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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1 TEST S-02-8 (BLOWDOWN HEAT TRANSFER TEST)

HERBERT S. CRAPO

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EXPERIMENT DATA REPORT FOR SEMISCALE

MOD-1 TEST S-02-8

(BLOWDOWN HEAT TRANSFER TEST)

by

Herbert S. Crapo
Kenneth E. Sackett

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EXPERIMENT DATA REPORT FOR SEMISCALE

MOD-1 TEST S-02-8

(BLOWDOWN HEAT TRANSFER TEST)

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ABSTRACT

Recorded test data are presented for Test S-02-8 of the Semiscale Mod-1 blowdown heat transfer test series. This test is one of 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 system, and to provide a data base for a regulatory standard problem.

Test S-02-8 was conducted from an initial cold leg fluid temperature of 542°F and an initial pressure of 2,262 psia. A simulated double-ended offset shear cold leg break was used to investigate the system response to a depressurization transient with full core power (1.6 MW). An electrically heated core was used in the pressure vessel to simulate the effects of a nuclear core. System flow was set to achieve the full design core temperature differential of 66°F. The flow resistance of the intact loop was based on core area scaling. During system depressurization, core power was reduced from the initial level of 1.6 MW to simulate the surface heat flux response of nuclear fuel rods until such time that departure from nucleate boiling occurs. Blowdown to the pressure suppression system was accomplished without simulated emergency core cooling injection or pressure suppression system coolant spray.

The purpose of this report is to make available the uninterpreted data from Test S-02-8 for future data analysis and test results reporting activities. The data, presented in the form of graphs in engineering units, have been analyzed only to the extent necessary to assure that they are reasonable and consistent.

SUMMARY

Test S-02-8 was performed as part of the Mod-1 portion of the Semiscale Program conducted by Aerojet Nuclear Company for the United States Government. This test was one of the Semiscale Mod-1 tests (Test Series 2) performed with an electrically heated core in place of the core simulator used in previous isothermal tests (Test Series 1). Hardware configuration and test parameters were selected to yield a system response that simulates the response of a pressurized water reactor to a hypothesized loss-of-coolant accident. Test S-02-8 utilized a pressure vessel with internals; an intact loop with active pump, steam generator, and pressurizer; a broken loop with simulated pump, simulated steam generator, and rupture assemblies; and a pressure suppression system with header and pressure suppression tank. The electrically heated core consisted of 39 heater rods with a maximum total power capacity of 1.6 MW.

Test S-02-8 was conducted from initial conditions of 2,262 psia and 542°F (at the intact loop cold leg vessel inlet), with a simulated full-size (200%), double-ended offset shear of the cold leg broken loop piping at an initial core power level of 1.6 MW and an initial core inlet flow rate of 155 gpm. The instantaneous offset shear of the broken loop cold leg piping was simulated by simultaneous actuation (within 10 milliseconds) of the rupture assemblies. During system depressurization, core power was reduced from the initial level of 1.6 MW to simulate the surface heat flux response of nuclear fuel rods until such time that departure from nucleate boiling occurs.

This test was specifically conducted for the purpose of providing a data base for the United States Nuclear Regulatory Commission's Standard Problem Five. As a part of the standard problem specification, a number of measured variables (of the more than 200 measured during Test S-02-8) were chosen to be representative of the phenomena occurring in the Semiscale system during blowdown. To aid in the comparison of the analytical predictions with the measured data, these specific variables, complete with estimated total error bands, are included as Appendix A.

The data presented in the body of this report represent all data successfully obtained for the conduct of Test S-02-8. In order to present the data in a readily usable form in advance of detailed analysis, these data have been analyzed only to the extent necessary to assure that they are reasonable and consistent.

Test S-02-8 was generally conducted as specified. Those conditions which did not conform to the specified test configuration were considered to be acceptable within the test objectives.

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DATA REPORT FOR SEMISCALE MOD-1

Test S-02-8

(Blowdown Heat Transfer Test)

I. INTRODUCTION

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

Test S-02-8 was conducted September 19, 1975 as part of a series of tests (Test Series 2) to obtain thermal-hydraulic response data from a blowdown transient in a simulated nuclear reactor with a heated core to provide an experimental basis for analytical model development and verification. Specifically, Test S-02-8 was a large-break test conducted to provide a data base for a regulatory standard problem.

For this test, a 39-rod electrically heated core was used in the core barrel of the pressure vessel in place of the core simulator used in previous (isothermal) tests. (The heater array can accommodate forty rods, but one location was used for a water level detector.) The initial core power level was set at the maximum design power of 1.6 MW. The radial power profile was flat. During the blowdown, the core heater power was adjusted to simulate the thermal response characteristics of nuclear-heated rods prior to departure from nucleate boiling (DNB). The pipe break configuration simulated a full-size (200%), double-ended break in the cold leg broken loop piping.

The purpose of this report is to present the test data in an uninterpreted, but readily usable form for use by the nuclear community in advance of detailed analysis and interpretation. Section II briefly describes the system configuration, procedures, initial test conditions, and events that are applicable to Test S-02-8. A description of the overall Semiscale Program and test series, a more detailed description of the Semiscale Mod-1 system, and a description of the measurement and data processing techniques and uncertainties can be found in Reference 1.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TEST S-02-8

The following system configuration, procedures, initial test conditions, and events are specific to Test S-02-8.

1. SYSTEM CONFIGURATION AND TEST PROCEDURES

The Semiscale Mod-1 system used for Test S-02-8 consisted of a pressure vessel with internals; an intact loop with steam generator, pump, and pressurizer; a blowdown loop with simulated steam generator, simulated pump, and two rupture assemblies; a 39-rod electrically heated core; and a pressure suppression system with a suppression tank and header. For this test the intact loop steam generator was maintained in the active condition, in which the steam generator secondary pressure and water level are automatically adjusted to control the water temperature in the cold leg of the intact loop.

In preparation for Test S-02-8 the system was filled with treated demineralized water and vented at strategic points to assure a liquid-full system. Prior to warmup, the system was pressurized to check for leakage. 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 100-degree 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. After the core power was increased to 1.6 MW, initial test conditions were held for about 13 minutes to establish equilibrium in the system. At the end of this period all auxiliary systems including the bypass lines were isolated to prevent blowdown through those systems.

The system was successfully subjected to a simulated double-ended cold leg pipe break through two rupture assemblies and two blowdown nozzles, each nozzle having a break area of 0.00262 ft². Pressure to operate the rupture assemblies and initiate blowdown was taken from an accumulator system filled with water and pressurized to 2,250 psig with gaseous nitrogen. Immediately (0.02 second) after initiation of blowdown, the lines to the accumulator were again isolated. The effluent from the primary system was ejected into the pressure suppression system. During the blowdown transient, power to the primary coolant circulation pump was controlled to maintain the speed of the pump as close as possible to its initial value for the duration of the test. A flywheel mounted on the pump motor shaft aided in controlling the speed of the pump. During the blowdown transient, power to the electrically heated core was automatically controlled to simulate the thermal response of the nuclear-heated fuel rods until such time as DNB occurred.

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</u> ^[a]	<u>Specified</u>
Core power	1.59 MW	1.60 ± 0.01 MW
Intact loop cold leg fluid temperature	542°F	544° ± 2°F
Hot leg to cold leg temperature differential	68°F	66° ± 1°F
Pressurizer pressure	2,262 psia	2,263 ± 5 psia
Pressurizer water volume	0.58 ft ³	[b]
Steam generator feedwater temperature	430°F	435° ± 10°F
Steam generator liquid level (from bottom of tube sheet)	116 in.	116 ± 2 in.
Fluid temperature in broken loop (pump side)	595°F	605 ± 5°F
Intact loop cold leg flow	155 gpm	[c]
Pressure suppression tank water level	65 in.	65.4 in.
Pressure suppression tank pressure	32 psia	32 psia
Pressure suppression tank water temperature	74°F	75°F

[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 water volume was specified in terms of differential pressure in the level measuring system.

[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 AT RUPTURE

	<u>Detector</u>	<u>Temperature (°F)</u>
Vessel lower plenum (lower portion)	TFV-LP-7.5	540
Vessel lower plenum (upper portion)	TFV-LP-27.5	543
Hot leg, intact loop (near vessel)	RBU-2	609
Cold leg, intact loop (near steam generator)	TFU-10	539
Cold leg, intact loop	RBU-14A	542
Cold leg, broken loop (near nozzle)	TFB-23	536
Hot leg, broken loop (near vessel)	TFB-30	606
Cold leg, broken loop (near nozzle)	TFB-42	595

TABLE IIIWATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

pH	10.5
Conductivity (μmhos/cm)	98.2
Lithium (ppm)	3.1
Chlorides (ppm)	0.14
Fluorides (ppm)	<0.3
Oxygen (ppm)	<0.1
Total gas (cc/l)	178.0

[a] Water sample taken at a system pressure of 2,250 psig and a system temperature of 540°F.

TABLE IV
SEQUENCE OF EVENTS DURING TEST^[a]

Event	Time Relative to Rupture
Established core power level	-13.0 min
Bypass lines valved out of system	-2.5 sec
Initiation of blowdown	0.0 sec
Steam generator feedwater and discharge valves closed	1.0 sec
Core power tripped off	42.0 sec
Pump power tripped off	42.0 sec

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

III. DATA PRESENTATION

The data from Test S-02-8 are presented with brief comment. Processing analysis has been performed only to the extent necessary to obtain appropriate engineering units and to assure that the data are reasonable and consistent. In all cases, in converting transducer output to engineering units, a homogeneous fluid was assumed. Further 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 the test was monitored by about 200 detectors. The data obtained were recorded on both digital and analog data acquisition systems. The digital system was used to process the data presented in this report. The analog system was used primarily to provide redundancy.

The data are presented in the form of graphs of single test measurements. The scales selected for the graphs do not reflect the obtainable resolution of the data (the data processing techniques are described in greater detail in Reference 1).

Figures 1 through 6 and Table V provide supporting information for interpretation of the data graphs shown in Figures 7 through 234. Figures 1 through 6 show the relative locations of detectors used during Test S-02-8. Table V groups the measurements taken during Test S-02-8 according to measurement type; identifies the specific measurement location, and the range of the detector and actual recording range of the data acquisition system; provides brief comments regarding the data; and references the measurements and comments to the corresponding figure. Figures 7 through 234 represent all the blowdown data obtained. Time zero on the graphs is the time of rupture initiation.

