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EXPERIMENT DATA REPORT FOR SEMISCALE
MOD-1 TEST S-01-2
(ISOTHERMAL BLOWDOWN WITH CORE RESISTANCE SIMULATOR)

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by

S. N. Zender

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ABSTRACT

Recorded test data are presented for Test S-01-2 of the semiscale Mod-1 isothermal blowdown test series. Test S-01-2 is one of several semiscale Mod-1 experiments which are counterparts of the LOFT nonnuclear experiments. System hardware is of the LOFT design selected using volumetric scaling methods, and initial conditions duplicate those identified for LOFT.

Test S-01-2 employed an intact loop resistance that was high relative to that of other tests in the series to establish the importance of intact loop resistance on system response during blowdown. An orificed structure was used in the pressure vessel to duplicate the LOFT core simulator. The test was initiated at initial isothermal conditions of 2230 psig and 538°F by a simulated offset shear of the cold leg broken loop piping. After system depressurization, coolant was injected into the cold leg of the operating loop to investigate the hot wall effect on ECC delivery to the lower plenum.

The purpose of this report is to make available the uninterpreted data from Test S-01-2 and to provide the reference material needed 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-01-2 was performed as part of the semiscale Mod-1 portion of the Semiscale Blowdown and Emergency Core Cooling (ECC) Project conducted by Aerojet Nuclear Company for the United States Energy Research and Development Administration. This test was one of the semiscale Mod-1 tests in Test Group 1 performed with hardware configuration and test parameters selected to yield a system response that simulates the Loss-of-Fluid Test (LOFT) system response during the LOFT nonnuclear blowdown experiments. Test S-01-2 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; a pressure suppression system with header and pressure suppression tank, and a coolant injection system with low-pressure injection pumps, high-pressure injection pumps, and accumulators. An orificed structure was used in the core barrel of the pressure vessel to simulate the flow resistance of the core simulator to be used in the LOFT nonnuclear tests.

The overall objective of the semiscale program is to provide data for use in the development and verification of analytical models that are used to predict the transient thermal-hydraulic response of a water-cooled nuclear reactor system during a hypothetical loss-of-coolant accident (LOCA). The Mod-1 program has the further general 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.

The areas of interest specific to Test S-01-2 were the effect of intact loop resistance on system response and the influence of hot downcomer walls on the delivery of coolant to the lower plenum. In order to establish the importance of the resistance of the intact loop on system response, this test was conducted with an intact loop resistance that was high relative to that of other tests in the series. The delay time before coolant is delivered to the lower plenum was studied by injecting coolant into the cold leg of the intact loop after the system depressurized.

The recorded initial conditions of 2230 psig and 538°F and other initial conditions were within acceptable bounds to allow analysis of the test data. The rupture assemblies were actuated almost simultaneously (within 10 milliseconds) satisfactorily simulating an instantaneous offset cold leg shear of the broken loop piping. In general, instrumentation used in Test S-01-2 functioned as intended (of 197 measurements attempted, 180 produced usable data). Data loss during Test S-01-2 was sufficiently low that the test was considered conducted successfully.

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EXPERIMENT DATA REPORT FOR SEMISCALE MOD-1

TEST S-01-2

(Isothermal Blowdown with Core Resistance Simulator)

I. INTRODUCTION

The semiscale Mod-1 experimental program is part of the Semiscale Blowdown and Emergency Core Cooling (ECC) Project conducted by Aerojet Nuclear Company. The semiscale project in turn is part of the United States Energy Research and Development Administration sponsored research and development program to investigate the response of a water-cooled nuclear reactor system to a hypothesized loss-of-coolant accident (LOCA). The underlying objectives of the semiscale project are to quantify the physical processes controlling system behavior during an 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.

The semiscale Mod-1 program is conducted in an experimental system designed to simulate a pressurized water reactor (PWR). Relative to previous experimental systems, the semiscale Mod-1 system advances the representation of a PWR and thus provides a means of acquiring coupled-system response data from which to obtain a more comprehensive understanding of the thermal and hydraulic processes during an LOCA.

Test S-01-2, the first test in the semiscale Mod-1 system, was conducted as part of a series of tests to provide data for comparison of the isothermal blowdown response of the semiscale system with that of the Loss-of-Fluid Test (LOFT) system^[1]. The semiscale Mod-1 experimental configuration for this test utilized hardware components selected to produce a system performance which simulates LOFT system performance during the LOFT nonnuclear tests. An orificed structure with hydraulic resistance scaled to the LOFT core simulator resistance was used to simulate the resistance to flow through the electrically heated core of subsequent tests. This test employed an intact loop flow resistance that was high relative to that of other tests in the series in order to establish the importance of intact loop resistance on system response during blowdown. The test was initiated by a simulated offset shear of the cold-leg broken-loop piping and was conducted in two phases: a blowdown phase and a hot-wall phase. The blowdown phase was conducted without coolant injection to provide baseline system hydraulic behavior for the Mod-1 system without the added complication of coolant injection. The hot-wall phase following blowdown was conducted with coolant injection into the cold leg of the intact loop to determine the effect of hot downcomer walls on the delivery of coolant to the lower plenum.

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-01-2. Section III presents the data graphs and provides comments and supporting information necessary for interpretation of the data. Appendix A describes the overall semiscale program and the test series which includes Test S-01-2. Appendix B describes the semiscale Mod-1 system in greater detail. Appendix C discusses the measurement and data processing techniques and presents data uncertainties.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TEST S-01-2

The following system configuration, procedures, initial test conditions, and events are specific to Test S-01-2.

1. SYSTEM CONFIGURATION AND TEST PROCEDURES

The semiscale Mod-1 system used for Test S-01-2 consisted of a pressure vessel with internals; an operating loop with steam generator, pump, and pressurizer; a blowdown loop with simulated steam generator, simulated pump, and two rupture assemblies; a coolant injection system with accumulators and both high and low pressure injection pumps, and a pressure suppression system with a suppression tank and header. The semiscale Mod-1 experimental system is described in detail in Appendix B.

For Test S-01-2 the operating loop steam generator was maintained in the hot standby condition, in which the steam generator secondary side was valved off and the steam generator primary tubes were completely covered with water (at isothermal system temperature) when blowdown occurred. The system was heated to isothermal conditions with heaters in the bypass lines between the broken and unbroken loops.

In preparation for Test S-01-2 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 heaters located in the 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. These systems were valved out just prior to initiation of blowdown. At 100-degree intervals during warmup, detector readings were sampled to allow the integrity of the measurement instrumentation and the operability of the data acquisition system to be checked.

Prior to initiation of the blowdown test, initial test conditions were held for about 25 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.

Pressure to operate the rupture assemblies and initiate blowdown was taken from the system through lines connected to the reflood bypass simulators. Immediately following initiation of blowdown (0.02 seconds after initiation of blowdown) these lines were again isolated.

Power to the primary coolant circulating pump was cut off at blowdown to allow the pump to coast down to a speed of 1300 rpm. This speed was then maintained throughout the remainder of the test. A flywheel was mounted on the pump motor shaft to provide a simulation of the predicted coastdown of the LOFT pumps.

The system was successfully subjected to a simulated double-ended cold-leg pipe break through two blowdown nozzles each having a break area of 0.00262 ft^2 . Blowdown was initiated by valving off a pressurized helium gas supply which maintained the innerdisc chamber at approximately one-half the system pressure. The pressure in the innerdisc chamber was allowed to decrease by briefly opening a valve which allowed the helium gas to escape. The system pressure then ruptured the upstream disc and subsequently the downstream disc. The effluent was ejected from the primary system into the pressure suppression system.

The system was then allowed to depressurize, the lower plenum was drained, and the hot-wall portion of the test which utilized the heat remaining in the system following blowdown was initiated by coolant injection into the cold leg of the intact loop. Coolant injection began 111 seconds after blowdown and was continued until after the lower plenum of the vessel was filled. Injection was initiated by an accumulator pressurized to 600 psig with nitrogen gas. The average rate of injection was approximately 35 gpm.

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

	Measured ^[a]	Specified
System Fluid Temperature (intact loop, vessel outlet)	538°F	540 ± 2°F
System Pressure (vessel upper plenum)	2230 psig	2250 ± 5 psig
Intact Loop Cold Leg Flow	173 gpm	173 ± 2 gpm
Unbroken Loop Accumulator Pressure	605 psig	600 psig ^[b]
Temperature of Injected Coolant	87°F	85 ± 2°F
Unbroken Loop Accumulator Water Volume	1.76 ft ³	1.63 ft ³ ^[b]
Unbroken Loop Accumulator Gas Volume	1.16 ft ³	1.11 ft ³ ^[b]
Pressurizer Water Volume	0.72 ft ³	0.74 ± 0.05 ft ³
Steam Generator Secondary Steam Dome Pressure	995 psig	963 ± 40 psig
Steam Generator Secondary Fluid Temperature	548.5°F	540 ± 5°F
Steam Generator Liquid Level (from bottom of tube sheet)	123 in.	116 ± 2 in.
Pressure Suppression Tank Water Level	52.1 in.	47.5 in. ^[b]
Pressure Suppression Tank Pressure	20 psig	21 ± 1 psig
Pressure Suppression Tank Water Temperature	158°F	156 ± 2°F

[a] Measured initial conditions which did not meet the specified initial conditions were considered acceptable for analysis purposes within the test objectives.

[b] Tolerance not specified.

TABLE II

PRIMARY COOLANT TEMPERATURE DISTRIBUTION AT RUPTURE

Location	Detector	Temperature (°F)
Vessel lower plenum (lower portion)	TFV-LP-1-1/2	535
Vessel lower plenum (upper portion)	TFV-LP-27-1/2	545
Hot leg, intact loop (near vessel)	TFU-1	544
Hot leg, intact loop (104 in. from vessel center)	TFU-5	540
Hot leg, intact loop (near steam generator)	TSU-6	541
Cold leg, intact loop	RBV-14	540
Cold leg, broken loop (near vessel)	TFB-20	542
Cold leg, broken loop (near nozzle)	TFB-23	542
Hot leg, broken loop (near vessel)	TFB-30	542
Hot leg, broken loop (near nozzle)	TFB-42	538
Reflood bypass, cold leg	TFB-RFBC	541
Reflood bypass, hot leg	TFB-RFBH	538

TABLE III

WATER CHEMISTRY PRIOR TO BLOWDOWN^[a]

pH	7.60
Conductivity (μmhos/cm)	106.0
Suspended Solids (ppm)	23.7
Chlorides (ppm)	8.9
H ₂ (cc/l)	26.9
O ₂ (cc/l)	0.04
N ₂ (cc/l)	92.4
CO ₂ (cc/l)	0.3
Total Gas (cc/l)	120.6

[a] Water sample taken at a system pressure of 2230 psig and a system temperature of 538°F.

TABLE IV

SEQUENCE OF EVENTS FOR TEST S-01-2^[a]

<u>Event</u>	<u>Time Relative to Rupture (sec)</u>
Heatup bypass lines valved out of system ^[b]	-2
Initiation of blowdown portion of test	0
Termination of blowdown portion of test	70
Initiation of draining of lower plenum	88
Completion of draining of lower plenum	107
Initiation of hot-wall portion of test	111
Initiation of coolant injection from intact loop accumulator	111
Termination of flow from intact loop accumulator	179

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

[b] The block valves used to isolate the heatup bypass lines from the system leaked and allowed the heatup bypass lines to blow down during the blowdown test.

III. DATA PRESENTATION

The data from semiscale Mod-1 Test S-01-2 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 interpretation and analysis should consider that sudden decompression processes such as those occurring in the isothermal tests may have subjected the measurement devices to nonhomogeneous fluid conditions.

The performance of the semiscale Mod-1 system during Test S-01-2 was monitored by 197 detectors. The data obtained were recorded on a digital data acquisition system and on an analog data acquisition system. The digital system, which is part of the computerized data acquisition system, was used to process the data presented in this report. The analog system was used for redundancy and for better resolution capability for certain detector outputs. The data are presented, in many instances, in the form of composite graphs to facilitate comparison of a given variable at several locations during the test. The scales selected for the graphs were chosen to provide an overview of the blowdown and hot-wall portions of the test, and do not reflect the obtainable resolution of the data. The conditioning of output of each detector and the system used to process data from these signals is described in Appendix C.

Figures 1 through 5 and Table V provide supporting information for interpretation of the data graphs shown in Figures 6 through 209. Figures 1 through 5 show the locations of all measurements in the isothermal system. Table V groups the measurements taken during Test S-01-2 according to measurement type; identifies the specific measurements, their locations, and the ranges of the detector and the actual recording range of the data acquisition system; provides brief comments regarding the data; and references the measurements and comments to the corresponding figure on which the data are presented. Figures 6 through 117 present the data from the blowdown phase of the test. Time zero on these graphs is the time of rupture initiation. Figures 118 through 209 present the data from the hot-wall portion of the test. Time zero on these graphs is 111 sec following rupture initiation (time of initiation of coolant injection into the cold leg).

Fig. 1 Semiscale Mod-1 system and instrumentation -- isometric.

Fig. 2 Semiscale Mod-1 system and instrumentation -- schematic.

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

TABLE V

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
FLUID TEMPERATURE					
<u>Intact Loop</u>					
TFU-1	Hot leg, Spool 1, 31 in. from vessel center	0-2300°F	0-591°F	6, 118	
RHU-2	Hot leg, Spool 2, 46 in. from vessel center (platinum resistance bulb)	0-1000°F	0-1000°F		
TFU-5	Hot leg, Spool 5, 104 in. from vessel center				
TSU-6	Hot leg, Spool 6, 114 in. from vessel center (shielded)				
RHU-14A	Cold leg, Spool 14, 43 in. from vessel center, upstream of cold leg injection port (platinum resistance bulb)	0-1000°F	0-1000°F		
TFU-15	Cold leg, Spool 15, 16 in. from vessel center				
<u>Broken Loop</u>					
TFB-20	Cold leg, Spool 20, 21 in. from vessel center	0-2300°F	0-591°F	7, 119	
TFB-23	Cold leg, Spool 23, 91 in. from vessel center, upstream of vessel-side nozzle				Data questionable; thermocouple indicated >600°F at t=42 sec after rupture; thermocouple failed during hot-wall portion of test.
TFB-30	Hot leg, Spool 30, 16 in. from vessel center				
TFB-42	Cold leg, Spool 42, 414 in. from vessel center along hot leg, upstream of pump-side nozzle				
TFB-RFBC	Reflood bypass, near end cap, cold-leg side				
TFB-RFBB	Reflood bypass, near end cap, hot-leg side				
<u>Inlet Annulus</u>					
	4 in. below cold leg centerline, 0.2 in. from vessel wall, Type J iron-constantan	0-1400°F	0-692°F	8, 120	
TFV-ANN-4A	0°				
TFV-ANN-4M	180°				
<u>Downcomer Annulus</u>					
	Centered in annulus, Type J iron-constantan	0-1400°F	0-692°F		
TFV-ANN-15A	15 in. below cold leg centerline, 0°			9, 121	
TFV-ANN-15M	15 in. below cold leg centerline, 180°			9, 121	
TFV-ANN-15T	15 in. below cold leg centerline, 270°			9, 121	
TFV-ANN-35A	35 in. below cold leg centerline, 0°			9, 121	
TFV-ANN-35M	35 in. below cold leg centerline, 180°			9, 122	
TFV-ANN-35T	35 in. below cold leg centerline, 270°			9, 122	
TFV-ANN-70A	70 in. below cold leg centerline, 0°			9, 122	
TFV-ANN-115A	115 in. below cold leg centerline, 0°			9, 122	
TFV-ANN-156A	156 in. below cold leg centerline, 0°			9, 122	
<u>Lower Plenum</u>					
	On fluid thermocouple rack, 1 in. from vessel center, 45°	0-2300°F	0-591°F	10, 123	
TFV-LP-1-1/2	1.5 in. from bottom				Data do not follow saturation temperature from 0 to 20 sec during the blowdown portion of the test. No measurement system malfunctions were detected
TFV-LP-7-1/2	7.5 in. from bottom				Data do not follow saturation temperature and remain constant until 15 sec after rupture. No measurement system malfunctions were detected

