9
GU-15B	7.807 2.076 8.752 2.299 6.000	0 to 22 22 to 59 59 to 69 69 to 116 116 to 243	C-64	Test S-28-7

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GU-15B (continued)	1.252	243 to 460		
	10.712	460 to 600		
	6.371	0 to 23	C-65	Test S-28-9
	2.364	23 to 61		
	8.900	61 to 70		
	1.719	70 to 94		
	7.336	94 to 208		
	1.371	208 to 465		
	8.458	465 to 600		
GU-15C	9.353	0 to 23	C-66	Test S-28-7
	2.919	23 to 60		
	7.713	60 to 69		
	2.150	69 to 117		
	5.485	117 to 243		
	0.664	243 to 460		
	11.103	460 to 600		
	8.513	0 to 23	C-67	Test S-28-9
	1.812	23 to 54		
	8.990	54 to 70		
	0.678	70 to 94		
	6.540	94 to 207		
	0.725	207 to 471		
	8.887			
GB-23VR	9.077	0 to 73	C-68	Test S-28-9
	1.138	73 to 178		
	10.619	178 to 187		
	1.111	187 to 458		
	4.555	458 to 600		
GV-COR-150HZ	1.904	0 to 42	C-69	Test S-28-7
	6.421	42 to 61		
	1.572	61 to 361		
	12.895	361 to 400		
	1.192	400 to 462		
	3.976	462 to 600		
	0.293	0 to 48	C-70	Test S-28-9
	10.792	48 to 61		
	1.299	61 to 347		
	15.802	347 to 371		
	0.921	371 to 460		
	6.582	460 to 600		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
GVLP-165HZ	4.434	0 to 42	C-71	Test S-28-7
	7.217	42 to 244		
	2.614	244 to 600		
	7.088	0 to 18	C-72	Test S-28-9
	0.696	18 to 48		
	13.186	48 to 62		
	0.495	62 to 137		
	5.867	137 to 209		
	2.528	209 to 459		
	3.486	459 to 600		
GVLP-172HZ	2.183	0 to 600	C-73	Test S-28-7
	4.572	0 to 71	C-74	Test S-28-9
	1.061	71 to 600		
FTU-1, GU-1C	0.328	0 to 294	C-75	Test S-28-7
	0.558	294 to 459		
	0.301	459 to 600		
	0.399	0 to 247	C-76	Test S-28-9
	0.187	247 to 600		
FDU-5, GU-5VR	0.346	0 to 42	C-77	Test S-28-7 Only short-term (0 to 42 s) error bands are re- ported.
	0.357	0 to 42	C-78	Test S-28-9 Only short-term (0 to 42 s) error bands are re- ported.
FTU-15, GU-15C	2.028	0 to 67	C-79	Test S-28-7
	0.668	67 to 124		
	1.592	124 to 243		
	0.344	243 to 464		
	3.111	464 to 600		
	1.784	0 to 70	C-80	Test S-28-9
	0.193	70 to 94		
	1.917	94 to 205		
	0.282	205 to 471		
	3.327	471 to 600		

TABLE C-I (continued)

Measurement	Random Error Variance σ_R	Period of Application (s)	Figure	Comments
FDB-21, GB-21C	3.092	0 to 14	C-81	Test S-28-7 Only short-term (0 to 42 s) error bands are re- ported.
	0.794	14 to 20		
	3.603	20 to 42		
	3.058	0 to 14	C-82	Test S-28-9 Only short-term (0 to 42 s) error bands are re- ported.
	0.861	14 to 20		
	3.698	20 to 42		
FTB-21, GB-21C	3.469	0 to 70	C-83	Test S-28-7
	0.563	70 to 600		
	3.205	0 to 70	C-84	Test S-28-9
	0.572	70 to 600		
FTV-CORE-IN, GV-COR-150HZ	0.709	0 to 361	C-85	Test S-28-7
	5.683	361 to 600		
	0.686	0 to 356	C-86	Test S-28-9
	8.863	356 to 600		

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

Fig. C-1 Fluid temperature in broken loop, Test S-28-7 (TFB-23).

Fig. C-2 Fluid temperature in broken loop, Test S-28-9 (TFB-23).

Fig. C-3 Fluid temperature in downcomer annulus, Test S-28-7 (TFV-ANN-35A).

Fig. C-4 Fluid temperature in downcomer annulus, Test S-28-9 (TFV-ANN-35A).

Fig. C-5 Fluid temperature in lower plenum, Test S-28-7 (TFV-LP-2).

Fig. C-6 Fluid temperature in lower plenum, Test S-28-9 (TFV-LP-2).

Fig. C-7 Fluid temperature in lower plenum, Test S-28-7 (TFV-LP-4).

Fig. C-8 Fluid temperature in lower plenum, Test S-28-9 (TFV-LP-4).

Fig. C-9 Fluid temperature in lower plenum, Test S-28-7 (TFV-LP-7).

Fig. C-10 Fluid temperature in lower plenum, Test S-28-9 (TFV-LP-7).