Presented in Appendix A are selected data, complete with estimated total error bands, which were chosen to provide a basis of comparison with analytical predictions submitted by participants in the Regulatory Standard Problem activity.

Test S-02-8
ANCA-9528

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

Fig. 3 Semiscale Mod-1 pressure vessel -- cross section showing instrumentation.

Test S-02-8
ANC-B-9435

Test S-02-B
ANC-A-9436

Fig. 4 Semiscale Mod-1 pressure vessel -- isometric showing instrumentation.

Fig. 5 Semiscale Mod-1 pressure vessel -- penetrations and instrumentation.

Fig. 6 Semiscale Mod-1 heater core -- plan view.

TABLE V
DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
FLUID TEMPERATURE	Chromel-Alumel thermocouples unless specified otherwise	0-2,300°F	0-1,017°F		
Intact Loop					
RBU-2	Hot leg, Spool 2, 46 in. from vessel center (platinum resistance bulb)	0-1,000°F	0-1,000°F	7	
TFU-5	Hot leg, Spool 5, 104 in. from vessel center				Thermocouple failed
TFU-10	Cold leg, Spool 10, 144 in. from vessel center			8	
RBU-14A	Cold leg, Spool 14, 43 in. from vessel center, upstream of cold leg injection port (platinum resistance bulb)	0-1,000°F	0-1,000°F	9	
Broken Loop		0-2,300°F	0-591°F		
TFB-20	Cold leg, Spool 20, 21 in. from vessel center			10	
TFB-23	Cold leg, Spool 23, 91 in. from vessel center, upstream of vessel-side nozzle			11	
TFB-30	Hot leg, Spool 30, 16 in. from vessel center	0-2,300°F	0-1,017°F	12	
TFB-42	Cold leg, Spool 42, 414 in. from vessel center along cold leg, upstream of pump-side nozzle	0-2,300°F	0-1,017°F	13	Spurious transient near t=9 sec.
Downcomer Annulus		0-1,400°F	0-803°F		
TFV-ANN-15M	15 in. below cold leg centerline, 180°			14	
TFV-ANN-35A	35 in. below cold leg centerline, 0°			15	
TFV-ANN-35T	35 in. below cold leg centerline, 270°			16	
TFV-ANN-115A	115 in. below cold leg centerline, 0°			17	
TFV-ANN-115M	115 in. below cold leg centerline, 180°			18	
Upper Plenum		0-2,300°F	0-1,017°F		
TFV-UP-13	In upper plenum, 13.5 in. above cold leg centerline at 180°			19	
Lower Plenum		0-2,300°F	0-1,017°F		
TFV-LP-7.5	7.5 in. from bottom			20	
TFV-LP-14.5	14.5 in. from bottom			21	
TFV-LP-27.5	27.5 in. from bottom			22	
Core Grid Spacers		0-2,300°F	0-2,382°F		
Grid Spacer 5					
TFG-5CD-45	55 in. below cold leg centerline, 21.5 in. above top of heated length Thermocouple in space defined by Columns C and D, Rows 4 and 5			23	
Grid Spacer 6					
TFG-6AB-45	76 in. below cold leg centerline, 1/2 in. above top of heated length Thermocouple in space defined by Columns A and B, Rows 4 and 5			24	
TFG-6CD-45	Thermocouple in space defined by Columns C and D, Rows 4 and 5			25	
TFG-6DE-45	Thermocouples in space defined by Columns D and E, Rows 4 and 5, and 6 and 7			26	
TFG-6DE-67				27	
TFG-6GH-45	Thermocouple in space defined by Columns G and H, Rows 4 and 5			28	
Grid Spacer 8					
	109 in. below cold leg centerline at center of heated length				

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Grid Spacer 8 (contd.)</u>					
TFG-8CD-45	Thermocouple in space defined by Columns C and D, Rows 4 and 5			29	
TFG-8DE-23	Thermocouples in space defined by Columns D and E, Rows 2 and 3, 4 and 5, 6 and 7			30	
TFG-8DE-45				31	
TFG-8DE-67				32	
TFG-8EF-45	Thermocouple in space defined by Columns E and F, Rows 4 and 5			33	
<u>Grid Spacer 10</u>					
	143 in. below cold leg centerline at bottom of heated length				
TFG-10CD-45	Thermocouple in space defined by Columns C and D, Rows 4 and 5			34	
TFG-10DE-67	Thermocouple in space defined by Columns D and E, Rows 6 and 7			35	
TFG-10EF-45	Thermocouple in space defined by Columns E and F, Rows 4 and 5			36	
TFG-10GH-45	Thermocouple in space defined by Columns G and H, Rows 4 and 5			37	
<u>Steam Generator</u>					
		0-2,300°F	0-591°F		
TFU-SGFW	In feedwater line leading to steam generator			38	
TFU-SGSD	In steam dump, 129.5 in. from bottom of tube sheet			39	
TFU-SG1	Secondary side, 12 in. above bottom of tube sheet			40	
TFU-SG2	Secondary side, 24 in. above bottom of tube sheet			41	
TFU-SG3	Secondary side, 48 in. above bottom of tube sheet			42	
TFU-SG4	Secondary side, 96 in. above bottom of tube sheet			43	
<u>Pressurizer</u>					
		0-2,300°F	0-1,017°F		
TFU-PRIZE	In surge line, near pressurizer exit, between turbine flowmeter and pressurizer			44	
<u>Pressure Suppression System</u>					
		0-2,300°F	0-591°F		
TF-PSS-33	33 in. from bottom of tank			45	
TF-PSS-130	130 in. from bottom of tank			46	
<u>MATERIAL TEMPERATURE</u>					
	Chromel-Alumel thermocouples unless specified otherwise	0-2,300°F	0-591°F		
<u>Intact Loop</u>					
TMU-/S16	Cold leg, Spool 7, side, 1/16 in. from pipe ID, 242 in. from vessel center (vertical pipe)			47	
TMU-8S16	Cold leg, Spool 8, side, in pump trap, 1/16 in. from pipe ID, 195 in. from vessel center			48	
<u>Broken Loop</u>					
		0-2,300°F			
TMB-20T16	Cold leg, Spool 20, top, 1/16 in. from pipe ID, 21 in. from vessel center		0-591°F	49	
TMB-20T4	Hot leg, Spool 20, top, 1/4 in. from pipe ID, 16 in. from vessel center		0-1,017°F	50	
TMB-30T16	Hot leg, Spool 30, top, 1/16 in. from pipe ID, 16 in. from vessel center		0-1,017°F	51	
<u>Vessel Wall</u>					
	1/8 in. from vessel ID	0-2,300°F	0-591°F		