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
FLUID TEMPERATURE (Contd.)					
<u>Lower Plenum</u> (Contd.)					
TFV-LP-14-1/2	14.5 in. from bottom				Data do not follow saturation temperature and remain constant until 15 sec after rupture. No measurement system malfunctions were detected
TFV-LP-21-1/2	21.5 in. from bottom				
TFV-LP-27-1/2	27.5 in. from bottom				
<u>Core</u>		0-2300°F	0-591°F	11, 124	
TF-LOFT-COR	Near LOFT core turbine flowmeter, 14 in. below cold leg centerline				
<u>Core Barrel Insulation Gap</u>		0-1400°F	0-692°F	12, 125	
TFV-CIG-70A	70 in. below cold leg centerline, 0°				
TFV-CIG-115A	115 in. below cold leg centerline, 0°				
<u>Vessel Filler - Insulation Gap</u>		0-1400°F	0-692°F	13, 126	
TFV-FIG-70A	70 in. below cold leg centerline, 0°				
TFV-FIG-156A	156 in. below cold leg centerline, 0°				
<u>ECC System</u>		0-2300°F	0-591°F	14, 127	
TFU-ECC-14	On centerline of ECC line at junction with Spool 14				
<u>Steam Generator</u>		0-2300°F	0-591°F	15, 128	
TFU-SG1	Secondary side, 12 in. above bottom of tube sheet				
TFU-SG2	Secondary side, 24 in. above bottom of tube sheet				
TFU-SG3	Secondary side, 48 in. above bottom of tube sheet				
TFU-SG4	Secondary side, 96 in. above bottom of tube sheet				Data not recorded; data acquisition system malfunctioned
<u>Pressurizer</u>		0-2300°F	0-591°F	16, 129	Fluctuations during hot-wall portion of test not understood
TFU-PR12E	In surge line, near pressurizer exit, between turbine flowmeter and pressurizer				
<u>Pressure Suppression System</u>		0-2300°F	0-591°F	17, 130	
TF-PSS-17	17 in. from bottom of tank				Thermocouple failed
TF-PSS-33	33 in. from bottom of tank				
TF-PSS-63	63 in. from bottom of tank				
TF-PSS-130	130 in. from bottom of tank				
MATERIAL TEMPERATURE					
Chromel-Alumel thermocouples unless specified otherwise		0-2300°F	0-591°F		
<u>Intact Loop</u>					
TMU-1T4	Hot leg, Spool 1, top, 1/4 in. from pipe ID, 29 in. from vessel center			18, 131	
TMU-1T16	Hot leg, Spool 1, top, 1/16 in. from pipe ID, 29 in. from vessel center			18, 131	
TMU-1B16	Hot leg, Spool 1, bottom, 1/16 in. from pipe ID, 29 in. from vessel center			18, 131	
TMU-8S16	Cold leg, Spool 8, side, in pump trap, 1/16 in. from pipe ID, 195 in. from vessel center			18, 131	
TMU-15T4	Cold leg, Spool 15, top, 1/4 in. from pipe ID, 17 in. from vessel center			19, 132	
TMU-15T16	Cold leg, Spool 15, top, 1/16 in. from pipe ID, 17 in. from vessel center			19, 132	

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
MATERIAL TEMPERATURE (Contd.)					
<u>Intact Loop (Contd.)</u>					
TMU-15S16	Cold leg, Spool 15, side, 1/16 in. from pipe ID, 17 in. from vessel center			19, 132	
TMU-15B16	Cold leg, Spool 15, bottom, 1/16 in. from pipe ID, 17 in. from vessel center			19, 132	
<u>Broken Loop</u>		0-2300°F	0-591°F	20, 133	
TMB-20B4	Cold leg, Spool 20, bottom, 1/4 in. from pipe ID, 21 in. from vessel center				
TMB-20T16	Cold leg, Spool 20, top, 1/16 in. from pipe ID, 21 in. from vessel center				
TMB-20S16	Cold leg, Spool 20, side, 1/16 in. from pipe ID, 21 in. from vessel center				
TMB-20B16	Cold leg, Spool 20, bottom, 1/16 in. from pipe ID, 21 in. from vessel center				
TMB-40S16	Cold leg, Spool 40, discharge of simulated pump, vertical section, side, 1/16 in. from pipe ID, 368 in. from vessel center along hot leg				
<u>Vessel Wall</u>	1/8 in. from vessel ID	0-2300°F	0-591°F	21, 134	
TMV-VI-35A	35 in. below cold leg centerline, 0°				
TMV-VI-156A	156 in. below cold leg centerline, 0°				
TMV-VI-177M	177 in. below cold leg centerline, 180°				Data have an unexplained -25°F offset
<u>Vessel Filler</u>	Type J iron-constantan	0-1400°F	0-692°F		
TMV-FO-35A	35 in. below cold leg centerline, 0.65 in. from filler ID, 0°			22, 135	
TMV-FO-156A	156 in. below cold leg centerline, 0.65 in. from filler ID, 0°			22, 135	
TMV-FO-177M	177 in. below cold leg centerline, 0.65 in. from filler ID, 180°				Thermocouple failed
TMV-FI-4M	4 in. below cold leg centerline, 1/16 in. from filler ID, 180°			23, 136	
TMV-FI-15A	15 in. below cold leg centerline, 1/16 in. from filler ID, 0°			23, 136	
TMV-FI-35A	35 in. below cold leg centerline, 1/16 in. from filler ID, 0°			23, 136	
TMV-FI-70A	70 in. below cold leg centerline, 1/16 in. from filler ID, 0°			23, 136	
TMV-FI-115A	115 in. below cold leg centerline, 1/16 in. from filler ID, 0°			23, 136	
TMV-FI-156A	156 in. below cold leg centerline, 1/16 in. from filler ID, 0°			23, 136	
TMV-FI-177M	177 in. below cold leg centerline, 1/16 in. from filler ID, 180°			23, 136	
TMV-FI-184M	184 in. below cold leg centerline, 1/16 in. from filler ID, 180°				Thermocouple failed
<u>Vessel Filler Insulator</u>	Outer surface of insulator, Type J iron-constantan	0-1400°F	0-692°F	24, 137	
TIV-FO-4A	4 in. below cold leg centerline, 0°				
TIV-FO-35A	35 in. below cold leg centerline, 0°				
TIV-FO-35M	35 in. below cold leg centerline, 180°				
TIV-FO-70A	70 in. below cold leg centerline, 0°				

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
MATERIAL TEMPERATURE (Contd.)					
<u>Vessel Filler (Contd.)</u>					
TIV-FO-115A	115 in. below cold leg centerline, 0°				
TIV-FO-156A	156 in. below cold leg centerline, 0°				
<u>Lower Plenum</u>	Chromel-Alumel thermocouple	0-2300°F	0-591°F	25, 138	
TMV-LH	In vessel bottom head, 1/8 in. from inside surface, 2 in. from vessel centerline, 90°				
<u>Core Barrel</u>	Type J iron-constantan	0-1400°F	0-692°F		
TMV-CO-4A	4 in. below cold leg centerline, in inlet annulus region, 1/16 in. from core barrel OD, 0°			26, 139	
TMV-CO-4M	4 in. below cold leg centerline, in inlet annulus region, 1/16 in. from core barrel OD, 180°			26, 139	
TMV-CO-15A	15 in. below cold leg centerline, 1/16 in. from core barrel OD, 0°			26, 139	
TMV-CO-70A	70 in. below cold leg centerline, 1/16 in. from barrel OD, 0°			26, 139	
TMV-CO-115A	115 in. below cold leg centerline, 1/16 in. from core barrel OD, 0°			26, 139	
TMV-CO-115M	115 in. below cold leg centerline, 1/16 in. from core barrel OD, 180°				Thermocouple failed
TMV-CI-35A	35 in. below cold leg centerline, 1/16 in. from core barrel ID, 0°			27, 140	
TMV-CI-70A	70 in. below cold leg centerline, 1/16 in. from core barrel ID, 0°			27, 140	
TMV-CI-115A	115 in. below cold leg centerline, 1/16 in. from core barrel ID, 0°			27, 140	
<u>Steam Generator</u>		0-2300°F	0-591°F	28, 141	
TMU-SG1	On steam generator tubes, 12 in. above bottom of tube sheet, on OD of tube				
TMU-SG2	On steam generator tubes, 24 in. above bottom of tube sheet, on OD of tube				
TMU-SG3	On steam generator tubes, 48 in. above bottom of tube sheet, on OD of tube				
TMU-SG4	On steam generator tubes, 96 in. above bottom of tube sheet, on OD of tube				
PRESSURE					
<u>Intact Loop</u>		0-3000 psig	0-4000 psig		
PU-13(F)	Cold leg, Spool 13, 54 in. from vessel center (flush mount)				Data not digitized due to limited channel availability; data available on analog system
<u>Broken Loop</u>		0-3000 psig	0-4000 psig	29, 142	
PB-23	Cold leg, Spool 23, 92 in. from vessel center, upstream of nozzle (tee off DP tap)				
PB-CN1	Vessel-side nozzle, nozzle throat, 96 in. from vessel center, (tee off DP tap)				
PB-42	Cold leg, Spool 42, 415 in. from vessel center along hot leg, upstream of pump-side nozzle (tee off DP tap)				
PB-HN1	Pump-side nozzle, nozzle throat, 419 in. from vessel center along hot leg (tee off DP tap)				

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
PRESSURE (Contd.)					
<u>Vessel</u>		0-3000 psig	0-4000 psig	30, 143	
PV-UP+10	In upper plenum, 10 in. above cold leg centerline, mounted on standoff, 30"				
PV-LP-180	In upper part of lower plenum, 180 in. below cold leg centerline, mounted on standoff, 225"				
PV-IANN-9	In vessel inlet annulus, 9 in. below cold leg centerline, mounted on standoff, 225"				
<u>ECC System</u>		0-750 psig	0-750 psig	31, 144	
PECC-UL-ACC	In intact loop accumulator				Data shift at 30 sec during blowdown and between blowdown and hot-wall portions of the test questionable
<u>Steam Generator</u>		0-3000 psig	0-4000 psig		Data not digitized due to limited channel availability; data available on analog system
PU-SGIP	Inlet plenum, 13 in. below bottom of tube sheet (flush mount)				
PU-SGOP	Outlet plenum, 13 in. below bottom of tube sheet (flush mount)				
<u>Pressurizer</u>		0-3000 psig	0-4000 psig	32, 145	
PU-PRIZE	Steam dome				
<u>Pressure Suppression System</u>		0-100 psig	0-100 psig	33, 146	
P-PSS	Suppression tank top				
DIFFERENTIAL PRESSURE					
<u>Intact Loop</u>					
DPU-UP-1	Upper plenum 10.5 in. above cold leg centerline at 30° to hot leg, Spool 1, 31 in. from vessel center, upper plenum tap approximately 2 in. above Spool 1 tap	±20 in. water	±1.0 psid	34, 147	Data acquisition system saturated before rupture. Measurement system failure occurred after 42 sec during blowdown. Data appear reasonable during the hot-wall portion of the test
DPU-UP-3	Upper plenum 10.5 in. above cold leg centerline at 30° to hot leg, Spool 3, 62 in. from vessel center, upper plenum tap approximately 2 in. above Spool 3 tap	±50 in. water	±2.5 psid	35, 148	
DPU-3-7	Across steam generator, hot leg, Spool 3, 62 in. from vessel center to cold leg Spool 7, 231 in. from vessel center, Spool 3 tap approximately 18 in. above Spool 7 tap	±50 psid	±50 psid	36, 149	
DPU-3-7L	Across steam generator, hot leg, Spool 3, 62 in. from vessel center to cold leg Spool 7, 231 in. from vessel center, Spool 3 tap approximately 18 in. above Spool 7 tap (low range)	±50 in. water	±2.5 psid	37, 150	Data acquisition system saturated until 6 sec during blowdown and from 7 to 12 sec during the hot-wall portion of the test
DPU-3-SGIP	Across inlet orifice of steam generator; hot leg, Spool 3, 62 in. from vessel center to steam generator inlet plenum, 145 in. from vessel center, Spool 3 tap is 16 in. below SGIP tap	±500 in. water	±25 psid	38, 151	
DPU-SGIP-SG1	Steam generator inlet plenum, 145 in. from vessel center to 12.25 in. above bottom of tube sheet, SG1 tap is 24 in. above SGIP taps	±300 in. water	±15.0 psid	39	Data have -6 psid offset after rupture. Data are considered questionable during the hot-wall portion of the test and are not presented
DPU-SG1-SG2	Across primary side tubes, 12 to 24 in. above bottom of tube sheet, SG1 tap is 12 in. below SG2 tap	±20 in. water	±1.0 psid	40	Data acquisition system saturated at 2 sec after rupture. Data are questionable afterwards due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SG2-SG3	Across primary side tubes, 24 to 48 in. above bottom of tube sheet, SG2 tap is 24 in. below SG3 tap	±50 in. water	±2.5 psid	41	Data are questionable due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SG3-SG4	Across primary side tubes, 48 to 96 in. above bottom of tube sheet, SG3 tap is 48 in. below SG4 tap	±100 in. water	±50 psid	42	Detector range exceeded at rupture; data appear questionable due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SGOP-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 35 in. below SGOP tap	±500 in. water	±25 psid	43, 152	Detector range exceeded at rupture
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	44, 153	Detector range exceeded until 2 sec after rupture

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
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	+50 psid	+50 psid	45, 154	
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	46, 155	Data acquisition system saturated until 6 sec after rupture and at t=21 sec during the hot-wall portion of test.
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	+50 in. water	+2.5 psid	47, 156	Data acquisition system saturated until 4 sec after rupture and at t=9, 10, and 24 sec during the hot-wall portion of test
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	48, 157	
DPU-15-1L	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 (low range)	+50 in. water	+2.5 psid	49, 158	Data acquisition system saturated until 3 sec after rupture and at various times from 6 to 26 sec during hot-wall portion of test
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	+20 in. water	+1.0 psid		Data acquisition system saturated throughout test
DPU-15-ATH	Cold leg Spool 15, 16 in. from vessel center to atmosphere	+500 psid	+500 psid	50, 159	Data acquisition system saturated until 25 sec after rupture
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	51, 160	Spurious data; actual liquid volume prior to blowdown was 0.72 ft ³
Broken Loop					
DPB-IANN-21	Vessel inlet annulus, 9 in. below cold leg centerline at 225° to cold leg Spool 21, 49 in. from vessel center, inlet annulus tap, 9 in. below Spool 21 tap	+100 in. water	+5.0 psid	52, 161	Detector range exceeded at 35 and 68 sec after rupture. Data appear to have -1 psid zero offset
DPB-21-23	Cold leg Spool 21, 49 in. from vessel center to cold leg Spool 23, 92 in. from vessel center	+800 in. water	+40 psid	53, 162	
DPB-23-CN1	Cold leg Spool 23, 92 in. from vessel center to vessel-side nozzle throat, 96 in. from vessel center	+500 psid	+500 psid	54, 163	
DPB-CN1-CN4	Vessel-side nozzle, nozzle throat, 96 in. from vessel center to nozzle divergent section, 101 in. from vessel center	+1000 psid	+1300 psid	55, 164	
DPB-23-24	Across vessel-side nozzle, Spool 23, 92 in. from vessel center to Spool 24, 104 in. from vessel center	+1000 psid	+1300 psid	56, 165	
DPB-UP-30	Vessel upper plenum 10.5 in. above cold leg centerline at 30° to hot leg Spool 30, 18 in. from vessel center, tap is 2 in. above Spool 30 tap	+100 in. water	+5.0 psid		Detector failed
DPB-30-38	Across entire simulated steam generator assembly and instrument spool downstream of simulated steam generator, hot leg Spool 30, 18 in. from vessel center to cold leg Spool 38, 305 in. from vessel center along hot leg, Spool 30 is 40 in. above Spool 38	+500 psid	+500 psid	57, 166	
DPB-30-32U	Hot leg Spool 30, 18 in. from vessel center to Spool 32 upper tap, 73 in. from vessel center, Spool 30 tap is 30 in. below Spool 32 upper tap	+100 psid	+100 psid	58, 167	
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	59, 168	