Fig. C-11 Fluid temperature in core, Grid Spacer 5, Test S-28-7 (TFG-5CD-45).

Fig. C-12 Fluid temperature in core, Grid Spacer 5, Test S-28-9 (TFG-5CD-45).

Fig. C-13 Fluid temperature in steam generator, secondary side, Test S-28-7 (TFU-SG3).

Fig. C-14 Fluid temperature in steam generator, secondary side, Test S-28-9 (TFU-SG3).

Fig. C-15 Fluid temperature in pressurizer surge line, Test S-28-7, (TFU-PRIZE).

Fig. C-16 Fluid temperature in pressurizer surge line, Test S-28-9, (TFU-PRIZE).

Fig. C-17 Material temperature in intact loop, Test S-28-7 (TMU-1T16).

Fig. C-18 Material temperature in intact loop, Test S-28-9 (TMU-1T16).

Fig. C-19 Material temperature in vessel filler, Test S-28-7 (TMV-CI-70A).

Fig. C-20 Material temperature in vessel filler, Test S-28-9 (TMV-CI-70A).

Fig. C-21 Core heater temperature, Rod E-4, Test S-28-7 (TH-E4-09).

Fig. C-22 Core heater temperature, Rod E-4, Test S-28-9 (TH-E4-09).

Fig. C-23 Core heater temperature, Rod E-4, Test S-28-7 (TH-E4-27).

Fig. C-24 Core heater temperature, Rod E-4, Test S-28-9 (TH-E4-27).

Fig. C-25 Core heater temperature, Rod E-4, Test S-28-7 (TH-E4-55).

Fig. C-26 Core heater temperature, Rod E-4, Test S-28-9 (TH-E4-55).

Fig. C-27 Pressure in intact loop, Spool 13, Test S-28-7 (PU-13).

Fig. C-28 Pressure in intact loop, Spool 13, Test S-28-9 (PU-13).

Fig. C-29 Pressure in broken loop, Spool 23, Test S-28-7 (PB-23).

Fig. C-30 Pressure in broken loop, Spool 23, Test S-28-9 (PB-23).

Fig. C-31 Differential pressure in intact loop, Test S-28-7 (DPU-6-SGIP).

Fig. C-32 Differential pressure in intact loop, Test S-28-9 (DPU-6-SGIP).

Fig. C-33 Differential pressure in intact loop, Test S-28-7 (DPU-SGOP-7).

Fig. C-34 Differential pressure in intact loop, Test S-28-9 (DPU-SGOP-7).

Fig. C-35 Differential pressure in intact loop, Test S-28-7 (DPU-7-10).

Fig. C-36 Differential pressure in intact loop, Test S-28-9 (DPU-7-10).

Fig. C-37 Differential pressure in intact loop, Test S-28-7 (DPU-12-10).

Fig. C-38 Differential pressure in intact loop, Test S-28-9 (DPU-12-10).

Fig. C-39 Differential pressure in intact loop, Test S-28-7 (DPU-12-15).

Fig. C-40 Differential pressure in intact loop, Test S-28-9 (DPU-12-15).

Fig. C-41 Volumetric flow in intact loop, Test S-28-7 (FTU-1).

Fig. C-42 Volumetric flow in intact loop, Test S-28-9 (FTU-1).

Fig. C-43 Volumetric flow in intact loop, Test S-28-7 (FTU-15).

Fig. C-44 Volumetric flow in intact loop, Test S-28-9 (FTU-15).

Fig. C-45 Volumetric flow in intact loop high pressure injection line, Test S-28-7 (FTU-HPIS).

Fig. C-46 Volumetric flow in intact loop high pressure injection line, Test S-28-9 (FTU-HPIS).

Fig. C-47 Volumetric flow in intact loop low pressure injection line, Test S-28-7 (FTU-LPIS).

Fig. C-48 Volumetric flow in intact loop low pressure injection line, Test S-28-9 (FTU-LPIS).

Fig. C-49 Volumetric flow in intact loop accumulator discharge line, Test S-28-7 (FTU-ACC1).

Fig. C-50 Volumetric flow in intact loop accumulator discharge line, Test S-28-9 (FTU-ACC1).

Fig. C-51 Fluid velocity in vessel, Test S-28-9 (FTV-40A).

Fig. C-52 Fluid velocity in vessel, Test S-28-7 (FTV-40M).

Fig. C-53 Fluid velocity in vessel, Test S-28-9 (FTV-40M).

Fig. C-54 Density in intact loop, Test S-28-7 (GU-1T).

Fig. C-55 Density in intact loop, Test S-28-9 (GU-1T).

Fig. C-56 Density in intact loop, Test S-28-7 (GU-1B).

Fig. C-57 Density in intact loop, Test S-28-9 (GU-1B).

Fig. C-58 Density in intact loop, Test S-28-7 (GU-1C).

Fig. C-59 Density in intact loop, Test S-28-9 (GU-1C).

Fig. C-60 Density in intact loop, Test S-28-7 (GU-10VR).

Fig. C-61 Density in intact loop, Test S-28-9 (GU-10VR).