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Vessel Wall (contd.)</u>					
TMV-VI-15A	15 in. below cold leg centerline, 0°			52	
<u>Vessel Filler</u>					
TMV-PO-35A	Type J iron-constantan	0-1,400°F	0-803°F		
TMV-PO-35A	35 in. below cold leg centerline, 0.65 in. from filler ID, 0°			53	
TMV-VI-35M	35 in. below cold leg centerline, 1/16 in. from filler ID, 180°			54	
<u>Vessel Filler Insulator</u>					
TIV-PO-35A	Outer surface of insulator, Type J iron-constantan	0-1,400°F	0-803°F		
TIV-PO-35A	35 in. below cold leg centerline, 0°			55	
<u>Core Barrel</u>					
TMV-CO-35A	Type J iron-constantan	0-1,400°F	0-803°F		
TMV-CO-35A	35 in. below cold leg centerline, 1/16 in. from core barrel OD, 0°			56	
TMV-CI-35A	35 in. below cold leg centerline, 1/16 in. from core barrel ID, 0°			57	
<u>Core Heater Cladding Temperatures</u>		0-2,300°F	0-2,382°F		
<u>High Power Heaters</u>					
TH-D4-14	Heater at Column D Row 4. Thermocouples 14 in. (270°), 29 in. (315°), and 60 in. (105°) above bottom of core			58	
TH-D4-29				59	
TH-D4-60				60	
TH-D5-09	Heater at Column D Row 5. Thermocouples 9 in. (45°), 29 in. (225°) and 39 in. (135°) above bottom of core			61	
TH-D5-29				62	
TH-D5-39				63	
TH-E4-23	Heater at Column E Row 4. Thermocouples 23 in. (90°) and 27 in. (0°) above bottom of core.			64	
TH-E4-27				65	
TH-E5-14	Heater at Column E, Row 5. Thermocouples 14 in. (330°), 21 in. (180°), and 25 in. (90°) above bottom of core			66	
TH-E5-21				67	
TH-E5-25				68	
<u>Low Power Heaters</u>					
TH-A4-09	Heater at Column A Row 4. Thermocouples 9 in. (105°), 29 in. (240°), 33 in. (135°), and 39 in. (300°) above bottom of core			69	
TH-A4-29				70	
TH-A4-33				71	
TH-A4-39				72	
TH-A5-29	Heater at Column A Row 5. Thermocouples 29 in. (180°) above bottom of core			73	
TH-B3-32	Heater at Column B Row 3. Thermocouples 32 in. (135°) above bottom of core			74	
TH-B5-29	Heater at Column B Row 5. Thermocouples 29 in. (150°) above bottom of core			75	
TH-B6-29	Heater at Column B Row 6. Thermocouple 29 in. (45°) above bottom of core			76	
TH-C2-28	Heater at Column C Row 2. Thermocouples 28 in. (135°) above bottom of core			77	
TH-C3-13	Heater at Column C Row 3. Thermocouples 13 in. (285°), 28 in. (0°) and 60 in. (150°) above bottom of core			78	
TH-C3-28				79	
TH-C3-60				80	
TH-C4-26	Heater at Column C Row 4. Thermocouples 26 in. (75°) above bottom of core			81	
TH-C5-28	Heater at Column C Row 5. Thermocouples 28 in. (315°) above bottom of core			82	
TH-C6-20	Heater at Column C Row 6. Thermocouples 20 in. (165°) and 32 in. (225°) above bottom of core			83	
TH-C6-32				84	
TH-C7-15	Heater at Column C Row 7. Thermocouple 15 in. (255°) above bottom of core			85	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
Low Power Heaters (contd.)					
TH-D2-14	Heater at Column D Row 2. Thermocouples 14 in. (0°) above bottom of core			86	
TH-D3-29	Heater at Column D Row 3. Thermocouples 29 in. (150°), above bottom of core			87	
TH-D6-15	Heater at Column D Row 6. Thermocouples 15 in. (90°), 22 in. (345°), and 25 in. (255°) above bottom of core			88	TH-D6-22 not reported; thermocouple failed before start of test.
TH-D6-22				--	
TH-D6-25				89	
TH-D7-20	Heater at Column D Row 7. Thermocouple 20 in. (60°) above bottom of core			90	
TH-D8-25	Heater at Column D Row 8. Thermocouple 25 in. (0°) above bottom of core			91	
TH-E1-27	Heater at Column E Row 1. Thermocouples 27 in. (195°) and 33 in. (60°) above bottom of core			92	TH-E7-44 - spurious transient at t=11.2 sec due to data processing systems. TH-E7-60 failed.
TH-E1-33				93	
TH-E2-33	Heater at Column E Row 2. Thermocouple 33 in. (315°) above bottom of core			94	
TH-E3-05	Heater at Column E Row 3. Thermocouples 5 in. (15°), and 20 in. (165°), above bottom of core			95	
TH-E3-20				96	
TH-E6-08	Heater at Column E Row 6. Thermocouples 8 in. (150°), 28 in. (285°), 31 in. (225°), and 37 in. (330°) above bottom of core			97	
TH-E6-28				98	
TH-E6-31				99	
TH-E6-37				100	
TH-E7-13	Heater at Column E Row 7. Thermocouples 13 in. (45°), 29 in. (120°), 44 in. (195°), and 60 in. (270°) above bottom of core			101	TH-E7-44 - spurious transient at t=11.2 sec due to data processing systems. TH-E7-60 failed.
TH-E7-29				102	
TH-E7-44				103	
TH-E7-60				---	
TH-E8-14	Heater at Column E Row 8. Thermocouples 14 in. (150°), 29 in. (225°), and 45 in. (300°) above bottom of core			104	
TH-E8-29				105	
TH-E8-45				106	
TH-F2-22	Heater at Column F Row 2. Thermocouples 22 in. (105°) and 25 in. (0°) above bottom of core			107	
TH-F2-25				108	
TH-F3-22	Heater at Column F Row 3. Thermocouples 22 in. (105°) and 25 in. (30°) above bottom of core			109	
TH-F3-25				110	
TH-F4-14	Heater at Column F Row 4. Thermocouples 14 in. (90°), and 28 in. (165°) above bottom of core			111	
TH-F4-28				112	
TH-F5-20	Heater at Column F Row 5. Thermocouples 20 in. (255°), 26 in. (165°), 33 in. (315°), and 53 in. (30°) above bottom of core			113	
TH-F5-26				114	
TH-F5-33				115	
TH-F5-53				116	
TH-F6-08	Heater at Column F Row 6. Thermocouples 8 in. (60°), 28 in. (135°), and 28 in. (210°) above bottom of core			117	
TH-F6-28				118	
TH-F6-28				119	
TH-F7-29	Heater at Column F Row 7. Thermocouples 29 in. (150°), 33 in. (45°), and 39 in. (210°) above bottom of core			120	
TH-F7-33				121	
TH-F7-39				122	
TH-G4-33	Heater at Column G Row 4. Thermocouples 33 in. (225°) above bottom of core			123	
TH-G5-14	Heater at Column G Row 5. Thermocouples 14 in. (45°) and 24 in. (330°) above bottom of core			124	
TH-G5-24				125	
TH-G6-21	Heater at Column G Row 6. Thermocouples 21 in. (60°), 33 in. (135°), and 53 in. (195°) above bottom of core			126	TH-G6-21 - thermocouple opened at t=20 sec.
TH-G6-33				127	
TH-G6-53				128	
TH-H4-28	Heater at Column H Row 4. Thermocouple 28 in. (315°) above bottom of core			129	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
PRESSURE		0-3,000 psi			
<u>Intact Loop</u>					
PU-5(P)	Hot leg, Spool 5, 100 in. from vessel center (flush mount)		0-4,676 psia	130	
PU-7	Cold leg, Spool 7, 240 in. from vessel center		0-4,955 psia	131	
PU-13(P)	Cold leg, Spool 13, 54 in. from vessel center (flush mount)		0-4,384 psia	132	
		0-3,000 psi			
<u>Broken Loop</u>					
PB-23	Cold leg, Spool 23, 92 in. from vessel center, upstream of nozzle (tee off DP tap)		0-2,300 psia	133	
PB-CN1	Vessel-side nozzle, nozzle throat, 96 in. from vessel center, (tee off DP tap)		0-4,606 psia	134	
PB-42	Cold leg, Spool 42, 415 in. from vessel center along hot leg, upstream of pump-side nozzle (tee off DP tap)		0-3,276 psia	135	
PB-HN1	Pump-side nozzle, nozzle throat, 419 in. from vessel center along hot leg (tee off DP tap)		0-4,624 psia	136	
		0-3,000 psi			
<u>Vessel</u>					
PV-UP+10	In upper plenum, 10 in. above cold leg centerline, mounted on standoff, 30°		0-3,397 psia	137	
PV-LP-180	In upper part of lower plenum, 180 in. below cold leg centerline, mounted on standoff, 225°		0-2,563 psia	138	
		0-3,000 psi			
<u>Steam Generator</u>					
PU-SGSD	Secondary side, steam dome		0-1,521 psia	139	
PU-SGIP	Inlet plenum, 13 in. below bottom of tube sheet (flush mount)		0-4,603 psia	140	
		0-3,000 psi			
<u>Pressurizer</u>					
PU-PRIZE	Steam dome			141	
<u>Pressure Suppression System</u>					
P-PSS	Suppression tank top	0-750 psi	0-321.1 psia	142	
P-83	Suppression tank header just downstream from entrance to suppression tank	0-750 psi	0-380 psia	143	
DIFFERENTIAL PRESSURE					
Elevation difference between transducer taps is zero unless otherwise specified					
<u>Intact Loop</u>					
DPU-UP-1	Upper plenum 10.5 in. above cold leg centerline at 30° to intact loop hot leg, Spool 1, 31 in. from vessel center, upper plenum tap is ~2 in. above Spool 1 tap	±100 in. water	±5.0 psid	144	
DPU-1-3	Hot leg Spool 1, 31 in. from vessel center to hot leg Spool 3, 62 in. from vessel center	±20 in. water	±1.0 psid	145	
DPU-3-6	Hot leg Spool 3, 62 in. from vessel center to hot leg Spool 6, 114 in. from vessel center	±20 in. water	±1.0 psid	146	Detector saturated from t=1 to t=4 seconds.
DPU-6-7	Hot leg Spool 6, 114 in. from vessel center, across steam generator, to cold leg Spool 7, 231 in. from vessel center. Spool 6 tap is 17 in. above Spool 7 tap	±500 in. water	±25 psid	147	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Intact Loop (contd.)</u>					
DPU-SGOF-7	From steam generator outlet plenum, 269 in. from vessel center along cold leg to cold leg Spool 7, 231 in. from vessel center, including orifice. Spool 7 tap is 33 in. below SGOF tap	±500 in. water	±25 psid	148	
DPU-7-10	Steam generator outlet to pump inlet, cold leg Spool 7, 231 in. from vessel center to cold leg Spool 10, 141 in. from vessel center	±50 in. water	±2.5 psid	149	Detector saturated near t=5 seconds.
DPU-12-10	Pump outlet to pump inlet, cold leg Spool 12, 75 in. from vessel center to cold leg Spool 10, 141 in. from vessel center. Spool 10 tap is 10 in. below Spool 12 tap	±100 psid	±100 psid	150	
DPU-12-10L	Pump outlet to pump inlet, cold leg Spool 12, 75 in. from vessel center to cold leg Spool 10, 141 in. from vessel center. Spool 10 tap is 10 in. below Spool 12 tap (low range)	±100 in. water	±5.0 psid	151	Detector saturated to t=5 seconds.
DPU-12-15	Across cold leg injection point, cold leg Spool 12, 75 in. from vessel center to cold leg Spool 15, 16 in. from vessel center	±100 in. water	±10 psid	152	Detector saturated intermittently to t=5 seconds.
DPU-15-1	Cold leg to hot leg, cold leg Spool 15, 16 in. from vessel center to hot leg Spool 1, 31 in. from vessel center. Spool 15 tap is 8.5 in. below Spool 1 tap	±500 in. water	±25 psid	153	
DPU-15-IANN	Cold leg Spool 15, 16 in. from vessel center to inlet annulus 9 in. below cold leg centerline at 225°. Spool 15 tap is 9 in. above inlet annulus tap	±100 in. water	±5.0 psid	154	
DPU-15-ATM	Cold leg Spool 15, 16 in. from vessel center to atmosphere	±500 psid	±500 psid	155	Detector saturated to t=16 seconds.
DPU-PRESLL	Pressurizer water level, elevation difference between taps is 34 in. Lower tap is 3.5 in. above pressurizer exit	±50 in. water	±2.5 psid	156	
<u>Broken Loop</u>					
DPB-CN1-CN4	Vessel-side nozzle, nozzle throat, 96 in. from vessel center to nozzle divergent section, 101 in. from vessel center	±1,000 psid	±1,000 psid	157	
DPB-30-36L	Across entire simulated steam generator assembly, hot leg Spool 30, 18 in. from vessel center to cold leg Spool 36 lower tap, 242 in. from vessel center. Spool 30 tap is 19 in. below Spool 36 lower tap	±500 psid	±500 psid	158	
DPB-32U-36L	Across simulated steam generator orifice assembly, hot leg Spool 32 upper tap, 73 in. from vessel center to Spool 36 lower tap, 242 in. from vessel center. Spool 32 upper tap is 16 in. above Spool 36 lower tap	±500 psid	±500 psid	159	
DPB-38-40L	Across simulated pump, cold leg Spool 38, 305 in. from vessel center along hot leg to cold leg Spool 40, 365 in. from vessel center along hot leg	±1,000 psid	±1,000 psid	160	
<u>Vessel</u>					
NPV-TANN-UP	Inlet annulus, 9 in. below cold leg centerline at 225° to upper plenum, 10.5 in. above cold leg centerline at 30°. Elevation difference between taps is 19 in.	±500 in. water	±25 psid	161	
DPV-9-1800Q	Inlet annulus, 9 in. below cold leg centerline at 225° to lower plenum, 180 in. below cold leg centerline at 225°. Elevation difference between taps is 171 in.	±300 in. water	±15 psid	162	
DPV-22M	Differential pressure from inside to outside of downcomer filler insulator, 22 in. below cold leg centerline at 180°	±1,000 psid	±1,000 psid	163	Questionable data.