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Detector	Range [a]	Figure [a]	Measurement Comments [b]
			Data Acquisition System		
DIFFERENTIAL PRESSURE (Contd.)					
Broken Loop (Contd.)					
DPB-SGOR	Across first orifice plate of simulated steam generator, taps 87 and 95 in. from vessel center along hot leg, elevation difference between taps is 7 in.	+500 in. water	+25 psid	60, 169	
DPB-36L-37	Across nozzle assembly Spool 36 lower taps, 242 in. from vessel center along hot leg and Spool 37, 282 in. from vessel center along hot leg, Spool 37 is 40 in. below Spool 36 lower tap	150 psid	+50 psid	61, 170	
DPB-38-40	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	+1000 psid	+1300 psid	62, 171	Detector failed to record negative differential pressure during the hot-wall portion of the test
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 (low range)	+500 in. water	+25 psid	63, 172	Data erratic before rupture. Data acquisition system saturated from rupture until 40 sec after rupture
DPB-40-42	Across elbow leading to spool upstream of pump-side nozzle, cold leg Spool 40, 365 in. from vessel center along hot leg to Spool 42, 415 in. from vessel center along hot leg, Spool 40 tap is 40 in. below Spool 42 tap	+100 psid	+100 psid	64, 173	
DPB-42-43	Across pump-side nozzle, cold leg Spool 42, 415 in. from vessel center along hot leg to cold leg Spool 43, 427 in. from vessel center along hot leg	+1500 psid	+2000 psid	65, 174	Polarity of data reversed.
DPB-42-HN1	Spool 42 upstream of pump-side nozzle, 415 in. from vessel center along hot leg to nozzle throat, 419 in. from vessel center along hot leg	+500 in. water	+500 psid		Detector range exceeded throughout majority of test
DPB-HN1-HN4	Pump-side nozzle, nozzle throat, 419 in. from vessel center along hot leg to nozzle divergent section, 424 in. from vessel center along hot leg	+1500 psid	+2000 psid	66	Detector failed during hot-wall portion of the test
DPB-HN4-43	Pump-side nozzle, divergent section, 424 in. from vessel center along hot leg to downstream Spool 43, 427 in. from vessel center along hot leg	+200 psid	+200 psid	67, 175	
Vessel					
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	+20 in. water	+1.0 psid		Detector range exceeded throughout test
DPB-IANN-21	Vessel inlet annulus, 9 in. below cold leg centerline at 225° to broken loop cold leg, Spool 21, 49 in. from vessel center, inlet annulus tap is 9 in. below Spool 21 tap	+100 in. water	+5.0 psid	52, 161	Detector range exceeded at 35 and 68 sec after rupture
DPV-IANN-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.	+300 in. water	+14.8 psid	68, 176	Polarity of data reversed.
DPV-9-26QQ	Inlet annulus, 9 in. below cold leg centerline at 225° to downcomer gap 26 in. below cold leg centerline at 225°, elevation difference between taps is 17 in.	+20 in. water	+1.0 psid	69	Data acquisition saturated 14 sec after rupture; data spurious thereafter
DPV-9-180QQ	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	+14.8 psid		Valve in sense line open causing erroneous measurement
DPV-55-110AM	Across part of downcomer, 55 in. (0°) to 110 in. (180°) below cold leg centerline, elevation difference between taps is 55 in.	+100 in. water	+5.0 psid	70, 177	Detector range exceeded at rupture
DPV-110-156MQ	Across part of downcomer, 110 in. (180°) to 156 in. (225°) below cold leg centerline, elevation difference between taps is 46 in.	+100 in. water	+5.0 psid	71, 178	

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments	Range[a]		Figure[a]	Measurement Comments[b]
		Detector	Data Acquisition System		
DIFFERENTIAL PRESSURE (Contd.)					
Vessel (Contd.)					
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	72, 179	Data acquisition system saturated at rupture and from 58 to 70 sec of blowdown portion of test
DPV-166-173QQ	Across part of lower plenum, 166 in. (225°) to 173 in. (225°) below cold leg centerline, elevation difference between taps is 7 in.	±20 in. water	±1.0 psid		Valve in sense line open, causing erroneous measurement
DPV-173-180QQ	Across part of lower plenum, 173 in. (225°) to 180 in. (225°) below cold leg centerline, elevation difference between taps is 7 in.	±20 in. water	±1.0 psid		Valve in sense line open, causing erroneous measurement
DPV-180-191QT	Across part of lower plenum, 180 in. (225°) to 191 in. (270°) below cold leg centerline, elevation difference between taps is 11 in.	±20 in. water	±1.0 psid		Valve in sense line open, causing erroneous measurement
DPV-LP-UP	Lower plenum, 180 in. below cold leg centerline at 225° to upper plenum, 10.5 in. above cold leg centerline at 30°, elevation difference between taps is 191 in.	±300 in. water	±14.8 psid	73, 180	Erratic data before rupture unexplained
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	±20 in. water	±1.0 psid	34, 147	Data acquisition system saturated before rupture. Measurement system failure occurred after 42 sec during blowdown. Data appear reasonable during the hot-wall portion of the test
DPU-UP-3	Vessel upper plenum, 10.5 in. above cold leg centerline at 30° to intact loop hot leg Spool 3, 62 in. from vessel center, upper plenum tap is ~2 in. above Spool 3 tap	±50 in. water	±2.5 psid	35, 148	Detector range exceeded before and at rupture
DPB-UP-30	Vessel upper plenum, 10.5 in. above cold leg centerline at 30° to broken loop hot leg Spool 30, 18 in. from vessel center, upper plenum tap is 2 in. above Spool 30 tap	±100 in. water	±5.0 psid		Detector failed
Steam Generator					
DPU-3-SGIP	Across inlet orifice, hot leg Spool 3, 62 in. from vessel center to steam generator inlet plenum, 145 in. from vessel center, Spool 3 tap is 16 in. below SGIP tap	±500 in. water	±25 psid	38, 151	
DPU-SGIP-SG1	Steam generator inlet plenum, 145 in. from vessel center to 12.25 in. above bottom of tube sheet, SG1 tap is 24 in. above SGIP taps	±300 in. water	±15.0 psid	39	Data have -6 psid offset after rupture. Data are considered questionable during the hot-wall portion of the test and are not presented
DPU-SG1-SG2	Across primary side tubes, 12 to 24 in. above bottom of tube sheet, SG1 tap is 12 in. below SG2 tap	±20 in. water	±1.0 psid	40	Data acquisition system saturated at 2 sec after rupture. Data are questionable afterwards due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SG2-SG3	Across primary side tubes, 24 to 48 in. above bottom of tube sheet, SG2 tap is 24 in. below SG3 tap	±50 in. water	±2.5 psid	41	Data are questionable due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SG3-SG4	Across primary side tubes, 48 to 96 in. above bottom of tube sheet, SG3 tap is 48 in. below SG4 tap	±100 in. water	±5.0 psid	42	Detector range exceeded at rupture; data appear questionable due to possible sense line draining and are not presented for the hot-wall portion of the test
DPU-SGOP-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 35 in. below SGOP tap	±500 in. water	±25 psid	43, 152	Detector range exceeded at rupture
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.				Measurement system failed
Pressurizer					
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	51, 160	Spurious data; actual liquid volume prior to blowdown was 0.72 ft ³

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
VOLUMETRIC FLOW RATE	Turbine flowmeter, bidirectional				
<u>Intact Loop</u>	3-in. Schedule 160 pipe			74, 181	
FTU-1	Hot leg, Spool 1, 18 in. from vessel center	± 20 to ± 400 gpm	± 655 gpm		Detector measured only positive flow
FTU-9	Cold leg, Spool 9, 154 in. from vessel center	± 20 to ± 400 gpm	± 649		Data are questionable. Data indicate flow away from the pump immediately after blowdown which is improbable. Detector failed during hot-wall portion of the test
FTU-13	Cold leg, Spool 13, 64 in. from vessel center	± 20 to ± 400 gpm	± 649 gpm		Detector failed
FTU-15	Cold leg, Spool 15, 29 in. from vessel center	± 10 to ± 200 gpm	± 389 gpm		
<u>Broken Loop</u>	All measurements bidirectional, Schedule 160 pipe			75, 182	
FTB-21	Cold leg, Spool 21, 58 in. from vessel center, 3-in. pipe	± 20 to ± 400 gpm	± 847 gpm		Data are questionable. Data indicate ~ 250 gpm prior to rupture. Data acquisition system saturates between 25 and 56 sec after rupture. Data should be zero flow prior to $t=0$ sec and are erratic during hot-wall portion of test
FTB-30	Hot leg, Spool 30, 25 in. from vessel center, 3 in. pipe	± 20 to ± 400 gpm	± 408 gpm		
FTB-37	Cold leg, Spool 37, 290 in. from vessel center along hot leg, 2-in. pipe	± 10 to ± 200 gpm	± 647 gpm		Detector range exceeded from 14 to 54 sec after rupture but data are considered valid
<u>Core</u>				76, 183	
FTV-CORE-IN	Entrance to core, ~ 158 in. below cold leg centerline	± 10 to ± 200 gpm	± 405 gpm		
FTV-LOFT-COR	In LOFT core simulator, 14 in. below cold leg centerline (LOFT drag-disc, turbine flowmeter combination)	± 2 to ± 20 ft/sec	± 20 ft/sec		Detector failed
<u>ECC System</u>				184	
FTU-ACC	In line immediately after intact loop accumulator, 1-in. line	1 to 25 gpm	0 to 25 gpm		Data acquisition system saturated throughout injection. Detector failed at introduction of nitrogen ($t=68$ sec of hot-wall portion of test). Average flow rate computed to be 35 gpm from $t=0$ to 20 sec
<u>Pressurizer</u>	1-1/2-in. turbine				
FTU-PRIZE	Surge line	5 to 100 gpm	0 to 111 gpm		Detector failed
FLUID VELOCITY	Turbine flowmeter, bidirectional				
<u>Downcomer Gap</u>					
FTV-22M	22 in. below cold leg centerline, 180°	± 1.8 to ± 36 ft/sec	± 36 ft/sec		Detector failed
FTV-40A	40 in. below cold leg centerline, 0°	± 1.8 to ± 36 ft/sec	± 36 ft/sec	77, 185	Data acquisition system saturated at 66 sec during blowdown portion of test and at various times throughout hot-wall portion of test
FTV-40M	40 in. below cold leg centerline, 180°	± 1.8 to ± 36 ft/sec	± 36 ft/sec	78, 186	Data acquisition system saturated from 43 to 55 sec after rupture
FTV-83A	83 in. below cold leg centerline, 0°	± 0.9 to ± 18 ft/sec	± 18 ft/sec	79, 187	Data acquisition system saturated from 32 to 53 sec after rupture
FTV-83M	83 in. below cold leg centerline, 180°	± 0.9 to ± 18 ft/sec	± 18 ft/sec	80, 188	Data are questionable; negative flow before rupture, and detector appears insensitive to flow during blowdown
FTV-130M	130 in. below cold leg centerline, 180°	± 0.9 to ± 18 ft/sec	± 18 ft/sec	81, 189	Detector measured positive velocity only
FTV-161M	161 in. below cold leg centerline, 180°	± 0.9 to ± 18 ft/sec	± 18 ft/sec		Detector failed
MOMENTUM FLUX	Drag-disc, bidirectional				Momentum flux data presented indicate magnitude only
<u>Intact Loop</u>	3-in. pipe				
FDU-1	Hot leg, Spool 1, 29 in. from vessel center, target size 0.875 in.	± 250 to $\pm 11,500$ lb _m /ft-sec ²	$\pm 15,300$ lb _m /ft-sec ²	82	Data below reliable range of detector during hot-wall portion of the test
FDU-5	Hot leg, Spool 5, 100 in. from vessel center, target size 1 in.	± 1 to ± 2000 lb _m /ft-sec ²	± 2000 lb _m /ft-sec ²	83	Data are questionable. Thermocouple in contact with drag disc. Data below reliable range of detector during hot-wall portion of the test
FDU-10	Cold leg, Spool 10, 137 in. from vessel center, target size 0.875 in.	± 200 to $\pm 104,000$ lb _m /ft-sec ²	$\pm 130,000$ lb _m /ft-sec ²	84	Data below reliable range of detector during hot-wall portion of the test

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments [a]	Range [a]		Figure [a]	Measurement Comments [b]
		Detector	Data Acquisition System		
MOMENTUM FLUX (Contd.)					
Intact Loop (Contd.)					
FDU-13	Cold leg, Spool 13, 54 in. from vessel center, target size 0.875 in.	+200 to +11,000 lb _m /ft-sec ²	+14,800 lb _m /ft-sec ²	85	Data below reliable range of detector during hot-wall portion of the test
FDU-15	Cold leg, Spool 15, 19 in. from vessel center, target size 0.875 in.	+200 to +11,600 lb _m /ft-sec ²	+15,500 lb _m /ft-sec ²	86, 190	
Broken Loop					
FDB-21	Cold leg, Spool 21, 53 in. from vessel center, 3-in. pipe, target size 0.406 in.	+200 to +70,500 lb _m /ft-sec ²	+94,000 lb _m /ft-sec ²	87	Data below reliable range of detector during hot-wall portion of the test
FDB-23	Cold leg, Spool 23, 93 in. from vessel center, upstream of vessel-side nozzle 1.5-in. pipe, target size 0.406 in.	+200 to +125,000	+167,000 lb _m /ft-sec ²	88	Data below reliable range of detector during hot-wall portion of the test
FDB-30	Hot leg, Spool 30, 21 in. from vessel center, 3-in. pipe, target size 0.406 in.	+200 to +60,000 lb _m /ft-sec ²	+80,000 lb _m /ft-sec ²		Target on drag disc too small causing insensitivity to flow
FDB-37	Cold leg, Spool 37, 284 in. from vessel center along hot leg, steam generator outlet vertical pipe, 2-in. pipe, target size 0.406 in.	+200 to +131,000 lb _m /ft-sec ²	+175,000 lb _m /ft-sec ²	89	Data below reliable range of detector during hot-wall portion of the test
FDB-42	Cold leg, Spool 42, 416 in. from vessel center along hot leg, upstream of pump-side nozzle, downstream of injection point, 1.5-in. pipe, target size 0.406 in.	+200 to +11,600 lb _m /ft-sec ²	+155,000 lb _m /ft-sec ²	90	Data below reliable range of detector during hot-wall portion of the test
Vessel					
FDV-CORE-IN	In core flow mixer box, 150 in. below cold leg centerline, target size 1 in.	+100 to +1000 lb _m /ft-sec ²	+1000 lb _m /ft-sec ²		Detector failed
FDV-LOFT-COR	In LOFT core simulator, 14 in. below cold leg centerline (LOFT drag-disc, turbine flowmeter combination) target size 0.500 in.	+200 to +2100 lb _m /ft-sec ²	+3700 lb _m /ft-sec ²		Detector failed
DENSITY					
Intact Loop					
GU-1VR	Hot leg, Spool 1, 24 in. from vessel center, vertical	0.1 to 100 lb _m /ft ³	0.1 to 100 lb _m /ft ³	91, 191	
GU-1HZ	Hot leg, Spool 1, 26 in. from vessel center, horizontal				Detector failed
GU-5VR	Hot leg, Spool 5, 96 in. from vessel center, vertical			92, 192	
GU-10VR	Cold leg, Spool 10, 141 in. from vessel center, vertical			92, 192	
GU-13VR	Cold leg, Spool 13, 59 in. from vessel center, vertical			93, 193	
GU-15HZ	Cold leg, Spool 15, 20 in. from vessel center, horizontal			93, 193	
GU-15VR	Cold leg, Spool 15, 23 in. from vessel center, vertical			93, 193	
Broken Loop					
GB-21VR	Cold leg, Spool 21, 49 in. from vessel center, vertical			94, 194	
GB-23VR	Cold leg, Spool 23, 92 in. from vessel center, vertical			95, 195	
GB-30VR	Hot leg, Spool 30, 18 in. from vessel center, vertical			94, 194	
GB-37HZ	Cold leg, Spool 37, 279 in. from vessel center along hot leg, across vertical pipe, simulated steam generator discharge			95, 195	
GB-42VR	Cold leg, Spool 42, 415 in. from vessel center along hot leg, vertical			95, 195	