Fig. C-62 Density in intact loop, Test S-28-7 (GU-15T).

Fig. C-63 Density in intact loop, Test S-28-9 (GU-15T).

Fig. C-64 Density in intact loop, Test S-28-7 (GU-15B).

Fig. C-65 Density in intact loop, Test S-28-9 (GU-15B).

Fig. C-66 Density in intact loop, Test S-28-7 (GU-15C).

Fig. C-67 Density in intact loop, Test S-28-9 (GU-15C).

Fig. C-68 Density in broken loop, Test S-28-9 (GB-23VR).

Fig. C-69 Density in vessel, Test S-28-7 (GV-COR-150HZ).

Fig. C-70 Density in vessel, Test S-28-9 (GV-COR-150HZ).

Fig. C-71 Density in vessel, Test S-28-7 (GVLP-165HZ).

Fig. C-72 Density in vessel, Test S-28-9 (GVLP-165HZ).

Fig. C-73 Density in vessel, Test S-28-7 (GVLP-172HZ).

Fig. C-74 Density in vessel, Test S-28-9 (GVLP-172HZ).

Fig. C-75 Mass flow in intact loop, Test S-28-7 (FTU-1, GU-1C).

Fig. C-76 Mass flow in intact loop, Test S-28-9 (FTU-1, GU-1C).

Fig. C-77 Mass flow in intact loop, Test S-28-7 (FDU-5, GU-5VR).

Fig. C-78 Mass flow in intact loop, Test S-28-9 (FDU-5, GU-5VR).

Fig. C-79 Mass flow in intact loop, Test S-28-7 (FTU-15, GU-15C).

Fig. C-80 Mass flow in intact loop, Test S-28-9 (FTU-15, GU-15C).

Fig. C-81 Mass flow in broken loop, Test S-28-7 (FDB-21, GB-21C).

Fig. C-82 Mass flow in broken loop, Test S-28-9 (FDB-21, GB-21C).

Fig. C-83 Mass flow in broken loop, Test S-28-7 (FTB-21, GB-21C).

Fig. C-84 Mass flow in broken loop, Test S-28-9 (FTB-21, GB-21C).

Fig. C-85 Mass flow in vessel, Test S-28-7 (FTV-CORE-IN, GV-COR-150HZ).

Fig. C-86 Mass flow in vessel, Test S-28-9 (FTV-CORE-IN, GV-COR-150HZ).

An error analysis was not performed on Test S-28-12 due to an analog-to-digital data conversion problem experienced during the test. The resulting data traces are somewhat squared and cannot be reliably modeled in the random error evaluation program.

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

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

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.

TABLE C-II

GENERAL MEASUREMENT ENGINEERING ERROR SOURCES AND ERROR VALUES (TESTS S-28-7 and S-28-9)

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

TABLE C-II (continued)

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

TABLE C-II (continued)

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

where
 R = transducer reading (m/s)

TABLE C-II (continued)

Measurement Category	Error Sources	Error Value	Expected Error Value
Density (continued)	Flow regime	$Gr^{[d]}$	[d]
		where	
		$Gr = \text{flow regime error}$ (kg/m^3)	
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	$\pm 19.56 \times 10^{-2} \text{ l/s}$	
	Velocity profile	+2.9% of reading	
	Frequency-to-voltage conversion	+0.25% of transducer full scale	
	General data acquisition and processing	+0.1% of system full scale	

TABLE C-II (continued)

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 engineering errors.

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

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

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

TABLE C-III

TIME PERIODS WHEN FLOW REGIME ERRORS WERE APPLIED
(TESTS S-28-7 and S-28-9)

<u>Transducer Identification</u>	<u>Time during which Flow Regime Errors were Applied (s)</u>	<u>Figure</u>
GU-1C	1 to 18 80 to 600	C-58 (Test S-28-7)
	1 to 14 72 to 600	C-59 (Test S-28-9)
GU-10VR	7 to 600	C-60 (Test S-28-7)
	7 to 600	C-61 (Test S-28-9)
GU-15C	7 to 22 28 to 600	C-66 (Test S-28-7)
	8 to 22 80 to 600	C-67 (Test S-28-9)
FTU-1, GU-1C	1 to 18 80 to 600	C-75 (Test S-28-7)
	1 to 14 72 to 600	C-76 (Test S-28-9)
FDU-5, GU-5VR	2 to 25 72 to 600	C-77 (Test S-28-7)
	7 to 22 68 to 600	C-79 (Test S-28-7)
FTU-15, GU-15C	8 to 22 80 to 600	C-80 (Test S-28-9)
	2 to 600	C-83 (Test S-28-7)
FTB-GB-21C	3 to 600	C-84 (Test S-28-9)

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 random error variation and the total engineering error variance; that is,

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

where

σ_o = overall standard deviation of a data point

σ_R = random error standard deviation.

σ_E = engineering error standard deviation.

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

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

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

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

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

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- C-2. E. M. Feldman and S. A. Naff, *Error Analysis for 1-1/2-Loop Semiscale System Isothermal Test Data*, ANCR-1188 (May 1975).

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