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Vessel (contd.)</u>					
DPV-26-55QM	Across part of downcomer, 26 in. (225°) to 55 in. (180°) below centerline of cold leg. Elevation difference between taps is 29 in.	+50 in. Water	+2.5 psid	164	
DPV-156-173QQ	Across downcomer exit, 7 in. above exit to 10 in. below exit, taps at 156 in. (225°) and 173 in. (225°) below cold leg centerline. Elevation difference between taps is 17 in.	+20 in. Water	+1.0 psid	165	
DPV-166-191OT	Across lower plenum, 166 in. (225°) to 191 in. (270°) below cold leg centerline. Elevation difference between taps is 25 in.	+50 in. Water	+2.5 psid	166	
DPV-LP-UP	Lower plenum, 180 in. below cold leg centerline at 225° to lower plenum 10.5 in. above cold leg centerline at 30°. Elevation difference between taps is 191 in.	+300 in. Water	+15 psid	167	
DPU-UP-1	Upper plenum, 10.5 in. above cold leg centerline at 30° to intact loop hot leg Spool 1, 31 in. from vessel center, Upper plenum tap is ~2 in. above Spool 1 tap	+100 in. Water	+5.0 psid	144	
DPU-15-IANN	Cold leg Spool 15, 16 in. from vessel center to inlet annulus 9 in. below cold leg centerline at 225°. Spool 15 tap is 9 in. above inlet annulus tap	+100 in. Water	+5.0 psid	154	
<u>Steam Generator</u>					
DPS-SG-FEED	In steam generator feed line	+100 in. Water	+5.0 psid	168	
DPS-SG-DISC	In steam generator discharge line	+100 in. Water	+5.0 psid	169	
DPU-SGOP-7	Outlet plenum to intact loop hot leg Spool 7, including orifice. SGOP tap is 7 in. above Spool 7 tap	+500 in. Water	+25 psid	148	
DPU-SG-SEC	Secondary side, differential pressure taps at 45 and 126 in. above bottom of tube sheet. Elevation difference between taps is 81 in.	+100 in. Water	+5.0 psid	170	
<u>Pressurizer</u>					
DPU-PRESLL	Pressurizer water level. Elevation difference between taps is 34 in. Lower tap is ~3.5 in. above pressurizer exit	+50 in. Water	+2.5 psid	156	
<u>VOLUMETRIC FLOW RATE</u>					
<u>Intact Loop</u>					
3-in. Schedule 160 pipe					
FTU-1	Hot leg, Spool 1, 18 in. from vessel center	+20 - +400 gpm	+800 gpm	171	
FTU-9	Cold leg, Spool 9, 154 in. from vessel center	+20 - +400 gpm	+800 gpm	172	
FTU-13	Cold leg, Spool 13, 64 in. from vessel center	+20 - +400 gpm	+800 gpm	173	
FTU-15	Cold leg, Spool 15, 29 in. from vessel center	+10 - +200 gpm	+300 gpm	174	Data acquisition system saturated from t=23 to t=33 seconds.
<u>Broken Loop</u>					
3-in. schedule 160 pipe					
FTB-21	Cold leg, Spool 21, 58 in. from vessel center	+20 - +400 gpm	+1,500 gpm	175	
FTB-30	Hot leg, Spool 30, 25 in. from vessel center	+20 - +400 gpm	+700 gpm	176	
<u>Core</u>					
FTV-CORE-IN	Entrance to core, ~158 in. below cold leg centerline	+20 - +400 gpm	+400 gpm	177	
<u>Pressurizer</u>					
1-1/2-in. turbine					
FTU-PRIZE	Surge line	+5 - +100 gpm	+100 gpm	178	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
FLUID VELOCITY					
Turbine flowmeter, bidirectional					
Downcomer Gap					
FTV-40A	40 in. below cold leg centerline, 0°	+2.5 - +50 ft/sec	+70 ft/sec	179	Measurement is unidirectional due to failure of one pickup probe.
FTV-40H	40 in. below cold leg centerline, 180°	+2.5 - +50 ft/sec	+50 ft/sec	180	
FTV-83H	83 in. below cold leg centerline, 180°	+2.5 - +50 ft/sec	+40 ft/sec	181	
MOMENTUM FLUX					
Drag disc, bidirectional					
1-in. pipe					
FDU-1	Hot leg, Spool 1, 29 in. from vessel center, target size 1.0 in.	+1 - +2,000 lbm/ft-sec ²	+3,250 lbm/ft-sec ²	182	
FDU-5	Hot leg, Spool 5, 100 in. from vessel center, target size 1.0 in.	+1 - +2,000 lbm/ft-sec ²	+4,250 lbm/ft-sec ²	183	
FDU-10	Cold leg, Spool 10, 137 in. from vessel center, target size 0.875 in.	+200 - +104,000 lbm/ft-sec ²	+21,000 lbm/ft-sec ²	184	
FDU-13	Cold leg, Spool 13, 54 in. from vessel center, target size 0.875 in.	+200 - +14,800 lbm/ft-sec ²	+18,750 lbm/ft-sec ²	185	
FDU-15	Cold leg, Spool 15, 19 in. from vessel center, target size 0.875 in.	+200 - +14,500 lbm/ft-sec ²	+18,770 lbm/ft-sec ²	186	
Broken Loop					
FDB-21	Cold leg, Spool 21, 53 in. from vessel center, 3-in. pipe, target size 0.406 in.	+200 - +70,500 lbm/ft-sec ²	+87,940 lbm/ft-sec ²	187	
FDB-23	Cold leg, Spool 23, 93 in. from vessel center, upstream of vessel-side nozzle, 2.0-in. pipe, target size 0.406 in.	+200 - +125,000 lbm/ft-sec ²	+125,320 lbm/ft-sec ²	188	
FDB-30	Hot leg, Spool 30, 21 in. from vessel center, 3 in. pipe, target size 0.656 in.	+200 - +60,000 lbm/ft-sec ²	+44,250 lbm/ft-sec ²	189	
FDB-42	Cold leg, Spool 42, 416 in. from vessel center along hot leg, upstream of pump-side nozzle, downstream of injection point, 2.0-in. pipe, target size 0.406 in.	+200 - +116,000 lbm/ft-sec ²	+131,340 lbm/ft-sec ²	190	
Vessel					
FDV-CORE-IN	In core flow mixer box, 150 in. below cold leg centerline, target size 1.0 x 2.0 in.	+200 - +3,000 lbm/ft-sec ²	+4,750 lbm/ft-sec ²	191	
DENSITY					
Intact Loop					
		0.1-100 lbm/ft ³	0-100 lbm/ft ³		
GU-1VR	Hot leg, Spool 1, 24 in. from vessel center, vertical			192	
GU-1HZ	Hot leg, Spool 1, 26 in. from vessel center, horizontal			193	
GU-5VR	Hot leg, Spool 5, 96 in. from vessel center, vertical			194	
GU-10VR	Cold leg, Spool 10, 141 in. from vessel center, vertical			195	
GU-13VR	Cold leg, Spool 13, 39 in. from vessel center, vertical			196	
GU-15RZ	Cold leg, Spool 15, 20 in. from vessel center, horizontal			197	
GU-15VR	Cold leg, Spool 15, 23 in. from vessel center, vertical			198	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
<u>Broken Loop</u>		0.1-100 lbm/ft ³	0-100 lbm/ft ³		
GB-21VR	Cold leg, Spool 21, 49 in. from vessel center, vertical			199	
GB-23VR	Cold leg, Spool 23, 92 in. from vessel center, vertical			200	
GB-30VR	Hot leg, Spool 30, 18 in. from vessel center, vertical			201	
GB-42VR	Cold leg, Spool 42, 415 in. from vessel center along hot leg, vertical			202	
<u>Vessel</u>		0.1-100 lbm/ft ³	0-100 lbm/ft ³	203	
GV-COR-150HZ	Core flow mixer box, 152 in. below cold leg centerline, horizontal, 0-180°				
GV-161-192D	Lower plenum 161 in. below cold leg centerline (270°) to 192 in. below cold leg centerline (90°), 31 in. vertical 32.2 in. diagonal			204	
GVLP-165HZ	Upper part of lower plenum, 165 in. below cold leg centerline, 1.724 in. below downcomer exit, horizontal, 0-180°			205	
GVLP-172HZ	Lower plenum, 172 in. below cold leg centerline, 8.729 in. below downcomer exit, horizontal, 90-270°			206	
<u>Pressurizer</u>		0.1-100 lbm/ft ³	0-100 lbm/ft ³		
GU-PRIZE	Surge line			207	
<u>LIQUID LEVEL</u>					
<u>Steam Generator</u>					
DPU-SG-SEC	Secondary side, differential pressure taps at 45 and 126 in. above tube sheet. Elevation difference between taps is 81 in.	+100 in. water	+5.0 psid	170	
<u>Pressurizer</u>					
DPU-PRESLL	Pressurizer water level. Elevation difference between taps is 34 in. Lower tap is 3.5 in. above pressurizer exit	+50 in. water	+2.5 psid	156	
<u>MASS FLOW RATE</u>	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			
<u>Intact Loop</u>					
FDU-1, GU-1VR	Hot leg, Spool 1			208	
FTU-1, GU-1VR				209	
FDU-5, GU-5VR	Hot leg, Spool 5			210	
FTU-9, GU-10VR	Cold leg, Spool 9			211	
FDU-10, GU-10VR	Cold leg, Spool 10			212	
FDU-13, GU-13VR	Cold leg, Spool 13			213	
FTU-13, GU-13VR				214	
FDU-15, GU-15VR	Cold leg, Spool 15			215	
FTU-15, GU-15VR				216	
FTU-PRIZE, GU-PRIZE	Pressurizer surge line			217	
<u>Broken Loop</u>					
FDB-21, GB-21VR	Cold leg, Spool 21			218	
FTB-21, GB-21VR				219	
FDB-23, GB-23VR	Cold leg, Spool 23			220	
FDB-30, GB-30VR	Hot leg, Spool 30			221	
FTB-30, GB-30VR				222	