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments ^[a]	Detector	Range ^[a] Data Acquisition System	Figure ^[a]	Measurement Comments ^[b]
DENSITY (Contd.)					
Vessel					
GV-COR-150HZ	Core flow mixer box, 152 in. below cold leg centerline, horizontal, 0-180°			96, 196	
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			96, 196	
GVLP-165HZ	Upper part of lower plenum, 165 in. below cold leg centerline, 1.724 in. below downcomer exit, horizontal, 0-180°			97, 197	
GVLP-172HZ	Lower plenum, 172 in. below cold leg centerline, 8.729 in. below downcomer exit, horizontal, 90-270°			97, 197	
Pressurizer					
GU-PRIZE	Surge line			98, 198	
LIQUID LEVEL					
Steam Generator					
DPU-SG-SEC	Secondary side, differential pressure taps at 45 and 126 in. above tube sheet, elevation difference between taps is 0.1 in.	+100 in. water	+5.0 psid		Measurement system failed
Pressurizer					
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	51, 160	Spurious data; actual liquid volume prior to blowdown was 0.72 ft ³
MASS FLOW RATE					
	Mass flow rate obtained by combining density (gamma attenuation technique) with volumetric flow rate (turbine flowmeter) or momentum flux (drag-disc)		Density ranges are 0.1 to 100 lb _m /ft ³ for both detector and data acquisition system		
Intact Loop					
FDU-1 GU-1VR	Hot leg, Spool 1	+250 to +11,500 lb _m /ft-sec ²	+15,300 lb _m /ft-sec ²	99	
FTU-1 GU-1VR	Hot leg, Spool 1	+20 to +400 gpm	+655 gpm	100, 199	
FDU-5 GU-5VR	Hot leg, Spool 5	+1 to +2000 lb _m /ft-sec ²	+2000 lb _m /ft-sec ²	101	
FDU-10 GU-10VR	Cold leg, Spool 10	+200 to +104,000 lb _m /ft-sec ²	+130,000 lb _m /ft-sec ²	102	Data are questionable; calibration error suspected.
FDU-13 GU-13VR	Cold leg, Spool 13	+200 to +11,000 lb _m /ft-sec ²	+14,800 lb _m /ft-sec ²	103	
FDU-15 GU-15VR	Cold leg, Spool 15	+200 to +11,600 lb _m /ft-sec ²	+15,500 lb _m /ft-sec ²	104, 200	
FTU-15 GU-15VR	Cold leg, Spool 15	+10 to +200 gpm	+389 gpm	105, 201	
FDU-15 GU-15HZ	Cold leg, Spool 15	+200 to +11,600 lb _m /ft-sec ²	+15,500 lb _m /ft-sec ²	106, 202	
FTU-15 GU-15HZ	Cold leg, Spool 15	+10 to +200 gpm	+389 gpm	107, 203	
Broken Loop					
FDB-21 GB-21VR	Cold leg, Spool 21	+200 to +70,500 lb _m /ft-sec ²	+94,000 lb _m /ft-sec ²	108	
FDB-23 GB-23VR	Cold leg, Spool 23	+200 to +125,000 lb _m /ft-sec ²	+167,000 lb _m /ft-sec ²	109	
FTB-30 GB-30VR	Hot leg, Spool 30	+20 to +400 gpm	+408 gpm	110, 204	
FDB-37 GB-37HZ	Cold leg, Spool 37	+200 to +131,000 lb _m /ft-sec ²	+175,000 lb _m /ft-sec ²	111	
FTB-37 GB-37HZ	Cold leg, Spool 37	+10 to +200 gpm	+657 gpm	112, 205	
FDB-42 GB-42VR	Cold leg, Spool 42	+200 to +11,600 lb _m /ft-sec ²	+155,000 lb _m /ft-sec ²	113	
Vessel					
FTV-CORE-IN and GV-COR-150HZ	Entrance to core	+10 to +200 gpm	+405 gpm	114, 206	

TABLE V (Contd.)

DATA PRESENTATION FOR SEMISCALE MOD-1 TEST S-01-2

Measurement	Location and Comments ^[a]	Range ^[a]		Figure ^[a]	Measurement Comments ^[b]
		Detector	Data Acquisition System		
PUMP CHARACTERISTICS					
PUMFU-TORQ	Pump torque	0-500 in.-lb	0-500 in.-lb	115, 207	
PUMFU-POW	Pump motor power		0-24.2 kW	116, 208	
PUMFU-RPM	Pump speed	0-3600 rpm	0-3600 rpm	117, 209	
<div>[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.</div> <div>[b] Detectors which were subjected to overrange conditions during portions of the test were capable of withstanding these conditions without change in operation or measuring characteristics when the physical conditions were again within the detector range.</div>

Fig. 6 Fluid temperatures in intact loop -- blowdown.

Fig. 7 Fluid temperatures in broken loop -- blowdown.

Fig. 8 Fluid temperatures in inlet annulus -- blowdown.

Fig. 9 Fluid temperatures in downcomer annulus -- blowdown.

Fig. 10 Fluid temperatures in lower plenum -- blowdown.

Fig. 11 Fluid temperature in core (LOFT) -- blowdown.

Fig. 12 Fluid temperatures in core barrel insulation gap -- blowdown.

Fig. 13 Fluid temperatures in vessel filler insulation gap -- blowdown.

Fig. 14 Fluid temperature at cold leg injection point (Spool 14) -- blowdown.

Fig. 15 Fluid temperatures in steam generator -- blowdown.

Fig. 16 Fluid temperature in pressurizer -- blowdown.

Fig. 17 Fluid temperatures in pressure suppression tank -- blowdown.

Fig. 18 Material temperatures in intact loop (TMU-1T4, TMU-1T16, TMU-1B16, and TMU-8S16) -- blowdown.

Fig. 19 Material temperatures in intact loop (TMU-15T4, TMU-15T16, TMU-15S16, and TMU-15B16) -- blowdown.

Fig. 20 Material temperatures in broken loop -- blowdown.

Fig. 21 Material temperatures in vessel wall -- blowdown.

Fig. 22 Material temperatures in vessel filler OD -- blowdown.

Fig. 23 Material temperatures in vessel filler ID -- blowdown.

Fig. 24 Material temperatures in vessel filler insulator -- blowdown.

Fig. 25 Material temperature in vessel lower head -- blowdown.

Fig. 26 Material temperatures in core barrel OD -- blowdown.

Fig. 27 Material temperatures in core barrel ID -- blowdown.

Fig. 28 Material temperatures in steam generator -- blowdown.

Fig. 29 Pressures in broken loop -- blowdown.

Fig. 30 Pressures in vessel -- blowdown.

Fig. 31 Pressure in intact loop ECC accumulator -- blowdown.

Fig. 32 Pressure in pressurizer -- blowdown.

Fig. 33 Pressure in pressure suppression tank -- blowdown.

Fig. 34 Differential pressure in intact loop (upper plenum to Spool 1) -- blowdown.

Fig. 35 Differential pressure in intact loop (upper plenum to Spool 3) -- blowdown.

Fig. 36 Differential pressure in intact loop (Spool 3 to Spool 7) -- blowdown.

Fig. 37 Differential pressure in intact loop, low range (Spool 3 to Spool 7) -- blowdown.

Fig. 38 Differential pressure in intact loop (Spool 3 to steam generator inlet plenum) -- blowdown.

Fig. 39 Differential pressure in intact loop (steam generator inlet plenum to SG1) -- blowdown.

Fig. 40 Differential pressure in intact loop (SG1 to SG2) -- blowdown.

Fig. 41 Differential pressure in intact loop (SG2 to SG3) -- blowdown.

Fig. 42 Differential pressure in intact loop (SG3 to SG4) -- blowdown.

Fig. 43 Differential pressure in intact loop (steam generator outlet plenum to Spool 7) -- blowdown.

Fig. 44 Differential pressure in intact loop (Spool 7 to Spool 10) -- blowdown.

Fig. 45 Differential pressure in intact loop (Spool 12 to Spool 10) -- blowdown.

Fig. 46 Differential pressure in intact loop, low range (Spool 12 to Spool 10) -- blowdown.

Fig. 47 Differential pressure in intact loop (Spool 12 to Spool 15) -- blowdown.

Fig. 48 Differential pressure in intact loop (Spool 15 to Spool 1) -- blowdown.

Fig. 49 Differential pressure in intact loop, low range (Spool 15 to Spool 1) -- blowdown.

Fig. 50 Differential pressure in intact loop (Spool 15 to atmosphere) -- blowdown.

Fig. 51 Differential pressure in intact loop (pressurizer liquid level) -- blowdown.

Fig. 52 Differential pressure in broken loop (inlet annulus to Spool 21) -- blowdown.

Fig. 53 Differential pressure in broken loop (Spool 21 to Spool 23) -- blowdown.

Fig. 54 Differential pressure in broken loop (Spool 23 to cold-leg nozzle throat) -- blowdown.

Fig. 55 Differential pressure in broken loop (cold-leg nozzle throat to divergent section) -- blowdown.

Fig. 56 Differential pressure in broken loop (Spool 23 to Spool 24) -- blowdown.

Fig. 57 Differential pressure in broken loop (Spool 30 to Spool 38) -- blowdown.

Fig. 58 Differential pressure in broken loop (Spool 30 to Spool 32U) -- blowdown.

Fig. 59 Differential pressure in broken loop (Spool 32U to Spool 36L) -- blowdown.

Fig. 60 Differential pressure in broken loop (across simulated steam generator first orifice plate) -- blowdown.

Fig. 61 Differential pressure in broken loop (Spool 36L to Spool 37) -- blowdown.

Fig. 62 Differential pressure in broken loop (Spool 38 to Spool 40) -- blowdown.

Fig. 63 Differential pressure in broken loop, low range (Spool 38 to Spool 40) -- blowdown.

Fig. 64 Differential pressure in broken loop (Spool 40 to Spool 42) -- blowdown.

Fig. 65 Differential pressure in broken loop (Spool 42 to Spool 43) -- blowdown.

Fig. 66 Differential pressure in broken loop (hot-leg nozzle throat to divergent section) -- blowdown.

Fig. 67 Differential pressure in broken loop (hot-leg nozzle divergent section to Spool 43) -- blowdown.

Fig. 68 Differential pressure in vessel (inlet annulus to upper plenum) -- blowdown.

Fig. 69 Differential pressure in vessel (inlet annulus to downcomer gap) -- blowdown.

Fig. 70 Differential pressure in vessel (DPV-55-110AM) -- blowdown.

Fig. 71 Differential pressure in vessel (DPV-110-156MQ) -- blowdown.

Fig. 72 Differential pressure in vessel (DPV-156-173QQ) -- blowdown.

Fig. 73 Differential pressure in vessel (lower plenum to upper plenum) -- blowdown.

Fig. 74 Volumetric flows in intact loop -- blowdown.

Fig. 75 Volumetric flows in broken loop -- blowdown.

Fig. 76 Volumetric flow in core entrance -- blowdown.

Fig. 77 Fluid velocity in vessel (FTV-40A) -- blowdown.

Fig. 78 Fluid velocity in vessel (FTV-40M) -- blowdown.

Fig. 79 Fluid velocity in vessel (FTV-83A) -- blowdown.

Fig. 80 Fluid velocity in vessel (FTV-83M) -- blowdown.

Fig. 81 Fluid velocity in vessel (FTV-130M) -- blowdown.

Fig. 82 Momentum flux in intact loop (Spool 1) -- blowdown.

Fig. 83 Momentum flux in intact loop (Spool 5) -- blowdown.

Fig. 84 Momentum flux in intact loop (Spool 10) -- blowdown.

Fig. 85 Momentum flux in intact loop (Spool 13) -- blowdown.

Fig. 86 Momentum flux in intact loop (Spool 15) -- blowdown.

Fig. 87 Momentum flux in broken loop (Spool 21) -- blowdown.

Fig. 88 Momentum flux in broken loop (Spool 23) -- blowdown.

Fig. 89 Momentum flux in broken loop (Spool 37) -- blowdown.

Fig. 90 Momentum flux in broken loop (Spool 42) -- blowdown.

Fig. 91 Density in intact loop (GU-1VR) -- blowdown.

Fig. 92 Densities in intact loop (GU-5VR and GU-10VR) -- blowdown.

Fig. 93 Densities in intact loop (GU-13VR, GU-15HZ, and GU-15VR) -- blowdown.

Fig. 94 Densities in broken loop (GB-21VR and GB-30VR) -- blowdown.

Fig. 95 Densities in broken loop (GB-23VR, GB-37HZ, and GB-42VR) -- blowdown.

Fig. 96 Densities in vessel (GV-COR-150HZ and GV-161/192D) -- blowdown.

Fig. 97 Densities in vessel (GVLP-165HZ and GVLP-172HZ) -- blowdown.

Fig. 98 Density in pressurizer.

Fig. 99 Mass flow in intact loop (FDU-1 and GU-1VR) -- blowdown.

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Fig. 100 Mass flow in intact loop (FTU-1 and GU-1VR) -- blowdown.

Fig. 101 Mass flow in intact loop (FDU-5 and GU-5VR) -- blowdown.

Fig. 102 Mass flow in intact loop (FDU-10 and GU-10VR) -- blowdown.

Fig. 103 Mass flow in intact loop (FDU-13 and GU-13VR) -- blowdown.

Fig. 104 Mass flow in intact loop (FDU-15 and GU-15VR) -- blowdown.

Fig. 105 Mass flow in intact loop (FTU-15 and GU-15VR) -- blowdown

Fig. 106 Mass flow in intact loop (FDU-15 and GU-15HZ) -- blowdown.

Fig. 107 Mass flow in intact loop (FTU-15 and GU-15HZ) -- blowdown.