TABLE V (contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-02-8

Measurement	Location and Comments [a]	Detector	Range [a]	Figure [a]	Measurement Comments [b]
			Data Acquisition System		
<u>Broken Loop (contd.)</u>					
FDB-42, GB-42VR	Cold leg, Spool 42			223	
<u>Vessel</u>					
FTV-CORE-IN, GV-COR-150HZ	Entrance to core			224	
FDV-CORE-IN, GV-COR-150HZ	Entrance to core			225	
FTV/FDV-CORE-IN, GV-COR-150HZ	Composite			226	Data from $t = -6$ to $t = 1$ sec is taken from FDV-CORE-IN; remainder from FTV-CORE-IN
<u>CORE CHARACTERISTICS</u>					
PWRCOR T-1	Core Power			227	
PWSMR T-2	Core Power			228	
VOLTCOR-T	Core Voltage			229	
AMPCOR-T	Core Current			230	
P5 AMPS	Total Current Heater Rod P5			231	
<u>PUMP CHARACTERISTICS</u>					
PUMPU-TORQ	Pump torque			232	
PUMPU-PW	Pump motor power			233	
PUMPU-RPM	Pump speed			234	

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

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

Fig. 7 Fluid temperature in intact loop, Spool 2 (RBU-2).

Fig. 8 Fluid temperature in intact loop, Spool 10 (TFU-10)

Fig. 9 Fluid temperature in intact loop, Spool 14 (RBU-14A)

Fig. 10 Fluid temperature in broken loop, Spool 20 (TFB-20)

Fig. 11 Fluid temperature in broken loop, Spool 23 (TFB-23).

Fig. 12 Fluid temperature in broken loop, Spool 30 (TFB-30).

Fig. 13 Fluid temperature in broken loop, Spool 42 (TFB-42).

Fig. 14 Fluid temperature in downcomer annulus (TFV-ANN-15M).

Fig. 15 Fluid temperature in downcomer annulus (TFV-ANN-35A).

Fig. 16 Fluid temperature in downcomer annulus (TFV-ANN-35T).

Fig. 17 Fluid temperature in downcomer annulus (TFV-ANN-115A).

Fig. 18 Fluid temperature in downcomer annulus (TFV-ANN-115M).

Fig. 19 Fluid temperature in upper plenum (TFV-UP+13).

Fig. 20 Fluid temperature in lower plenum (TFV-LP-7.5).

Fig. 21 Fluid temperature in lower plenum (TFV-LP-14.5).

Fig. 22. Fluid temperature in lower plenum (TFV-LP-27.5).

Fig. 23 Fluid temperature in core, Grid Spacer 5 (TFG-5CD-45).

Fig. 24 Fluid temperature in core, Grid Spacer 6 (TFG-6AB-45).

Fig. 25. Fluid temperature in core, Grid Spacer 6 (TFG-6CD-45).

Fig. 26. Fluid temperature in core, Grid Spacer 6 (TFG-6DE-45).

Fig. 27 Fluid temperature in core, Grid Spacer 6 (TFG-6DE-67).

Fig. 28. Fluid temperature in core, Grid Spacer 6 (TFG-6GH-45).

Fig. 29. Fluid temperature in core, Grid Spacer 8 (TFG-8CD-45).

Fig. 30. Fluid temperature in core, Grid Spacer 8 (TFG-8DE-23).

Fig. 31. Fluid temperature in core, Grid Spacer 8 (TFG-8DE-45).

Fig. 32. Fluid temperature in core, Grid Spacer 8 (TFG-8DE-67).

Fig. 33. Fluid temperature in core, Grid Spacer 8 (TFG-8EF-45).

Fig. 34. Fluid temperature in core, Grid Spacer 10 (TFG-10CD-45).

Fig. 35. Fluid temperature in core, Grid Spacer 10 (TFG-10DE-67).

Fig. 36. Fluid temperature in core, Grid Spacer 10 (TFG-10EF-45).

Fig. 37. Fluid temperature in core, Grid Spacer 10 (TFG-10GH-45).

Fig. 38. Fluid temperature in steam generator feedwater line (TFU-SGFW).

Fig. 39. Fluid temperature in steam generator steam dome (TFU-SGSD).

Fig. 40. Fluid temperature in steam generator (TFU-SG1).

Fig. 41. Fluid temperature in steam generator (TFU-SG2).

Fig. 42 Fluid temperature in steam generator (TFU-SG3).

Fig. 43 Fluid temperature in steam generator (TFU-SG4).

Fig. 44 Fluid temperature in pressurizer surge line (TFU-PRIZE).

Fig. 45 Fluid temperature in pressure suppression tank (TF-PSS-33).

Fig. 46. Fluid temperature in pressure suppression tank (TF-PSS-130).

Fig. 47 Material temperature in intact loop, Spool 7 (TMU-7S16).

Fig. 48 Material temperature in intact loop, Spool 8 (TMU-8S16).

Fig. 49 Material temperature in broken loop, Spool 20 (TMB-20T16).

Fig. 50 Material temperature in broken loop, Spool 30 (TMB-30T4).

Fig. 51 Material temperature in broken loop, Spool 30 (TMB-30T16).

Fig. 52 Material temperature in vessel wall (TMV-VI-15A).

Fig. 53 Material temperature in vessel filler (TMV-F0-35A).

Fig. 54 Material temperature in vessel filler (TMV-FI-35M).

Fig. 55 Material temperature in vessel filler insulator (TIV-FO-35A).

Fig. 56 Material temperature in core barrel (TMV-CO-35A).

Fig. 57 Material temperature in core barrel (TMV-CI-35A).

Fig. 58 Core heater temperature, Rod D4 (TH-D4-14).

Fig. 59 Core heater temperature, Rod D4 (TH-D4-29).

Fig. 60 Core heater temperature, Rod D4 (TH-D4-60).

Fig. 61 Core heater temperature, Rod D5 (TH-D5-09).

Fig. 62 Core heater temperature, Rod D5 (TH-D5-29).

Fig. 63 Core heater temperature, Rod D5 (TH-D5-39).

Fig. 64 Core heater temperature, Rod E4 (TH-E4-23).

Fig. 65 Core heater temperature, Rod E4 (TH-E4-27).

Fig. 66 Core heater temperature, Rod E5 (TH-E5-14).

Fig. 67 Core heater temperature, Rod E5 (TH-E5-21).

Fig. 68 Core heater temperature, Rod E5 (TH-E5-25).

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Fig. 71 Core heater temperature, Rod A4 (TH-A4-33).

Fig. 72 Core heater temperature, Rod A4 (TH-A4-39).

Fig. 73 Core heater temperature, Rod A5 (TH-A5-29).

Fig. 74 Core heater temperature, Rod B3 (TH-B3-32).

Fig. 75 Core heater temperature, Rod B5 (TH-B5-29).

Fig. 76 Core heater temperature, Rod B6 (TH-B6-29).

Fig. 77. Core heater temperature, Rod C2 (TH-C2-28).

Fig. 78. Core heater temperature, Rod C3 (TH-C3-13).

Fig. 79 Core heater temperature, Rod C3 (TH-C3-28).

Fig. 80 Core heater temperature, Rod C3 (TH-C3-60).

Fig. 81 Core heater temperature, Rod C4 (TH-C4-26).

Fig. 82 Core heater temperature, Rod C5 (TH-C5-28).

Fig. 83 Core heater temperature, Rod C6 (TH-C6-20).

Fig. 84 Core heater temperature, Rod C6 (TH-C6-32).

Fig. 85 Core heater temperature, Rod C7 (TH-C7-15).

Fig. 86 Core heater temperature, Rod D2 (TH-D2-14).

Fig. 87. Core heater temperature, Rod D3 (TH-D3-29).

Fig. 88. Core heater temperature, Rod D6 (TH-D6-15).

Fig. 89. Core heater temperature, Rod D6 (TH-D6-25).

Fig. 90 Core heater temperature, Rod D7 (TH-D7-20).

Fig. 91 Core heater temperature, Rod D8 (TH-D8-25).

Fig. 92 Core heater temperature, Rod E1 (TH-E1-27).

Fig. 93 Core heater temperature, Rod E1 (TH-E1-33).

Fig. 94 Core heater temperature, Rod E2 (TH-E2-33).

Fig. 95 Core heater temperature, Rod E3 (TH-E3-05).

Fig. 96 Core heater temperature, Rod E3 (TH-E3-20).

Fig. 97 Core heater temperature, Rod E6 (TH-E6-08).

Fig. 98 Core heater temperature, Rod E6 (TH-E6-28).

Fig. 99 Core heater temperature, Rod E6 (TH-E6-31).

Fig. 100 Core heater temperature, Rod E6 (TH-E6-37).

Fig. 101 Core heater temperature, Rod E7 (TH-E7-13).

Fig. 102 Core heater temperature, Rod E7 (TH-E7-29).

Fig. 103 Core heater temperature, Rod E7 (TH-E7-44).

Fig. 104 Core heater temperature, Rod E8 (TH-E8-14).

Fig. 105 Core heater temperature, Rod E8 (TH-E8-29).

Fig. 106 Core heater temperature, Rod E8 (TH-E8-45).

Fig. 107 Core heater temperature, Rod F2 (TH-F2-22).

Fig. 108 Core heater temperature, Rod F2 (TH-F2-25).

Fig. 109 Core heater temperature, Rod F3 (TH-F3-22).

Fig. 110 Core heater temperature, Rod F3 (TH-F3-25).

Fig. 111 Core heater temperature, Rod F4 (TH-F4-14).

Fig. 112 Core heater temperature, Rod F4 (TH-F4-28).

Fig. 113 Core heater temperature, Rod F5 (TH-F5-20).

Fig. 114 Core heater temperature, Rod F5 (TH-F5-26).

Fig. 115 Core heater temperature, Rod F5 (TH-F5-33).

Fig. 116 Core heater temperature, Rod F5 (TH-F5-53).

Fig. 117 Core heater temperature, Rod F6 (TH-F6-08).

Fig. 118 Core heater temperature, Rod F6 (TH-F6-28).

Fig. 119 Core heater temperature, Rod F6 (TH-F6-28).

Fig. 120 Core heater temperature, Rod F7 (TH-F7-29).

Fig. 121 Core heater temperature, Rod F7 (TH-F7-33).

Fig. 122 Core heater temperature, Rod F7 (TH-F7-39).

Fig. 123. Core heater temperature, Rod G4 (TH-G4-33).

Fig. 124. Core heater temperature, Rod G5 (TH-G5-14).

Fig. 125. Core heater temperature, Rod G5 (TH-G5-24).

Fig. 126. Core heater temperature, Rod G6 (TH-G6-21).

Fig. 127. Core heater temperature, Rod G6 (TH-G6-33).

Fig. 128. Core heater temperature, Rod G6 (TH-G6-53).

Fig. 129 Core heater temperature, Rod H4 (TH-H4-28).

Fig. 130 Pressure in intact loop, Spool 5 [PU-5(F)].

Fig. 131 Pressure in intact loop, Spool 7 (PU-7).

Fig. 132 Pressure in intact loop, Spool 13 [PU-13 (F)].

Fig. 133 Pressure in broken loop, Spool 23 (PB-23).

Fig. 134. Pressure in broken loop, vessel - side nozzle throat (PB-CN1).

Fig. 135 Pressure in broken loop, Spool 42 (PB-42).

Fig. 136 Pressure in broken loop, pump - side nozzle throat, (PB-HN1).

Fig. 137 Pressure in vessel upper plenum (PV-UP+10).

Fig. 138 Pressure in vessel lower plenum (PV-LP-80).

Fig. 139 Pressure in steam generator, secondary side (PU-SGSD).

Fig. 140 Pressure in steam generator, primary side (PU-SGIP).

Fig. 141 Pressure in pressurizer (PU-PRIZE).

Fig. 142 Pressure in pressure suppression tank (P-PSS).

Fig. 143 Pressure in pressure suppression tank header outlet (P-83).

Fig. 144 Differential pressure in intact loop (upper plenum to Spool 1) (DPU-UP-1).

Fig. 145 Differential pressure in intact loop (Spool 1 to Spool 3) (DPU-1-3).

Fig. 146 Differential pressure in intact loop (Spool 3 to Spool 6) (DPU-3-6).

Fig. 147 Differential pressure in intact loop (Spool 6 to Spool 7) (DPU-6-7).

Fig. 148 Differential pressure in intact loop (steam generator outlet plenum to Spool 7) (DPU-SGOP-7).

Fig. 149 Differential pressure in intact loop (Spool 7 to Spool 10) (DPU-7-10).

Fig. 150 Differential pressure in intact loop (Spool 12 to Spool 10) (DPU-12-10).

Fig. 151 Differential pressure in intact loop, low range (Spool 12 to Spool 10) (DPU-12-10L).

Fig. 152 Differential pressure in intact loop (Spool 12 to Spool 15) (DPU-12-15).

Fig. 153 Differential pressure in intact loop (Spool 15 to Spool 1) (DPU-15-1).

Fig. 154 Differential pressure in intact loop (Spool 15 to vessel inlet annulus) (DPU-15-IANN).

Fig. 155 Differential pressure in intact loop (Spool 15 to atmosphere) (DPU-15-ATM).

Fig. 156 Differential pressure in intact loop (pressurizer liquid level) (DPU-PRESLL).

Fig. 157 Differential pressure in broken loop (vessel - side nozzle throat to divergent section) (DPB-CN1-CN4).

Fig. 158 Differential pressure in broken loop (Spool 30 to Spool 36L) (DPB-30-36L).

Fig. 159 Differential pressure in broken loop (Spool 32U to Spool 36L) (DPB-32U-36L).

Fig. 160 Differential pressure in broken loop (Spool 38 to Spool 40) (DPB-38-40).

Fig. 161 Differential pressure in vessel (inlet annulus to upper plenum) (DPV-IANN-UP).

Fig. 162 Differential pressure in vessel (DPV-9-180QQ).

Fig. 163 Differential pressure in vessel (DPV-22M).

Fig. 164 Differential pressure in vessel (DPV-26-55QM).

Fig. 165 Differential pressure in vessel (DPV-156-173QQ).

Fig. 166 Differential pressure in vessel (DPV-166-191QT).

Fig. 167 Differential pressure in vessel (DPV-LP-UP).

Fig. 168 Differential pressure across steam generator feedwater inlet orifice (DPS-SG-FEED).

Fig. 169 Differential pressure across steam generator discharge outlet orifice(DPS-SG-DISC).

Fig. 170. Differential pressure across steam generator secondary (DPU-SG-SEC).

Fig. 171 Volumetric flow in intact loop (FTU-1).

Fig. 172 Volumetric flow in intact loop (FTU-9).

Fig. 173 Volumetric flow in intact loop (FTU-13).

Fig. 174 Volumetric flow in intact loop (FTU-15).

Fig. 175 Volumetric flow in broken loop (FTB-21).

Fig. 176 Volumetric flow in broken loop (FTB-30).

Fig. 177 Volumetric flow in core entrance (FTV-CORE-IN).

Fig. 178 Volumetric flow in pressurizer surge line (FTU-PRIZE).

Fig. 179 Fluid velocity in vessel (FTV-40A).

Fig. 180 Fluid velocity in vessel (FTV-40M).

Fig. 181 Fluid velocity in vessel (FTV-83M).

Fig. 182 Momentum flux in intact loop (FDU-1).

Fig. 183 Momentum flux in intact loop (FDU-5).

Fig. 184 Momentum flux in intact loop (FDU-10).

Fig. 185 Momentum flux in intact loop (FDU-13).

Fig. 186 Momentum flux in intact loop (FDU-15).

Fig. 187 Momentum flux in broken loop (FDB-21).

Fig. 188 Momentum flux in broken loop (FDB-23).

Fig. 189 Momentum flux in broken loop (FDB-30).

Fig. 190 Momentum flux in broken loop (FDB-42).

Fig. 191 Momentum flux in core entrance (FDV-CORE-IN).

Fig. 192 Density in intact loop (GU-1VR).

Fig. 193 Density in intact loop (GU-1HZ).

Fig. 194 Density in intact loop (GU-5VR).

Fig. 195 Density in intact loop (GU-10VR).

Fig. 196 Density in intact loop (GU-13VR).

Fig. 197 Density in intact loop (GU-15HZ).

Fig. 198 Density in intact loop (GU-15VR).

Fig. 199 Density in broken loop (GB-21VR).

Fig. 200 Density in broken loop (GB-23VR).

Fig. 201 Density in broken loop (GB-30VR).

Fig. 202 Density in broken loop (GB-42VR).

Fig. 203 Density in vessel (GV-COR -150HZ).

Fig. 204 Density in vessel (GV-161-192D).

Fig. 205 Density in vessel (GVLP-165HZ).

Fig. 206 Density in vessel (GVLP-172HZ).

Fig. 207 Density in pressurizer (GU-PRIZE).

Fig. 208 Mass flow in intact loop (FDU-1, GU-1VR).

Fig. 209 Mass flow in intact loop (FTU-1, GU-1VR).

Fig. 210 Mass flow in intact loop (FDU-5, GU-5VR).

Fig. 211 Mass flow in intact loop (FTU-9, GU-10VR).

Fig. 212 Mass flow in intact loop (FDU-10, GU-10VR).

Fig. 213 Mass flow in intact loop (FDU-13, GU-13VR).

Fig. 214 Mass flow in intact loop (FTU-13, GU-13VR).

Fig. 215 Mass flow in intact loop (FDU-15, GU-15VR).

Fig. 216 Mass flow in intact loop (FTU-15, GU-15VR).

Fig. 217 Mass flow in pressurizer surge line (FTU-PRIZE, GU-PRIZE).

Fig. 218 Mass flow in broken loop (FDB-21, GB-21VR).

Fig. 219 Mass flow in broken loop (FTB-21, GB-21VR).

Fig. 220 Mass flow in broken loop (FDB-23, GB-23VR).

Fig. 221 Mass flow in broken loop (FDB-30, GB-30VR).

Fig. 222 Mass flow in broken loop (FTB-30, GB-30VR).

Fig. 223 Mass flow in broken loop (FDB-42, GB-42 VR).

Fig. 224 Mass flow in vessel (FTV-CORE-IN, GV-COR-150HZ).

Fig. 225 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ).

Fig. 226 Mass flow in vessel, composite (FDV/FTV-CORE-IN, GV-COR-150HZ).

Fig. 227 Total power in heated core (PWRCOR T-1),

Fig. 228 Total power in heated core (PWRCOR T-2).

Fig. 229 Voltage to heated core (VOLTCOR-T).

Fig. 230 Current to heated core (AMPCOR-T).

Fig 231 Current to heater rod F5 (F5 AMPS).

Fig. 232 Primary pump torque (PUMPU-TORQ).

Fig. 233 Primary pump power (PUMPU-POW).

Fig. 234 Primary pump speed (PUMPU-RPM).

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
SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM
SEMISCALE MOD-1 TEST S-02-8

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APPENDIX A

SELECTED DATA WITH ESTIMATED TOTAL ERROR BANDS FROM SEMISCALE MOD-1 TEST S-02-8

I. OUTLINE OF PROCEDURE FOR COMPUTING ERROR BANDS

A certain number of the more than 200 data channels recorded during Semiscale Mod-1 Test S-02-8 have been chosen as a basis for comparison of analytical predictions performed by the Regulatory Standard Problem Five participants with measured Semiscale data.

For convenience, presentation of these specific data is repeated in this appendix. Additionally, these data have been further analyzed for engineering and random error components, with the end result that the data are presented with estimated total error bands (95% confidence level). The procedure by which error bands were established for the data presented in this appendix is described in the following paragraphs.

The data trace under analysis was empirically fitted with a linear difference equation, which was subject to a white noise input at each sampling time point. The objective of the empirical fitting procedure was to characterize the white noise, which was taken to represent the instrument repeatability (measurement error). The procedures for fitting the difference equation are discussed in depth in Reference A-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 measurement error standard deviation as shown in Table A-I.