Fig. 108 Mass flow in broken loop (FDB-21 and GB-21VR) -- blowdown.

Fig. 109 Mass flow in broken loop (FDB-23 and GB-23VR) -- blowdown.

Fig. 110 Mass flow in broken loop (FTB-30 and GB-30VR) -- blowdown.

Fig. 111 Mass flow in broken loop (FDB-37 and GB-37HZ) -- blowdown.

Fig. 112 Mass flow in broken loop (FTB-37 and GB-37HZ) -- blowdown.

Fig. 113 Mass flow in broken loop (FDB-42 and GB-42VR) -- blowdown.

Fig. 114 Mass flow in vessel (FTV-CORE-IN and GV-COR-150HZ) -- blowdown.

Fig. 115 Primary pump torque -- blowdown.

Fig. 116 Primary pump power -- blowdown.

Fig. 117 Primary pump speed -- blowdown.

Fig. 118 Fluid temperatures in intact loop -- hot wall.

Fig. 119 Fluid temperatures in broken loop -- hot wall.

Fig. 120 Fluid temperatures in inlet annulus -- hot wall.

Fig. 121 Fluid temperatures in downcomer annulus (TFV-ANN-15A, TFV-ANN-15M, TFV-ANN-15T, and TFV-ANN-35A) -- hot wall.

Fig. 122 Fluid temperatures in downcomer annulus (TFV-ANN-35M, TFV-ANN-35T, TFV-ANN-70A, TFV-ANN-115A, and TFV-ANN-156A -- hot wall).

Fig. 123 Fluid temperatures in lower plenum -- hot wall.

Fig. 124 Fluid temperature in core (LOFT) -- hot wall.

Fig. 125 Fluid temperatures in core barrel insulation gap -- hot wall.

Fig. 126 Fluid temperatures in vessel filler insulation gap -- hot wall.

Fig. 127 Fluid temperature at cold-leg injection point (Spool 14) -- hot wall.

Fig. 128 Fluid temperatures in steam generator -- hot wall.

Fig. 129 Fluid temperature in pressurizer -- hot wall.

Fig. 130 Fluid temperatures in pressure suppression tank -- hot wall.

Fig. 131 Material temperatures in intact loop (TMU-1T4, TMU-1T16, TMU-1B16, and TMU-8S16) -- hot wall.

Fig. 132 Material temperatures in intact loop (TMU-15T4, TMU-15T16, TMU-15S16, and TMU-15B16) -- hot wall.

Fig. 133 Material temperatures in broken loop -- hot wall.

Fig. 134 Material temperatures in vessel wall -- hot wall.

Fig. 135 Material temperatures in vessel filler OD -- hot wall.

Fig. 136 Material temperatures in vessel filler ID -- hot wall.

Fig. 137 Material temperatures in vessel filler insulator -- hot wall.

Fig. 138 Material temperatures in vessel lower head -- hot wall.

Fig. 139 Material temperatures in core barrel OD -- hot wall.

Fig. 140 Material temperatures in core barrel ID -- hot wall.

Fig. 141 Material temperatures in steam generator -- hot wall.

Fig. 142 Pressures in broken loop -- hot wall.

Fig. 143 Pressures in vessel -- hot wall.

Fig. 144 Pressures in intact loop ECC accumulator -- hot wall.

Fig. 145 Pressures in pressurizer -- hot wall.

Fig. 146 Pressure in pressure suppression tank -- hot wall.

Fig. 147 Differential pressure in intact loop (upper plenum to Spool 1) -- hot wall.

Fig. 148 Differential pressure in intact loop (upper plenum to Spool 3) -- hot wall.

Fig. 149 Differential pressure in intact loop (Spool 3 to Spool 7) -- hot wall.

Fig. 150 Differential pressure in intact loop, low range (Spool 3 to Spool 7) -- hot wall.

Fig. 151 Differential pressure in intact loop (Spool 3 to steam generator inlet plenum) -- hot wall.

Fig. 152 Differential pressure in intact loop (steam generator outlet plenum to Spool 7) -- hot wall.

Fig. 153 Differential pressure in intact loop (Spool 7 to Spool 10) -- hot wall.

Fig. 154 Differential pressure in intact loop (Spool 12 to Spool 10) -- hot wall.

Fig. 155 Differential pressure in intact loop, low range (Spool 12 to Spool 10) -- hot wall.

Fig. 156 Differential pressure in intact loop (Spool 12 to Spool 15) -- hot wall.

Fig. 157 Differential pressure in intact loop (Spool 15 to Spool 1) -- hot wall.

Fig. 158 Differential pressure in intact loop, low range (Spool 15 to Spool 1) -- hot wall.

Fig. 159 Differential pressure in intact loop (Spool 15 to atmosphere) -- hot wall.

Fig. 160 Differential pressure in intact loop (pressurizer liquid level) -- hot wall.

Fig. 161 Differential pressure in broken loop (inlet annulus to Spool 21) -- hot wall.

Fig. 162 Differential pressure in broken loop (Spool 21 to Spool 23) -- hot wall.

Fig. 163 Differential pressure in broken loop (Spool 23 to cold leg nozzle throat) -- hot wall.

Fig. 164 Differential pressure in broken loop (cold leg nozzle throat to divergent section) -- hot wall.

Fig. 165 Differential pressure in broken loop (Spool 23 to Spool 24) -- hot wall.

Fig. 166 Differential pressure in broken loop (Spool 30 to Spool 38) -- hot wall.

Fig. 167 Differential pressure in broken loop (Spool 30 to Spool 32U) hot wall.

Fig. 168 Differential pressure in broken loop (Spool 32U to Spool 36L) --- hot wall.

Fig. 169 Differential pressure in broken loop (across simulated steam generator first orifice plate) -- hot wall.

Fig. 170 Differential pressure in broken loop (Spool 36L to Spool 37) -- hot wall.

Fig. 171 Differential pressure in broken loop (Spool 38 to Spool 40) -- hot wall.

Fig. 172 Differential pressure in broken loop, low range (Spool 38 to Spool 40) -- hot wall.

Fig. 173 Differential pressure in broken loop (Spool 40 to Spool 42) -- hot wall.

Fig. 174 Differential pressure in broken loop (Spool 42 to Spool 43) -- hot wall.

Fig. 175 Differential pressure in broken loop (hot-leg nozzle divergent section to Spool 43) -- hot wall.

Fig. 176 Differential pressure in vessel (inlet annulus to upper plenum) hot wall.

Fig. 177 Differential pressure in vessel (DPV-55-110AM) -- hot wall.

Fig. 178 Differential pressure in vessel (DPV-110-156MQ) -- hot wall.

Fig. 179 Differential pressure in vessel (DPV-156-173QQ) -- hot wall.

Fig. 180 Differential pressure in vessel (lower plenum to upper plenum) hot wall.

Fig. 181 Volumetric flows in intact loop -- hot wall.

Fig. 182 Volumetric flows in broken loop -- hot wall.

Fig. 183 Volumetric flow in core entrance -- hot wall.

Fig. 184 Volumetric flow from accumulator -- hot wall.

Fig. 185 Fluid velocity in vessel (FTV-40A) -- hot wall.

Fig. 186 Fluid velocity in vessel (FTV-40M) -- hot wall.

Fig. 187 Fluid velocity in vessel (FTV-83A) -- hot wall.

Fig. 188 Fluid velocity in vessel (FTV-83M) -- hot wall.

Fig. 189 Fluid velocity in vessel (FTV-130M) -- hot wall.

Fig. 190 Momentum flux in intact loop (Spool 15) -- hot wall.

Fig. 191 Density in intact loop (GU-1VR) -- hot wall.

Fig. 192 Densities in intact loop (GU-5VR and GU-10VR) -- hot wall.

Fig. 193 Densities in intact loop (GU-13VR, GU-15HZ, and GU-15VR) -- hot wall.

Fig. 194 Densities in broken loop (GB-21VR and GB-30VR) -- hot wall.

Fig. 195 Densities in broken loop (GB-23VR, GB-37HZ, and GB-42VR) -- hot wall.

Fig. 196 Densities in vessel (GV-COR-150HZ and GV-161/192D) -- hot wall.

Fig. 197 Densities in vessel (GVLP-165HZ and GVLP-172HZ) -- hot wall.

Fig. 198 Density in pressurizer -- hot wall.

Fig. 199 Mass flow in intact loop (FTU-1 and GU-1VR) -- hot wall.

Fig. 200 Mass flow in intact loop (FDU-15 and GU-15VR) -- hot wall.

Fig. 201 Mass flow in intact loop (FTU-15 and GU-15VR) -- hot wall.

Fig. 202 Mass flow in intact loop (FDU-15 and GU-15HZ) -- hot wall.

Fig. 203 Mass flow in intact loop (FTU-15 and GU-15HZ) -- hot wall.

Fig. 204 Mass flow in broken loop (FTB-30 and GB-30VR) -- hot wall.

Fig. 205 Mass flow in broken loop (FTB-37 and GB-37HZ) -- hot wall.

Fig. 206 Mass flow in vessel (FTV-CORE-IN and GV-COR-150HZ) -- hot wall.

Fig. 207 Primary pump torque -- hot wall.

Fig. 208 Primary pump power -- hot wall.

Fig. 209 Primary pump speed -- hot wall.

IV. REFERENCE

1. G. A. Dinneen (ed.), *LOFT Integral Test System Final Safety Analysis Report*, ANCR-1142, publication pending.

APPENDIX A

SEMISCALE MOD-1 PROGRAM DESCRIPTION FOR TEST GROUP 1

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APPENDIX A

SEMISCALE MOD-1 PROGRAM DESCRIPTION FOR TEST GROUP 1

The semiscale Mod-1 program is part of the Semiscale Blowdown and Emergency Core Cooling (ECC) Project conducted by Aerojet Nuclear Company in the overall ERDA-sponsored research and development program to investigate the behavior of water-cooled nuclear reactor systems during a hypothesized loss-of-coolant accident. The semiscale program consists of a series of experiments starting with separate effects tests and evolving into more complex coupled effects tests which more nearly simulate reactor conditions. The Mod-1 program has been planned and developed concurrent with earlier experiments. The 1-1/2-loop semiscale isothermal blowdown tests were recently completed and testing in the 1-1/2-loop semiscale Mod-1 program was initiated with Test Group 1, a series of six isothermal blowdown tests. The earlier tests were conducted on a plan that permitted the findings of one test series to govern the conduct of subsequent tests and correspondingly the system configuration. The final tests prior to the Mod-1 program were conducted in the 1-1/2-loop system consisting of one intact loop with active components, but nonrepresentative of nuclear components, and one broken loop with passive components. In contrast, the semiscale Mod-1 program is a well-defined long-range program to be conducted in a 1-1/2-loop system with the intact loop containing active components representative of nuclear system components and with the broken loop containing passive simulated nuclear components. Eventually the program is to employ a two-loop system encompassing active components in both loops as well as other features of a nuclear system.

The program objectives of the semiscale Mod-1 program are to:

- (1) Produce separate and integral effects experimental thermal-hydraulic response data to provide an experimental basis for analytical model development and assessment.
- (2) Provide data for assessing the requirements and reliability of selected Loss-of-Fluid Test^[A-1] (LOFT) instrumentation.
- (3) Produce experimental data to aid other ERDA-sponsored experimental programs in optimizing test series, selecting test parameters, and evaluating test results.

The separate effects tests provide detailed information in a specific area of interest. This information is used to determine the applicability of previously developed correlations and models to the Mod-1 system and to provide an initial basis for modification of these correlations and models, if necessary. The resulting analytical description of the Mod-1 system that is supported by the separate effects test data provides insight into the interacting effects that may occur during integral type tests.

The integral test data from the Mod-1 test program serves two purposes in the assessment of the analytical models. The data are used to evaluate the adequacy of the analytical models that are used to predict the transient thermal-hydraulic response of a system to a loss-of-coolant accident (LOCA). The data are also used to indicate areas of weakness in the analytical models and to suggest what changes may be necessary to improve the analytical models if a weakness is found to exist during the evaluation process.

The Mod-1 program provides experimental data on the performance and reliability of instrumentation that is the same as, or very similar to, LOFT instrumentation. Since the data requirements of Mod-1 and LOFT are similar, much of the instrumentation used in the Mod-1 system is of the same type as that to be used in LOFT. Some of the special instrumentation that has been designed specifically for LOFT is installed and tested in Mod-1. Whenever similar instrumentation is used care is taken to ensure duplication of the LOFT instrumentation attachment methods and the signal processing electronics.

The Mod-1 program provides support for other ERDA-sponsored experimental programs such as the LOFT or the coolant circulation pump programs. For example, the Mod-1 system is scaled to the LOFT system and, therefore, the data from the Mod-1 system are useful in predicting the behavior of the LOFT system. The Mod-1 program also provides supporting experimental studies that will aid in meeting the LOFT overall program objectives and in evaluating the LOFT test results.

The first group of tests (Test Group 1) conducted in the semiscale Mod-1 experimental program is composed of six tests (Tests S-01-1 through S-01-6). These tests are conducted from initially isothermal system conditions and are for the primary purpose of providing isothermal blowdown data for comparison with results of corresponding tests in the LOFT system. The test configurations and conditions, therefore, simulate those of the LOFT isothermal tests. The results of these tests are expected to aid in the planning of the LOFT tests and, when compared with LOFT test results, to indicate effects due to differences in physical scale.

Five of the six isothermal tests (Tests S-01-1 through S-01-5) use a core resistance simulator and the sixth test (Test S-01-6) uses a core of electrical heater rods in place, but unpowered. Table A-I summarizes the initial conditions and configurations for these isothermal tests. The isothermal tests are initiated by a simulated break in the broken loop piping. Coolant is injected during the blowdown portion of the test unless a hot-wall study is conducted, in which case, coolant is injected only during the hot-wall portion of the test.

The tests provide the following types of information:

- (1) Characteristics of energy transfer from the intact loop steam generator
- (2) Pump performance

TABLE A-I

INITIAL CONDITIONS AND CONFIGURATION FOR SEMISCALE MOD-1 ISOTHERMAL TESTS.

Condition or Configuration	Test S-01-1 ^[a]	Test S-01-2	Test S-01-3	Test S-01-4	Test S-01-5	Test S-01-6
Pressure vessel core	resistance simulator	resistance simulator	resistance simulator	resistance simulator	resistance simulator	simulated core (electrical heaters)
Initial pressure in upper plenum (psig)	1600	2250	2250	2250	2250	2250
Initial temperature (°F)	540	540	540	540	540	540
Break						
Location	hot-leg	cold-leg	cold-leg	cold-leg	cold-leg	cold-leg
Type	double-ended offset shear	double-ended offset shear	double-ended offset shear	double-ended offset shear	double-ended offset shear	double-ended offset shear
Size (%) ^[b]	100	200	200	200	200	200
Coolant injection						
Location	vessel inlet annulus	intact loop cold leg	lower plenum	intact loop cold leg	intact loop cold leg	intact loop cold leg
System pressure at coolant injection initiation (psig)	600	---	600	600	600	600
Portion of test	blowdown	hot-wall 1111 sec after rupture	blowdown	blowdown	blowdown	blowdown
Intact loop resistance ^[c]	low	high	low	low	low	low
Contents of steam generator	saturated water and steam	saturated water and steam	saturated water and steam	saturated water and steam	pressurized nitrogen	saturated water and steam

[a] Test S-01-1, a hot-leg break test, is conducted fifth in the series to minimize the impact on test schedules of changing the broken loop configuration.

[b] The break area of one nozzle in the scaled double-ended offset shear configuration is the reference area for defining total break area.

[c] Low intact loop resistance inlet and outlet orifices to steam generator are 1.61 and 1.59 in. ID, respectively; high resistance inlet and outlet orifices to steam generator are 1.357 in. ID.

- (3) Piping heat transfer without complication of core heat input
- (4) Break flow
- (5) Simulated steam generator and simulated pump responses
- (6) Effect of coolant injection on system response.

(a) Test S-01-1. Test S-01-1 is an isothermal test conducted at conditions of 1600 psig and 540°F. The break configuration represents an intermediate size (100%)^[a] double-ended hot-leg break. Coolant is injected into the inlet annulus of the vessel. Flow from the high pressure injection system is initiated at blowdown, flow from the accumulator is initiated at a system pressure of 600 psig, and flow from the low pressure injection system is initiated at a system pressure of 250 psig. This test is conducted at reduced system subcooling and break area to duplicate the first isothermal test in the LOFT system. The reduced subcooling in the LOFT test is expected to reduce the potential for primary system damage due to subcooled decompression loads.

(b) Test S-01-2. Test S-01-2 is an isothermal test conducted at conditions of 2250 psig and 540°F. The break configuration represents a full size (200%) double-ended offset shear of the cold leg without coolant injection during blowdown. Test S-01-2 employs an intact loop high resistance (in contrast to the other five tests which have a low resistance) to provide data for comparison with that obtained from the first 12 to 15 sec of Test S-01-4 in order to establish the importance of intact loop resistance on system response during blowdown. Results of this test provide baseline system hydraulic behavior for the Mod-1 system without the added complication of coolant injection during blowdown.

Following blowdown, a hot-wall study is conducted with coolant injection from an accumulator into the cold leg of the intact loop. The delay time for coolant delivery to the lower plenum observed during this experiment is an index on which to base predictions of delay time during tests in which coolant is injected during blowdown.

(c) Test S-01-3. Test S-01-3 is an isothermal test conducted at conditions of 2250 psig and 540°F with coolant injection into the lower plenum initiated from an accumulator at 600-psig system pressure and from the low pressure injection system at 35.5 sec after blowdown initiation. The low pressure injection system flow rate is adjusted to simulate both low pressure injection system and high pressure injection system flow rates of LOFT.

(d) Test S-01-4. Test S-01-4 is an isothermal test conducted at conditions of 2250 psig and 540°F with coolant injection into the cold leg of the intact loop initiated from an

[a] The break area of one nozzle in the scaled double-ended offset shear configuration is the reference area for defining total break-area (100% = 0.00262 ft²).

accumulator at 600-psig system pressure and from the low pressure injection system at 35.5 sec after blowdown initiation. The low pressure injection system flow rate is adjusted to simulate both low pressure injection system and high pressure injection system flow rates of LOFT. Results from this test provide information on the mixing effects at the cold-leg injection point, and the delay time for injected coolant to reach the lower plenum.

(e) Test S-01-5. The system configuration and initial test conditions of Test S-01-4 are duplicated in Test S-01-5, except the secondary side of the intact loop steam generator contains pressurized nitrogen rather than saturated water and steam. Comparison of the Test S-01-5 results with the Test S-01-4 results provides an indication of the effect of heat transfer from the steam generator on the overall system behavior.

(f) Test S-01-6. The core resistance simulator is removed and the simulated core with 40 electrical heater pins is installed for this test. Otherwise, the system configuration and initial test conditions of Test S-01-4 are duplicated in Test S-01-6. The results from Test S-01-6 compared with Test S-01-4 results provide an indication of the effect of distributing the core flow resistance along the entire length of the core rather than having the core flow resistance lumped into an orifice.

REFERENCE

- A-1. G. A. Dinneen (ed.), *LOFT Integral Test System Final Safety Analysis Report*, ANCR-1142, publication pending.

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APPENDIX B
SEMISCALE MOD-1 TEST APPARATUS

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APPENDIX B

SEMISCALE MOD-1 TEST APPARATUS

The semiscale Mod-1 system consists of a pressure vessel with simulated reactor internals; an intact loop with active steam generator, pump, and pressurizer; a broken loop with a simulated steam generator, a simulated pump, and pipe rupture assemblies; a pressure suppression system with header and suppression tank; and a coolant injection system with injection pumps, accumulators, and delivery piping. The semiscale Mod-1 system is designed to operate at temperature and pressure of 540°F and 2250 psig. The intact loop simulates three operating loops of a commercial PWR, and the broken loop simulates a broken loop of a PWR during an LOCA. The exterior of the entire system and piping is thermally insulated. The experimental system components for a cold leg double-ended offset shear configuration are shown in Figures B-1 and B-2. System liquid volumes are recorded in Table B-I, and experimentally determined hydraulic resistances are given in Table B-II, Table B-III, and Table B-IV.

1. VESSEL ASSEMBLY

The semiscale Mod-1 vessel assembly consists of a pressure vessel, vessel filler, vessel filler insulator, core barrel, core barrel insulator, and core resistance simulator or 40-electrical-heater-pin core. The semiscale Mod-1 vessel when assembled forms the following internal regions; inlet annulus, downcomer annulus or gap, lower plenum, core, and upper plenum. A cross-sectional view of the vessel with core resistance simulator is shown in Figure B-3.

1.1 Pressure Vessel

The pressure vessel consists of an upper section, midsection, lower section, upper head, lower head, and nozzles. The upper section is constructed of 10-inch Schedule 160 ASTM A-106 Grade B carbon steel pipe. The lower section and midsection are constructed of 10-inch Schedule 160 316 ASME SA-376 stainless steel pipe. The upper and lower heads are Grayloc blind hubs constructed of 316 ASME SA-182 stainless steel. The lower head has a thermal liner plate fitted flat against the bottom inside surface. The liner plate is Grafoil 0.015 inch thick. The nozzles are constructed of ASME SA-182 Grade F 316 stainless steel and are welded in place. The separate pressure vessel segments are connected by Grayloc connectors.

The assembled pressure vessel is about 21 feet long. It has an OD of 10.75 inches, and an ID of 8.585 inches. The vessel is designed for pressure and temperature of 2500 psig and 650°F. Six 3-inch nozzle penetrations are provided in the vessel sides, two for inlet nozzles and four for outlet nozzles. Additional penetrations are provided in the vessel for installation of instrumentation.

Fig. B-1 Semiscale Mod-1 system -- isometric.

Fig. B-2 Semiscale Mod-1 system -- schematic.

TABLE B-I

LIQUID VOLUME DISTRIBUTION FOR SEMISCALE MOD-1 SYSTEM
IN THE COLD LEG BREAK CONFIGURATION

Component	Liquid Volume (ft ³)
<u>Vessel</u>	
Inlet annulus	0.178
Downcomer annulus	0.771
Lower plenum	0.894
Below core support structure (0.763 ft ³)	
Within lower core support (0.062 ft ³)	
Above lower core support to active core (0.069 ft ³)	
Core with core resistance simulator	1.24
Core with 40 electrical heater pins	0.289
Upper plenum	<u>0.867</u>
Vessel Total Liquid Volume	
with core resistance simulator	3.95
with 40-electrical-heater-pin core	2.999
<u>Operating Loop</u>	
Hot leg	0.380
Pressurizer ^[a]	
Surge line	0.013
Steam generator	1.485
Pump suction leg	0.391
Pump	0.144
Cold leg	<u>0.332</u>
Operating Loop Total Liquid Volume	2.745 ^[b]
<u>Blowdown Loop</u>	
Hot leg	0.107
Steam generator simulator	0.560
Pump suction leg	0.084
Pump simulator	0.052
Pipe	0.080
Cold leg	<u>0.213</u>
Blowdown Loop Total Liquid Volume	1.096

TABLE B-I (Contd.)

Component	Liquid Volume (ft ³)
<u>Reflood Bypass Loop</u>	
Hot leg	0.190
Cold leg	<u>0.226</u>
Reflood Bypass Loop Total Liquid Volume	0.416
<u>System Total Liquid Volume</u> ^[b]	
with core resistance simulator	8.207
with 40-electrical-heater-pin core	7.256
<p>[a] Pressurizer liquid volume is a test variable. The total volume of the pressurizer including liquid and steam volumes is 1.1 ft³.</p> <p>[b] Excluding pressurizer liquid volume.</p>	

1.2 Vessel Filler

The vessel filler is constructed of 8-inch Schedule 160 pipe (316 stainless steel ASTM A-312) which slip fits inside the vessel. It has an OD of 8.545 inches and an ID of 7.100 inches. The filler ID is increased to 8.190 inches from about 3 inches above to about 10.5 inches below the cold-leg centerline to form the inlet annulus region.

1.3 Vessel Filler Insulator

The inside of the vessel filler is lined with a 1/8-inch-thick 304 stainless steel ASTM A-269 insulator. A 0.050-inch gap exists between the vessel filler and the stainless steel insulator.

1.4 Core Barrel

The core barrel is constructed of copper alloy No. 175 (Cu-Be). It has an OD of 5.490 inches, and an ID of 4.875 inches. The core barrel entrance is about 163 inches below the cold-leg centerline.

1.5 Core Barrel Insulator

The outside of the core barrel is lined with a 1/8-inch-thick 304 stainless steel ASTM A-269 insulator. A 0.050-inch gap exists between the core barrel and the stainless steel insulator.

TABLE B-II

MEASURED FORWARD FLOW HYDRAULIC RESISTANCE IN THE VESSEL AND INTACT LOOP^[a]

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)	R' from steady flow tests with pump running (sec ² /ft ³ -in. ²)	R' from pump coastdown tests (sec ² /ft ³ -in. ²)
DPU-UP-3	Vessel upper plenum, 10.5 in. above cold leg centerline at 30° to intact loop hot leg Spool 3, 62 in. from vessel center, upper plenum tap is ~2 in. above Spool 3 tap	0.458	0.496	0.463
DPU-1-3	Hot leg Spool 1, 31 in. from vessel center to hot leg Spool 3, 62 in. from vessel center	0.017	0.024	0.019
DPU-3-7	Across steam generator, hot leg, Spool 3, 62 in. from vessel center to cold leg Spool 7, 231 in. from vessel center, Spool 3 tap approximately 18 in. above Spool 7 tap	---[b]	4.44 ^[c] 2.2 ^[d]	4.24
DPU-6-SGIP	Hot leg, Spool 6, 114 in. from vessel center to steam generator inlet plenum 145 in. from vessel center, Spool 6 tap is 16 in. below SGIP tap	0.8 ^[d]	---[e]	---[e]
DPU-SGOP-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 35 in. below SGOP tap	0.97 ^[d]	---[e]	---[e]
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	0.284	0.307	0.291
DPU-8C-8D	In pump trap, cold leg Spool 8, Tap 8C, 197 in. from vessel center to Tap 8D, 209 in. from vessel center, Tap 8C is 10 in. below tap 8D	0.196	0.020	0.016
DPU-8D-8E	In pump trap, cold leg Spool 8, Tap 8D, 209 in. from vessel center to Tap 8E, 219 in. from vessel center, Tap 8D is 10 in. below Tap 8E	0.004	---[e]	---[e]
DPU-8E-10	From pump trap to pump inlet, pump trap Tap 8E, 219 in. from vessel center to pump inlet cold leg Spool 10, 141 in. from vessel center, Tap 8E is 12 in. below Spool 10 tap	0.244	0.252	0.243
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	---[f]	---[f]	---[f]
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	0.121	0.61	0.584
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	0.281	0.364	0.353
DPV-0-180	Cold leg centerline to 180 in. (225°) below cold leg centerline, elevation difference between taps is 180 in.	0.219	0.213	0.198
DPV-LP-UP	Upper plenum, 10.5 in. above cold leg centerline at 30° to lower plenum 180 in. below cold leg centerline at 225°, elevation difference between taps is 191 in.	1.26	1.45	1.35

TABLE B-II (Contd.)

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²) ---[g]	R' from steady flow tests with pump running (sec ² /ft ³ -in. ²) ---[g]	R' from pump coastdown tests (sec ² /ft ³ -in. ²) ---[g]
DPV-156- 173QQ	Across part of lower plenum, 156 in. (225°) to 173 in. (225°) below cold leg centerline, elevation difference between taps is 17 in.			
DPV-IANN-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.	1.55	1.64	1.53
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 13 tap is 8.5 in. above Spool 15 tap	2.39	2.4	2.18

[a] Data do not apply to Test S-01-6.

[b] Not available in calibration loop configuration.

[c] Value for Test S-01-2 only.

[d] Value for Tests S-01-3 and S-01-4.

[e] No measurement taken.

[f] Pump R' data not applicable.

[g] Differential pressure too small for accurate measurements.

TABLE B-III

MEASURED FORWARD FLOW HYDRAULIC RESISTANCES IN THE BROKEN LOOP^[a]

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)
DPB-UP-30	Vessel upper plenum, 10.5 in. above cold leg centerline at 30° to hot leg Spool 30, 18 in. from vessel center, upper plenum tap is 2 in. above Spool 30 tap	---[b]
DPB-30-32U	Hot leg Spool 30, 18 in. from vessel center to Spool 32 upper tap, 73 in. from vessel center, Spool 30 tap is 30 in. below Spool 32 upper tap	12.45
DPB-30-38	Across entire simulated steam generator assembly and instrument spool downstream of simulated steam generator, hot leg Spool 30, 18 in. from vessel center to cold leg Spool 38, 305 in. from vessel center along hot leg, Spool 30 is 40 in. above Spool 38	52.4
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	25.83
DPB-SGOR	Across first orifice plate of simulated steam generator, taps 87 and 95 in. from vessel center along hot leg, elevation difference between taps is 7 in.	2.09
DPB-38-40	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	210 (with 9 plates)
DPB-40-42	Across elbow leading to spool upstream of pump-side nozzle, cold leg Spool 40, 365 in. from vessel center along hot leg to Spool 42, 415 in. from vessel center along hot leg, Spool 40 tap is 40 in. below Spool 42 tap	---[b]
DPB-42-43	Across pump-side nozzle, cold leg Spool 42, 415 in. from vessel center along hot leg to cold leg Spool 43, 427 in. from vessel center along hot leg	4.23

TABLE B-III (Contd.)

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)
DPB-42-HN1	Spool 42 upstream of pump-side nozzle, 415 in. from vessel center along hot leg to nozzle throat, 419 in. from vessel center along hot leg	17.52 ^[c]
DPB-21-23	Cold leg Spool 21, 49 in. from vessel center to cold leg Spool 23, 92 in. from vessel center	0.487
DPB-23-CN1	Cold leg Spool 23, 92 in. from vessel center to vessel-side nozzle throat, 96 in. from vessel center	17.29 ^[c]
DPB-23-24	Across vessel-side nozzle, Spool 23, 92 in. from vessel center to Spool 24, 104 in. from vessel center	5.14

[a] Data do not apply to Tests S-01-1 and S-01-6.

[b] Measurement not taken or too small to be accurate.

[c] The hydraulic resistance over the entrance is much larger than the total nozzle hydraulic resistance (DPB-42-43 or DPB-23-24) because a pressure loss due to increased flow velocity occurs in the nozzle throat. The pressure partially recovers downstream of the nozzle.

TABLE B-IV

MEASURED REVERSE FLOW HYDRAULIC RESISTANCE IN THE VESSEL AND INTACT LOOP^[a]

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)
DPU-UP-3	Upper plenum 10.5 in. above cold leg centerline at 30° to hot leg, Spool 3, 62 in. from vessel center, upper plenum tap approximately 2 in. above Spool 3 tap	0.383
DPU-1-3	Hot leg Spool 1, 31 in. from vessel center to hot leg Spool 3, 62 in. from vessel center	0.0289
DPU-3-7	Across steam generator, hot leg, Spool 3, 62 in. from vessel center to cold leg Spool 7, 231 in. from vessel center, Spool 3 tap approximately 18 in. above Spool 7 tap	--- ^[b]

TABLE B-IV (Contd.)