Other errors in the data exist because of such factors as variability in installation procedures and techniques, calibration errors, variability in materials, and temperature and pressure sensitivity. These errors and the procedures for estimating them are discussed in Reference A-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 (A-2). Table A-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

TABLE A-I

MEASUREMENT ERROR VARIANCE

Transducer Identification	Measurement Variance σ_{random}	Period of Application (sec)	Figure Number
TFV-ANN-35A	0.34	0 - 42	A-1
TFV-ANN-35T	0.52	0 - 29.2	A-2
	0.16	29.2 - 42	
TFV-UP+13	0.64	0 - 12.95	A-3
	1.14	12.95 - 26.8	
	0.42	26.8 - 42	
TFV-LP-7.5	0.47	0 - 8.5	A-4
	0.69	8.5 - 35.3	
	0.25	35.3 - 42	
TFV-LP-14.5	0.60	0 - 19	A-5
	0.42	19 - 42	
TFV-LP-27.5	1.53	0 - 30.35	A-6
	1.47	30.35 - 42	
TFG-10EF-45	1.09	0 - 31.4	A-7
	0.57	31.4 - 42	
TFU-SC3	0.22	0 - 7.5	A-8
	0.11	7.5 - 12.6	
	0.08	12.6 - 42	
TMV-FO-35A	0.95	0 - 30.6	A-9
	0.09	30.6 - 42	
TH-D4-14	0.78	0 - 42	A-10
TH-D4-60	0.52	0 - 4.5	A-11
	1.34	4.5 - 12	
	0.87	12 - 42	
TH-D5-29	3.79	0 - 42	A-12
TH-E5-21	0.89	0 - 28.8	A-13
	0.31	28.8 - 42	
TH-C3-13	1.86	0 - 4	A-14
	0.56	4 - 29.6	
	0.50	29.6 - 42	

TABLE A-I (contd.)

<u>Transducer Identification</u>	<u>Measurement Variance σ_{random}</u>	<u>Period of Application (sec)</u>	<u>Figure Number</u>
TH-C3-60	0.67	0 - 17	A-15
	0.33	17 - 29	
	0.10	29 - 42	
TH-C6-20	0.70	0 - 42	A-16
TH-C6-32	1.21	0 - 42	A-17
TH-D2-14	2.74	0 - 4.3	A-18
	0.72	4.3 - 32.3	
	0.43	32.3 - 42	
TH-D7-20	0.80	0 - 42	A-19
TH-E3-20	0.72	0 - 42	A-20
TH-E7-13	1.11	0 - 30.1	A-21
	0.33	30.1 - 42	
TH-E7-44	0.8	0 - 3	A-22
	0.68	3 - 28.4	
	0.34	28.4 - 42	
TH-E8-45	1.18	0 - 3.5	A-23
	0.74	3.5 - 42	
TH-F2-22	0.93	0 - 18.5	A-24
	0.41	18.5 - 42	
TH-F3-22	1.0	0 - 42	A-25
TH-F5-20	0.90	0 - 42	A-26
TH-F6-08	0.88	0 - 8.7	A-27
	0.45	8.7 - 29	
	0.43	29 - 42	
TH-F7-33D	0.75	0 - 42	A-28
PB-23	2.96	0 - 42	A-29
PB-42	3.2	0 - 42	A-30
PV-UP+10	14.31	0 - 42	A-31
PU-SGSD	0.64	0 - 42	A-32

TABLE A-I (contd.)

<u>Transducer Identification</u>	<u>Measurement Variance σ_{random}</u>	<u>Period of Application (sec)</u>	<u>Figure Number</u>
DPU-6-7	2.73	0 - .5	A-33
	0.37	.5 - 9	
	0.25	9 - 12	
	0.06	12 - 42	
DPU-12-10	1.6	0 - 4	A-34
	0.11	4 - 42	
DPU-15-1	0.86	0 - 16	A-35
	0.02	16 - 42	
DPB-30-36L	9.66	0 - 15	A-36
	0.24	15 - 42	
DPB-38-40	3.78	0 - 6	A-37
	2.25	6 - 9.5	
	2.83	9.5 - 13	
	0.64	13 - 33	
	0.37	33 - 42	
DPV-LP-UP	0.26	0 - 17	A-38
	0.09	17 - 42	
FTV-40A	0.89	0 - 10	A-39
	1.13	10 - 16	
	0.16	16 - 31.5	
	0.06	31.5 - 40	
	0	40 - 42	
FTV-40M	1.28	0 - 17	A-40
	0.12	17 - 31.5	
	0.16	31.5 - 42	
GU-1VR	1.72	0 - 7	A-41
	2.27	7 - 13.5	
	0.68	13.5 - 42	
GU-5VR	1.59	0 - 7.75	A-42
	2.65	7.75 - 14	
	0.82	14 - 42	

TABLE A-I (contd.)

<u>Transducer Identification</u>	<u>Measurement Variance σ_{random}</u>	<u>Period of Application (sec)</u>	<u>Figure Number</u>
GU-10VR	1.45	0 - 11.5	A-43
	0.48	11.5 - 42	
GB-23VR	8.76	0 - 15	A-44
	1.94	15 - 42	
GB-30VR	1.69	0 - 5	A-45
	0.33	5 - 42	
GB-42VR	1.14	0 - 8	A-46
	0.41	8 - 42	
GV-COR-150HZ	2.46	0 - 4.8	A-47
	3.88	4.8 - 12	
	0.88	12 - 42	
GVLP-165HZ	2.24	0 - 18.6	A-48
	0.87	18.6 - 42	
GVLP-172HZ	1.44	0 - 9	A-49
	3.02	9 - 33.5	
	0.23	33.5 - 42	
FDU-1, GU-1VR	0.35	0 - 6.5	A-50
	0.29	6.5 - 15.9	
	0.08	15.9 - 42	
FDU-5, GU-5VR	0.37	0 - 10.29	A-51
	0.15	10.25 - 42	
FDU-15, GU-15VR	2.63	0 - 5	A-52
	0.82	5 - 13	
	0.50	13 - 22	
	0.28	22 - 42	
FTU-PRIZE, GU-PRIZE	0.11	0 - 20.8	A-53
	0.04	20.8 - 42	
FDB-23, GB-23VR	3.48	0 - 16	A-54
	1.15	16 - 30	
	0.36	30 - 42	

TABLE A-I (contd.)

<u>Transducer Identification</u>	<u>Measurement Variance σ_{random}</u>	<u>Period of Application (sec)</u>	<u>Figure Number</u>
FTB-42, GB-42VR	0.56	0 - 9.3	A-55
	0.38	9.3 - 31	
	0.05	31 - 42	
FTB-30, GB-30VR	0.37	0 - 12.5	A-56
	0.31	12.5 - 35	
	0.05	35 - 42	
FDV-CORE-IN. GV-COR-150HZ	0.54	0 - 42	A-57
PUMPU-RPM	9.3	0 - 42	A-58

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), which are presented in this appendix, a more extensive assessment was conducted of additional engineering error due to flow regime effects. Table A-III identifies the data analyzed and the time 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 and in combination with the techniques outlined in Reference A-3. 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 flow was considered present, the gamma beam attenuation was considered 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 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, 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. The error values were, therefore, obtained 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 A-II

GENERAL MEASUREMENT ENGINEERING ERROR SOURCES AND ERROR VALUES

Measurement Category	Error Sources	Error Value	Expected Error Value
Fluid Temperature	Changes in homogeneity of the thermocouple wire due to cold working	$\pm 2^{\circ}\text{F}$	$\left. \begin{array}{l} \\ \\ \\ \end{array} \right\} \pm 5^{\circ}\text{F}^{[a]}$
	Data interpretation from standard reference tables	$\pm 2^{\circ}\text{F}$	
	General data acquisition and processing	$\pm 4.5^{\circ}\text{F}$	
	Thermal aging of the thermocouples	$\pm 0.5^{\circ}\text{F}$	
Material Temperature	Changes in homogeneity of the thermocouple wire due to cold working	$\pm 2^{\circ}\text{F}$	$\left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} \pm 7^{\circ}\text{F}$
	Thermocouple radial position	$\pm 5^{\circ}\text{F}$	
	Data interpretation from standard reference tables	$\pm 2^{\circ}\text{F}$	
	General data acquisition and processing	$\pm 4.5^{\circ}\text{F}$	
	Thermal aging of the thermocouples	$\pm 0.5^{\circ}\text{F}$	
Pressure	Entrance effects	$\pm 0.3\%$ of transducer full scale	$\left. \begin{array}{l} \\ \end{array} \right\} \pm 13 \text{ psi}^{[b]}$
	Calibration	$\pm 0.26\%$ of transducer full scale	

TABLE A-II (contd.)

<u>Measurement Category</u>	<u>Error Sources</u>	<u>Error Value</u>	<u>Expected Error Value</u>
Pressure (contd.)	Temperature sensitivity	±0.13% of transducer full scale	{ ±13 psi ^[b]
	General data acquisition and processing	±0.1% of system full scale	
Differential Pressure	Installation	±0.3% of transducer full scale	<u>DPU-6-7</u> : full scale = 25 psid ±[0.025 + (0.005R) ²] ^{1/2} psid
	Calibration	±[(0.05) + (0.5 R/FS) ²] ^{1/2} % of transducer full scale	<u>DPU-12-10</u> : full scale = 50 psid ±[0.095 + (0.005R) ²] ^{1/2} psid
	Transducer ranges: ±0.72, ±1.8, ±3.6, ±10.8, ±18, ±28.9		
	Transducer ranges: ±50, ±100, ±500	±[(0.05) + (0.5 R/FS) ²] ^{1/2} % of full scale	<u>DPU-15-1</u> : full scale = 25 psid ±[0.025 + (0.005R) ²] ^{1/2} psid
	Transducer ranges: ±1,000, ±1,500	±[(0.02) + (0.5 R/FS) ²] % of full scale	<u>DPV-LP-UP</u> : full scale = 15 psid ±[0.009 + (0.005R) ²] ^{1/2} psid
	Temperature sensitivity	±0.5% of transducer full scale	<u>DPB-30-36L</u> : full scale = 500 psid ±[9.5 + (0.005R) ²] ^{1/2} psid
	General data acquisition and processing	±0.1% of system full scale	<u>DPB-38-40</u> : full scale = 1,000 psid ±[37.0 + (0.005R) ²] ^{1/2} psid
	Air entrapment	±0.01 psid	
		where: R = transducer reading (psid) FS = transducer range full scale (psid)	where: R = transducer reading (psid)

TABLE A-II (contd.)