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)
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	0.363
DPU-8C-8D	In pump trap, cold leg Spool 8, Tap 8C, 197 in. from vessel center to Tap 8D, 209 in. from vessel center, Tap 8C is 10 in. below Tap 8D	0.013
DPU-8E-10	From pump trap to pump inlet, pump trap Tap 8E, 219 in. from vessel center to pump inlet cold leg Spool 10, 141 in. from vessel center, Tap 8E is 12 in. below Spool 10 tap	0.309
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	4.57 ^[c]
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	0.147
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	0.408
DPV-0-180	Cold leg centerline to 180 in. (225°) below cold leg centerline, elevation difference between taps is 180 in.	0.192
DPV-LP-UP	Upper plenum, 10.5 in. above cold leg centerline at 30° to lower plenum 180 in. below cold leg centerline at 225°, elevation difference between taps is 191 in.	1.342
DPV-156-173QQ	Across part of lower plenum, 156 in. (225°) to 173 in. (225°) below cold leg centerline, elevation difference between taps is 17 in.	0.054
DPV-IANN-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.	1.93

TABLE B-IV (Contd.)

Measurement	Location	R' from flow calibration loop data (sec ² /ft ³ -in. ²)
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 1 tap is 8.5 in. above Spool 15 tap	2.00

[a] Data do not apply to Test S-01-6.

[b] Not measured because the flow calibration loop was attached at the entrance to Spool 2 and exit to Spool 4 to give reverse flow.

[c] Data obtained with a free wheeling pump rotor.

1.6 Core Resistance Simulator

Semiscale Mod-1 Tests S-01-1 through S-01-5 use a passive orifice resistance simulator with the hydraulic resistance scaled to the LOFT core simulator resistance. The core simulator is constructed of 304 ASTM A-269 stainless steel. Figure B-3 illustrates the design of the core simulator and its placement in the vessel.

1.7 40-Electrical-Heater-Pin Core

For semiscale Mod-1 Test S-01-6 the core and internals consist of 40 electrical heater pins and the associated support structures. A more detailed description of the electrically heated core is deferred to the experiment data report for semiscale Mod-1 Test S-01-6.

1.8 Vessel Internal Regions

The vessel internal regions are located by following the coolant path through the vessel. The coolant enters the vessel inlet annulus region through the cold-leg inlet nozzles. The inlet annulus region extends about 10.5-inches below the cold-leg centerline. The coolant then flows down to the lower plenum region through the downcomer annulus formed between the inside of the vessel filler insulator and the outside of the core barrel insulator. The downcomer gap size is 0.42 inch, resulting in a cross-sectional area of the downcomer annulus of 0.0575 ft². The length of the region is about 152 inches. The coolant then flows up through a turbine flowmeter and then into the core region. The flow passes through the orifices of the core resistance simulator until it reaches the upper plenum region where it flows out the openings in the core barrel into the upper plenum and then out the outlet nozzles. A seal separates the inlet annulus from the upper plenum region.

Fig. B-3 Semiscale Mod-1 pressure vessel with core resistance simulator.

2. INTACT LOOP

The intact loop consists of the primary coolant piping, steam generator, pressurizer, and pump. The intact loop is shown in the schematic of Figure B-2.

2.1 Intact Loop Piping

Piping spools 6, 7, 8, 9, 10 and 11 are made of 3-inch Schedule 160 Grade 316 stainless steel conforming to ASME SA-376. All other piping spools are made of 3-inch Schedule 160 carbon steel conforming to Grade B ASTM A-106. The piping spool sections are joined by 3-inch Grayloc connections.

2.2 Steam Generator

The design of the Type I steam generator used in the intact loop is shown in Figure B-4 and is as follows:

The Type I steam generator is of the tube and shell design having a double pass tube side of the "U" bend configuration and a single pass shell side. The primary coolant passes through the tube side; and the secondary coolant, with resultant steam generation, passes through the shell side. The steam generator is situated in the vertical position with primary inlet-outlet ports located in the head of the primary side inlet-outlet plenum.

Major subassemblies of the unit are: the primary side inlet-outlet plenum, the tube sheet and tube bundle, and the secondary containment shell and internals.

The primary side inlet-outlet plenum consists of a hemispherical head welded to a 12-inch, 1500-lb weld neck flange which mates with the lower surface of the tube sheet. The plenum has external inlet and outlet nozzles for the primary system connections and an internal divider plate which divides flow between the tube inlets and outlets on the lower surface of the tube sheet. The inlet-outlet plenum assembly is constructed of Type 316 stainless steel.

The tube bundle assembly consists of an Inconel tube sheet, which is 3-5/8 inches thick across the diameter of the mating lower plenum flange, and 54 "U" bend tubes. The tubes are constructed of Inconel 600 and have an inner diameter of 0.402 inch and a wall thickness of 0.049 inch. They are arranged on a 0.75-inch triangular pitch and have an average length of 16.85 feet. Six baffle plates extending about one-half of the way across the bundle are spaced at equal intervals along the tube length.

Major components of the secondary shell and internals, as shown in Figure B-4 consist of the shell, the inlet nozzle spray ring, the flow separator assembly, and the secondary flow restrictor.

Fig. B-4 Intact loop steam generator.

The secondary shell is a section of 12-inch Schedule 80 pipe, 172 inches in length. The upper end is enclosed with a pipe cap, and a 12-inch weld neck flange is welded to the lower end. Nozzles and fittings are provided for the feedwater supply line, the steam exhaust line, secondary system drains, and instrumentation.

The inlet nozzle spray ring of carbon steel pipe is situated between the downcomer sleeve and the outer shell. This ring is connected to the feedwater supply system by a 1-1/2-inch nozzle through the vessel wall. The circumference of the spray ring has 24 openings (0.187-inch diameter) which permit feedwater to be injected downward into the downcomer annulus.

The flow separator assembly is constructed from 10 inch OD 304 stainless steel tubing with 0.125-inch-thick walls.

The secondary flow restrictor is constructed from 10.07-inch ID 304 stainless steel tubing with 0.1046-inch-thick walls.

2.3 Pressurizer

The pressurizer is an electrically heated vessel connected to the intact loop piping between the pressure vessel and the steam generator inlet. Pressurizer operation is similar to that of its counterpart in a PWR in that the pressurizer is partially filled with water maintained at the saturation temperature corresponding to the desired system pressure.

The pressurizer is designed for 2500 psig and 650°F and was hydrostatically tested to 4725 psig. It is made of 10-inch double extra strong Type 304 stainless steel pipe 45 inches long. Heat is supplied by thirty-two 0.25-kW heaters which are inserted down through the top of the pressurizer into dry wells. The wells are vertically mounted 0.75-inch-OD stainless steel tubes with closed bottom ends. The hot leg of the intact loop piping is connected to the pressurizer by 3/8-inch OD Type 304 stainless steel tubing. The total volume of the pressurizer up to the 3/8-inch tubing is 1.1 ft³. Overpressure protection is provided by a relief valve and a burst diaphragm that operate at 2750 psia.

2.4 Pump

The intact loop pump is a volute-type heavy duty horizontal centrifugal pump. The pump is rated for a nominal flow of 182 gpm at a total head of 192 feet of water when operated at rated speed of 3560 rpm. The material of construction for the wetted parts – that is, the casing, impeller, hub disc, and shaft – is Type 316 stainless steel. The remainder of the pump is of cast iron and steel. The pump is designed for 2500 psig and 650°F. The specific speed of the pump is 930, and the impeller diameter is 7-3/4 inches. The performance curve for pump operation at rated speed is given in Figure B-5.

The pump is coupled to a 25 hp, 2500-rpm, dc motor through a speed variation system which allows pump speed reduction to any desired operating point.

Fig. B-5 Intact loop primary coolant pump performance curves.

3. BROKEN LOOP

The broken loop consists of the primary coolant piping, simulated steam generator, simulated pump, two rupture nozzles, and two rupture assemblies. The broken loop is shown in the schematic of Figure B-2.

3.1 Broken Loop Piping

Piping sizes used in the blowdown loop are 3-inch Schedule 160, 2-inch Schedule 160, 1-1/2-inch Schedule 80, and 1-inch Schedule 80. Piping Spools 20, 21, 30, 31, 32, and 36 are 3 inch. Piping Spools 22, 23, 37, 38, and 42 are 2 inch. Piping Spools 40 and 41 are 1-1/2 inch. All pipe material is seamless austenitic steel pipe conforming to ASME SA-376, Grade 316. With the exception of the flanges holding the rupture assemblies and the 1-inch warmup system piping, all pipe spool piece connections are made with Grayloc connections. The warmup system piping is made with welded and flanged joints.

The 1-inch Schedule 80 pipe and valving are used for the lines that connect the hot and cold leg rupture assemblies to the operating loop and serve to provide a circulation path for system warmup. The line attached to the hot leg (or steam generator side) rupture assembly is routed to a point near the suction side of the primary coolant pump in the cold leg of the operating loop and the line attached to the cold leg rupture assembly is routed to a point near the upstream entrance to the steam generator in the hot leg of the operating loop. Each line contains remotely operated valves at locations adjacent to the rupture assembly and operating loop.

3.2 Simulated Steam Generator

The steam generator simulator models the LOFT steam generator simulator and is shown in Figure B-6. It consists of a housing in the form of an inverted "U" in which are installed 14 orifice plates, seven in each U leg. Each orifice plate has three holes whose diameter closely approximates the orifice hole diameter in the LOFT simulator. Orifice plate thickness also approximates that of LOFT. The orifice plate spacing is adjustable and the plates are removable. Spacing of the orifice plates initially is identical to that of the LOFT simulator plates.

The steam generator simulator housing is designed for a pressure of 2500 psig at 650°F. Housing material is Grade 316 stainless steel pipe (conforming to ASME AS-376) and Grayloc connectors (conforming to ASME SA-182). Internal parts (orifice plates, spacers, sleeves, ...) are also of stainless steel. Pipe joints utilize Grayloc hubs and are located to provide ease of installation and system versatility.

3.3 Simulated Pump

The broken loop simulated pump is modeled after the LOFT pump simulator and is shown in Figure B-7. It consists of a housing made of 3-inch Schedule 160 stainless steel pipe in which are installed 14 orifice plates. Each orifice plate has three holes located on a

NOTE

All Dimensions
Shown are in Inches
Unless Otherwise
Specified.

Fig. B-6 Broken loop steam generator simulator.

NOTE
All Dimensions Shown are in
Inches Unless Otherwise Specified

Fig. B-7 Broken loop pump simulator

triangular pitch; hole diameter is approximately equal to that of the orifice plates holes used in the LOFT simulator. Orifice plate thickness also approximates LOFT orifice plate thickness. Spacing of the orifice plates can be adjusted and the plates are removable. For Tests S-01-1 through S-01-6 only nine plates were installed.

The simulated pump housing is designed for a pressure of 2500 psig at 650°F. Housing material is Grade 316 stainless steel pipe (conforming to ASME SA-182). Internal parts (orifice plates, spacers, sleeves, ...) are also made of Grade 316 stainless steel. The simulated pump is connected to the blowdown loop piping by Grayloc connections.

3.4 Rupture Assemblies

Rupture assemblies, each consisting of a rupture disc subassembly and a blowdown nozzle subassembly, as shown in Figure B-8, are used to initiate a blowdown test.

Each rupture disc subassembly consists, as shown in Figure B-9, of instrument washers and two rupture discs bolted between two 3-inch, 1500-lb slip-on flanges. The rupture discs are constructed to withstand pressures greater than one-half the system pressure but less than the total system pressure. Blowdown is initiated by subjecting the innerdisc chamber to system pressure by opening the control valve in the 3/8-inch stainless steel line which connects the innerdisc chamber with the corresponding hot or cold leg reflood bypass line. The downstream disc ruptures first and then the upstream disc is also ruptured by the system pressure.

Figure B-10 shows a blowdown nozzle subassembly. Each blowdown nozzle simulates one-half of a double-ended offset shear. Nozzles with different throat sizes are used to provide different break areas. The ratio of liquid volume to break area for semiscale is based on the ratio of system liquid volume to loop pipe area for a typical PWR system. For simulated cold leg breaks this ratio is about 2970 ft and for simulated hot leg breaks this ratio is about 1670 ft. Maintaining these ratios for an average semiscale system liquid volume of about 7.78 ft³ results in a maximum scaled cold leg break area of 0.00262 ft². The specified break area percentage for a given test is expressed in terms of the maximum scaled area for the appropriate break location (hot or cold leg). Therefore, double-ended offset shear break simulations are specified as 200% hot or cold leg breaks.

4. PRESSURE SUPPRESSION SYSTEM

The pressure suppression system consists mainly of a pressure vessel with a downcomer and header. The configuration is depicted in Figures B-11 and B-12. The effluent is discharged from the broken loop (through two 3-inch Schedule 160 pipes) into a 16-inch header that simulates, in general, the drywell in a PWR pressure suppression system, and, specifically, the LOFT 42-inch header. The effluent flows from the header into the vessel water pool through an 8-inch downcomer. The pressure suppression vessel is oriented vertically, to achieve the desired distances from the downcomer to the water surface and to the bottom of the vessel.

Fig. B-8 Rupture assembly.

ANC-B-4296

Fig. B-9 Rupture disc subassembly.

ANC-B-4274

	Dimension "A"(in.)
200% Break Area Nozzle*	0.690 Dia 0.696
100% Break Area Nozzle*	0.513 Dia 0.519

* The Total Cross-Sectional Throat Area of the Two Blowdown Nozzles when Expressed as a Percentage is Referenced to the Break Area of One Nozzle in the Double-Ended Offset Shear Configuration Scaled to LOFT.

ANC-C-4295

Fig. B-10 Blowdown nozzle subassembly.

Fig. B-11 Pressure suppression system -- plan view.

Fig. B-12 Pressure suppression vessel.

4.1 Vessel

The total vessel volume is 90 ft³. The vessel is sized such that when 50% full of water the downcomer pipe extends 2.5 ft below the water surface. A flanged connection is provided for the downcomer pipe. A 3-inch Schedule 40 flanged nozzle (with blind flange installed) is located in the top of the vessel.

4.2 Downcomer

The 8.625-inch OD downcomer pipe penetrates through the side of the pressure suppression vessel near the top and extends horizontally to the axial center of the vessel and then downward to a point 3.0 feet from the bottom.

Inside the pressure suppression vessel, the downcomer pipe has a bolted connection which allows replacement of the vertical portion of the downcomer. Three vacuum breaker valves are located in the horizontal portion of the downcomer pipe to prevent suction of water by the downcomer after completion of blowdown.

4.3 Header

The 16-inch header is designed such that no water traps exist. Accordingly, the downcomer pipe connection is on the bottom of the header. A pressure relief device designed for a minimum capacity of 6.5 lb/sec of saturated steam at a pressure of 250 psia is mounted on the header.

5. COOLANT INJECTION SYSTEM

The coolant injection systems for the intact loop and the broken loop are each composed of three systems; the high pressure injection system (HPIS), the low pressure injection system (LPIS), and the accumulator injection system (AIS). Systems injecting coolant into the broken loop function independently of those injecting into the intact loop. The coolant injection system is shown in Figure B-2.

5.1 Intact Loop Injection System

The intact loop injection system consists of an HPIS, an LPIS system, an AIS system, and piping and valving.