Measurement Category	Error Sources	Error Value	Expected Error Value
Fluid Velocity (point velocities measured with turbo probes)	Installation	$\pm 0.8\%$ of transducer	$\pm [6.27 + (0.008R)^2]^{1/2}$ ft/sec where: R = transducer reading (ft/sec)
	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	$\pm (0.12 + 0.51\% \text{ of reading}) \text{ lbm/ft}^3$	[c]
	Detector system error		
	GU-1VR	$\pm 0.11 \text{ lbm/ft}^3$	
	GU-5VR	$\pm 0.12 \text{ lbm/ft}^3$	
	GU-10VR	$\pm 0.11 \text{ lbm/ft}^3$	
	GU-15VR	$\pm 0.11 \text{ lbm/ft}^3$	
	GB-23VR	$\pm 0.16 \text{ lbm/ft}^3$	
	GB-30VR	$\pm 0.12 \text{ lbm/ft}^3$	
	GB-42VR	$\pm 0.17 \text{ lbm/ft}^3$	
	GV-COR-150-HZ	$\pm 0.10 \text{ lbm/ft}^3$	
	GVLP-165-HZ	$\pm 0.04 \text{ lbm/ft}^3$	
	GVLP-172-HZ	$\pm 0.04 \text{ lbm/ft}^3$	

TABLE A-II (contd.)

Measurement Category	Error Sources	Error Value	Expected Error Value
Density (contd.)	General data acquisition and processing	$\pm 0.1 \text{ lbm/ft}^3$	[c]
	Flow regime	$Gr^{[c]}$	
		where: Gr = flow regime error (lbm/ft^3)	
Momentum Flux (drag disc)	Installation alignment and velocity profile changes from calibration conditions	$\pm 3\%$ of transducer reading (lbm/ft-sec^2)	[e]
	Calibration	[d]	
	General data acquisition and processing	$\pm 0.1\%$ of system full scale (lbm/ft-sec^2)	
	Data correction uncertainty		
	FDU-1	$[(3.2^2 + (3.6)^2)^{1/2}]$ (lbm/ft-sec^2)	
	FDU-5	$[(13.16)^2 + (0.8)^2]^{1/2}$ (lbm/ft-sec^2)	
	FDU-15	$[(337)^2 + (46.6)^2]^{1/2}$ (lbm/ft-sec^2)	
	FDB-23	$[(1,439)^2 + (226)^2]^{1/2}$ (lbm/ft-sec^2)	

TABLE A-II (contd.)

Measurement Category	Error Sources	Error Value	Expected Error Value
Volumetric Flow (turbine meter)	FDB-42	$[(1,360)^2 + (180)^2]^{1/2}$ (lbm/ft-sec ²)	[e]
	FDV-CORE-IM	$[(65)^2]^{1/2}$ (lbm/ft-sec ²)	
	Flow regimes	[e]	
	Calibration		
	Instrument reading	±0.25% of transducer full scale	
	Calibration standards	±3.1 gpm	
	Velocity profile	±2.9% of reading	
	Frequency-to-voltage conversion	±0.25% of transducer full scale	[e]
	General data acquisition and processing	±0.1% of system full scale	
	Dead bands	±5% of transducer full scale	
	Flow regimes	[e]	
Mass Flow Rate (from momentum flux and density data)	Combined results from individual error sources for momentum flux and density data ^[f]	---	[e]

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

[b] Value for transducers with 3,000 psig full-scale ranges.

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

[d] Dependent on transducer full-scale range reading[A-3].

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

[f] The general method for combining momentum flux and density data to obtain mass flow rate and the resulting errors on the data is explained in Reference A-2.

TABLE A-III

TIME PERIODS WHEN FLOW REGIME ERRORS WERE APPLIED

<u>Transducer Identification</u>	<u>Flow Regime Errors Were Applied (sec)</u>	<u>Figure Number</u>
GU-1VR	4 to 16	A-41
GU-5VR	3 to 40	A-42
GU-10VR	6 to 18	A-43
GB-23VR	13 to 42	A-44
GB-30VR	1 to 7	A-45
FDU-1, GU-1VR	4 to 16	A-50
FDU-5, GU-5VR	3 to 40	A-51
FDU-15, GU-15VR	7 to 19	A-52
FDB-23, GB-23VR	13 to 42	A-54
FTB-30, GB-30VR	1 to 7	A-56

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.

A unique solution to the equation was obtained by application of an iterative process in which the slip ratio and a velocity of one phase are varied. This process provided phase velocities. With the phase densities, velocities, and void fraction, a volumetric flow rate could be calculated. The difference between this value and the measured value was considered to be the error.

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

$$\sigma_0 = \sqrt{\sigma_M^2 + \sigma_E^2} \quad (A-1)$$

where:

σ_O = Overall standard deviation of a data point

σ_M = Measurement 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,

$$\text{error band} = \hat{y}_i \pm 1.96\sigma_O \quad (\text{A-2})$$

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 (A-2) is not appropriate. On these occasions, unsymmetrical error bands, were computed. (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 (A-2), was input to a computer plot package. The resulting plot contained the actual data trace surrounded by an error band derived both from measurement error and engineering error considerations. The indicated error bands on all traces prior to zero seconds and after thermocouple dryout occurred for the fluid temperature measurements should be ignored. Error bands for these segments of the data were not obtained and bands only appear because of limitations in the plotting package.

Fig. A-1 Fluid temperature in downcomer annulus (TFV-ANN-35A).

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

Fig. A-3 Fluid temperature in upper plenum (TFV-UP+13).

Fig. A-4 Fluid temperature in lower plenum (TFV-LP-7.5).

Fig. A-5 Fluid temperature in lower plenum (TFV-LP-14.5).

Fig. A-6 Fluid temperature in lower plenum (TFV-LP-27.5).

Fig. A-7 Fluid temperature in core at grid spacer 10 (TFG-10EF-45).

Fig. A-8 Fluid temperature in intact loop steam generator secondary (TFU-SG3).

Fig. A-9 Material temperature in vessel filler (TMV-FO-35A).

Fig. A-10 Core heater temperature, Rod D4 (TH-D4-14).

Fig. A-11 Core heater temperature, Rod D4 (TH-D4-60).

Fig. A-12 Core heater temperature, Rod D5 (TH-D5-29).

Fig. A-13 Core heater temperature, Rod E5 (TH-E5-21).

Fig. A-14 Core heater temperature, Rod C3 (TH-C3-13).

Fig. A-15 Core heater temperature, Rod C3 (TH-C3-60).

Fig. A-16 Core heater temperature, Rod C6 (TH-C6-20).

Fig. A-17 Core heater temperature, Rod C6 (TH-C6-32).

Fig. A-18 Core heater temperature, Rod D2 (TH-D2-14).

Fig. A-19 Core heater temperature, Rod D7 (TH-D7-20).

Fig. A-20 Core heater temperature, Rod E3 (TH-E3-20).

Fig. A-21 Core heater temperature, Rod E7 (TH-E7-13).

Fig. A-22 Core heater temperature, Rod E7 (TH-E7-44).

Fig. A-23 Core heater temperature, Rod E8 (TH-E8-45).

Fig. A-24 Core heater temperature, Rod F2 (TH-F2-22).

Fig. A-25 Core heater temperature, Rod F3 (TH-F3-22).

Fig. A-26 Core heater temperature, Rod F5 (TH-F5-20).

Fig. A-27 Core heater temperature, Rod F6 (TH-F6-08).

Fig. A-28 Core heater temperature, Rod F7 (TH-F7-33).

Fig. A-29 Pressure in broken loop vessel side of break (PB-23).

Fig. A-30 Pressure in broken loop pump side of break (PB-42).

Fig. A-31 Pressure in vessel upper plenum (PV-UP+10).

Fig. A-32 Pressure in steam generator, secondary side (PU-SGSD).

Fig. A-33 Differential pressure in intact loop (Spool 6 to Spool 7) (DPU-6-7).

Fig. A-34 Differential pressure in intact loop (Spool 12 to Spool 10) (DPU-12-10).

Fig. A-35 Differential pressure in intact loop (Spool 15 to Spool 1) (DPU-15-1).

Fig. A-36 Differential pressure in broken loop (Spool 30 to Spool 36L) (DPB-30-36L).

Fig. A-37 Differential pressure in broken loop (Spool 38 to Spool 40) (DPB-38-40).

Fig. A-38 Differential pressure in vessel (DPV-LP-UP).

Fig. A-39 Fluid velocity in vessel (FTV-40A).

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

Fig. A-41 Density in intact loop (GU-1VR).

Fig. A-42 Density in intact loop (GU-5VR).

Fig. A-43 Density in intact loop (GU-10VR).

Fig. A-44 Density in broken loop (GB-23VR).

Fig. A-45 Density in broken loop (GB-30VR).

Fig. A-46 Density in broken loop (GB-42VR).

Fig. A-47 Density in vessel (GV-COR-150HZ).

Fig. A-48 Density in vessel (GVLP-165HZ).

Fig. A-49 Density in vessel (GVLP-172HZ).

Fig. A-50 Mass flow in intact loop (FDU-1, GU-1VR).

Fig. A-51 Mass flow in intact loop (FDU-5, GU-5VR).

Fig. A-52 Mass flow in intact loop (FDU-15, GU-15VR).

Fig. A-53 Mass flow in pressurizer surge line (FTU-PRIZE, GU-PRIZE).

Fig. A-54 Mass flow in broken loop (FDB-23, GB-23VR).

Fig. A-55 Mass flow in broken loop (FTB-42, GB-42VR).

Fig. A-56 Mass flow in broken loop (FTB-30, GB-30VR).

Fig. A-57 Mass flow in vessel (FDV-CORE-IN, GV-COR-150HZ).

Fig. A-58 Primary pump speed (PUMPU-RPM).

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