The intact loop HPIS is piped to its respective loop injection points separate of the AIS and LPIS injection lines and injects into the loop through an injection point common with the AIS and LPIS lines. The HPIS water supply comes from a makeup system storage tank and is available at temperatures of 50 to 180°F. Activation of the HPIS is based on primary coolant pump outlet pressure; actuation setpoint may be set in the range of 1500 to 1800 psig. An alternate mode of injection actuation is based on actuating the pump discharge valve at a predetermined time after rupture. Two positive displacement Sprague

Engineering pumps, Model S-440-100 SS each having a capacity of 0.418 gpm (97.0 in.³ minimum at 2000 psi) are used to provide 0.81 gpm at 1500 to 1800 psig for the intact loop. The pumps are air driven.

The HPIS pumps function as the makeup system charging pumps during normal operation and when an experiment is about to be performed, are switched to function as HPIS pumps by pump discharge line valves.

The intact loop LPIS injects into either the cold leg of the intact loop, lower plenum, upper plenum, or inlet annulus or any combination of these. Activation of the LPIS injection occurs at an intact loop pump discharge pressure of 100 psig or at a predetermined time after rupture. The temperature of the water supplied to the LPIS from the makeup system is adjustable within the range of 50 to 180°F. An Oberdorfer Model 300 gear pump serves as the intact loop LPIS pump which at 1400 rpm has the capacity of 5.4 gpm at injection pressure of 0 psig and 4.5 gpm at injection pressure of 100 psig.

The intact loop AIS is comprised of an accumulator tank, a remotely operated block valve at the accumulator, an isolation valve near the injection point, check valves, a gate valve for throttling flow, and piping for injection coolant. Injection locations are the same as for the intact loop LPIS.

The accumulator is isolated from its respective injection points by a remotely operated isolation valve and a manual shutoff valve. Check valves are located in the line to prevent reverse flow. A nitrogen gas overpressure in the accumulator provides the driving force for injecting the stored coolant at flood rates similar to those of LOFT.

The effective liquid volume capable of discharge and the gas-to-liquid volume ratios are controlled by various combinations of liquid level and changeable lengths of discharge pipe extending from the top of the tank down through the nitrogen gas and into the liquid. The effective liquid volume is determined by the depth the pipe extends into the liquid. Heaters are provided in the accumulators for water temperature control over the range of 50 to 180°F.

The accumulator tank for the intact loop is designed and fabricated of Type 316 stainless steel and has a volume of about 9.5 ft³. It is a vertical vessel consisting of 12-inch Schedule 80 pipe with a 900-lb weld neck and modified 900-lb blind flange at the top and a 12-inch butt-welded cap on the bottom. The tank is somewhat greater than 10 feet in length.

Fittings are provided on the tank for filling, draining and sampling. Gas overpressure is supplied by the nitrogen system through a pressure regulator and shutoff valve. The tank is provided with a pressure relief valve set to open at 770 psig.

The intact loop coolant injection system piping and valves are of stainless steel. Valves and operators are selected to meet the specific operational and functional requirements of the coolant injection system.

Each injection point has a check valve and manual gate valve located as close to the injection point as physically possible. Each of the injection systems (HPIS, AIS, and LPIS) has a check valve and remotely operated shutoff valve near the pump or accumulator discharge point.

5.2 Broken Loop Injection System

The broken loop injection system consists of an HPIS, an LPIS, an AIS, and stainless steel piping and valving.

The broken loop HPIS is piped to its respective loop injection point separate of the AIS and LPIS injection lines and injects into the broken loop through an injection point common with the LPIS and AIS line.

The capacity of the broken loop HPIS is adjusted to one-third that of the intact loop HPIS. The pump water supply comes from a makeup system storage tank and is available at temperatures of 50 to 180°F. Activation of the high pressure injection systems is based on primary coolant pump outlet pressure; actuation setpoint may be set in the range of 1500 to 1800 psig. An alternate mode of injection actuation is based on actuating the pump discharge valve at a predetermined time after rupture. One Sprague Engineering positive displacement pump Model S-440-100 SS, is used to supply 0.27 gpm at 1500 to 1800 psig for the broken loop. The pump is air driven.

The HPIS pump functions as a makeup system charging pump during normal operation and when an experiment is about to be performed is switched to function as a HPIS pump by pump discharge line valves.

The broken loop LPIS injects into the cold or hot leg of the broken loop. Activation of the LPIS injection occurs at an operating loop pump discharge pressure of 100 psig or at a predetermined time after rupture. The temperature of the water supplied to the LPIS from the makeup system is adjustable within the range 50 to 180°F. The broken loop LPIS pump is an Oberdorfer Model 1000 gear type which operates at 1600 rpm to provide 1.8 gpm at injection pressure of 0 psig and 1.5 gpm at injection pressure of 100 psig.

The broken loop AIS is comprised of an accumulator tank, a remote operated block valve at the accumulator, an isolation valve near the injection point, check valves, a gate valve for throttling flow, and piping for injecting coolant into the described locations as required for the specific test being conducted.

Each accumulator is isolated from its respective injection points by a remote operated isolation valve and a manual shutoff valve. Check valves are located in the line to prevent reverse flow. A nitrogen gas overpressure in the accumulator provides the driving force for injecting the stored coolant at flood rates similar to those of LOFT.

The effective liquid volume capable of discharge and the gas-to-liquid volume ratios are controlled by various combinations of liquid level and changeable lengths of discharge pipe extending from the top of the tank down through the nitrogen gas and into the liquid.

The effective liquid volume is determined by the depth the pipe extends into the liquid. Heaters are provided in the accumulators for water temperature control over the range 50 to 180°F.

The broken loop accumulator tank is slightly greater than 7 feet in length and constructed primarily of 8-inch Schedule 80 carbon steel pipe conforming to ASTM A 106. The broken loop accumulator tank has a volume of about 2.1 ft³.

Fittings are provided on the tank for filling, draining, and sampling. Gas overpressure is supplied by the nitrogen system through a pressure regulator and shutoff valve. The tank is provided with a pressure relief valve set to open at 770 psig.

Each injection point has a check valve and manual gate valve located as close to the injection point as physically possible. Each of the injection systems (HPIS, AIS, and LPIS) has a check valve and remotely operated shutoff valve near the pump or accumulator discharge point.

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APPENDIX C
SEMISCALE MOD-1 INSTRUMENTATION SYSTEM

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APPENDIX C

SEMISCALE MOD-1 INSTRUMENTATION SYSTEM

The semiscale Mod-1 instrumentation system provides for the acquisition, processing, and presentation of test data. The instrumentation system is composed primarily of individual detectors, signal conditioning equipment, signal processing equipment, recording equipment, and display equipment. Figure C-1 schematically displays the instrument system. Individual detectors at selected locations in the test system provide data in the form of electrical signals. The data signals are then subjected to a signal conditioning process in which they are processed through low voltage level amplifiers and, when necessary, through additional signal conditioning electronics.

After the signal conditioning process, the data are recorded on tape in analog form or digitized and recorded on tape in digital form. The digital data thus obtained are then presented in tabular or graphical form.

1. DATA ACQUISITION AND PROCESSING SYSTEM

The data acquisition and processing system interfaces with the detectors and processes the data for warmup, monitoring, and presentation of test data in engineering units.

The semiscale Mod-1 data acquisition system consists of two hardware subsystems, an analog data acquisition system (ADAS) and a digital data acquisition and processing system (DDAPS).

The analog system (ADAS) consists of seven analog magnetic tape units which can be operated in either the record or playback mode. Up to 80 channels are recorded on one of the tape transports in an FM multiplex mode at bandwidths of 250 HZ and 1 KHZ. An additional 78 data channels can be recorded at bandwidths to 10 KHZ on the other six FM tape units on a one channel per tape track basis.

The digital system (DDAPS) is an on-line system capable of recording up to 256 channels of data at frequencies less than 50 HZ on disc type memory devices. This system is capable of producing data plots of all DDAPS channels and can also be used to digitize and plot the data recorded on the ADAS.

The DDAPS plots created have a resolution on the vertical axis of: system full scale divided by 1000. The horizontal axis, used to indicate time, represents 920 equally-spaced data samples. The data curves are produced by connecting each sample point with a straight line.

Fig. C-1 Data acquisition and processing system.

During semiscale Mod-1 system testing the DDAPS is used to record about 200 measurements. The ADAS is used to record up to 158 measurements most of which are a duplicate recording of the measurements recorded on the DDAPS. The data presented in the experiment data reports are obtained from the DDAPS system. The DDAPS system is used for convenience because this system provides digital data directly. The analog data could be digitized using the IBM 360/75 computer to obtain improved frequency response. However, for graphs of the size presented in this report, no improvement in data resolution is recognized.

The DDAPS and ADAS have a time correlation of $\pm 50 \mu\text{sec}$ between any data taped. The ADAS has calibration signals recorded with the data to allow gain and off-set corrections to the data during processing of the detector signals. The DDAPS has an internal self-check and calibration system which, during the acquisition and processing of the detector signals automatically corrects for gain and off-set variations in the data. The total uncertainty induced by the DDAPS is $\pm 0.1\%$ of full scale^[a].

Further corrections and processing of the digital data are performed with the DDAPS. Information concerning calibration and known transducer sensitivities to pressure and temperature are input manually to the DDAPS and applied to the data to produce corrected digital magnetic tapes for X-Y plots and for subsequent processing on an IBM 360/75 computer. The uncertainty in the correction process is estimated to be $\pm 0.5\%$ of full scale^[a].

Estimated electrical pick-up noise in transmission lines is $\pm 0.1\%$ of full scale^[a]. The root-sum-square summation technique applied to the individual acquisition and processing uncertainty estimates yields a probable uncertainty of $\pm 0.52\%$ of full scale^[a].

2. INSTRUMENTATION USED TO OBTAIN TEST DATA

Measurement of test variables is accomplished by detectors located in the semiscale Mod-1 system. Detectors are provided for measuring fluid and material temperatures, pressure, differential pressure, volumetric flow rate, velocity, momentum flux, density, liquid level, and pump torque, power, and speed. The nomenclature used to designate specific detectors consist of: (a) alphabetic symbols identifying the type of measurement (or detector type) or the location of the measurement relative to a component of the semiscale Mod-1 system, or both, and (b) arabic numerals identifying the pipe section (spool) or detector location from system reference points, or both. In the case of the differential

[a] Full scale refers to the data acquisition and processing system electrical data signal range and represents the actual monitored full range in engineering units for individual detectors.

pressure measurements, each detector has two pressure tap locations associated with it. The two locations are designated similar to other instrument locations. However, the order in which the locations are given designates the polarity of the data; the first location indicated is the positive reference. System reference locations are:

Steam generators	Divisions between hot and cold legs.
Vessel cold-leg centerline	References vertical vessel locations. Arabic numerals indicate distances from the cold-leg centerline. Angular vessel locations are in degrees clockwise from the cold-leg centerline as viewed from the top.
Vessel centerline	References detector locations in the intact and broken loops. Arabic numerals indicate distances from the vessel centerline along the centerline of the appropriate hot or cold leg, with the exception that locations in the broken loop cold-leg piping between the rupture assemblies and the steam generator are specified along the centerline of the broken loop hot leg.
Piping spool ID	References material thermocouple locations. Arabic numerals represent distances from the piping spool ID. For example, 16 = 1/16 in., 4 = 1/4 in.
Bottom of steam generator tube sheet	References locations in the steam generator. Arabic numerals represent distances from the bottom of the tube sheet.

Figure C-2 shows a typical installation for detectors in an instrumented spool piece. Table C-1 indicates the manufacturer of the detector, identifies the type of measurement device, indicates the general range and response of the detector, and specifies the total probable error introduced by the measurement system.

The total probable error is obtained by using the root-sum-square summation technique applied to all the individual errors occurring in the instrument, acquisition, and processing systems. All error components were considered to be independent, normally distributed, and to represent 2σ confidence limits.

Physical conditions which occur during pretest warmup and during the blowdown tests overrange some detectors in the system. Detectors in the system are capable of withstanding the overrange conditions without any change in operation or measuring characteristics when the physical conditions are again within the detector range.

Fig. C-2 Typical instrumented spool piece.

TABLE C-I

DETECTOR CHARACTERISTICS AND MEASUREMENT SYSTEM TOTAL PROBABLE ERROR^[a]

Measurement	Manufacturer	Type	Detector Range	Detector Rise-time ^[b]	Measurement System Total Probable Error
Fluid temperature	ARI Industries and Aerojet Nuclear Company	Type J thermocouple, welded junction	0 to 1400°F	20 msec	+5°F
		Type K thermocouple, exposed junction	0 to 2300°F	5 msec	+5°F
	Rosemount Engineering, Inc.	Platinum resistance detector	0 to 1000°F	250 msec	+0.5°F
Material temperature	Aerojet Nuclear Company	Type K thermocouple grounded, spaded junction	0 to 2300°F	~10 msec	+7°F
		Type J thermocouple grounded, spaded junction	0 to 1400°F	~10 msec	+7°F
Fluid pressure	Precise Sensors, Inc.	Flush diaphragm-bonded strain gaged	0 to 3000 psig	35 µsec	+1% full scale ^[c]
			0 to 750 psig	35 µsec	+1% full scale ^[c]
			0 to 100 psig	35 µsec	+1% full scale
Differential pressure	BLH Electronics, INC.	Diaphragm-bonded strain gage	+0.72 to +1500 psid	20 msec	+1.1 to +20% full scale ^[c]
Volumetric flow rate	ITT Barton, Flow Technology Inc., and Potter Instrument Company	Turbine	up to 100 gpm	3 msec	+1.5 gpm
			200 gpm	3 msec	+6.5 gpm
			400 gpm	5 msec	+10.0 gpm
Fluid velocity	Flow Technology, Inc.	Turbine	0 to 18 ft/sec	3 msec	+5% full scale ^[c]
			0 to 36 ft/sec	3 msec	+5% full scale ^[c]
			0 to 50 ft/sec	3 msec	+5% full scale ^[c]
Momentum flux	Ramapo Instrument Company, Inc. and Aerojet Nuclear Company	Strain-gaged cantilever beam with target	up to 13.1×10^4 lb/ft-sec ²	2 msec	+200 to +1000 lb/ft-sec ²
Fluid density	Technical Operations, Inc. and Aerojet Nuclear Company	Gamma attenuation	0.01 to 100 lb/ft ³	3.5 msec	+1.0 lb/ft ³
Liquid level	Aerojet Nuclear Company BLH Electronics, Inc.	Conductance	0 to 59.3 in.	1 msec	3.85 in. ^[d]
		Diaphragm-bonded strain gage	0 to +100 in.	20 msec	+1.0 in.
Pump torque	Lebow Associates, Inc.	Strain-gaged torque cell	+500 in.-lb	1 msec	+4.5 in.-lb
Pump speed	Lebow Associates, Inc.	60-tooth gear and magnetic coil	0 to 3600 rpm	1 msec	+36 rpm
Pump power	Ohio Semitronics, Inc. and Aerojet Nuclear Company	Hall-effect multiplier	0 to 24.2 kW	1 msec	+0.34 kW

[a] The total probable error is obtained by using the root-sum-square summation technique applied to all the individual errors occurring in the instrument, acquisition, and processing systems. All error components were considered to be independent, normally distributed, and to represent 2σ confidence limits.

[b] Risetime is the time required for the detector output to go from 10 to 90% of the value of an impressed step input.

[c] Full scale refers to detector full scale range.

[d] Maximum error.

2.1 Fluid Temperature

Fluid temperature measurements are made using thermocouples and variable resistance devices. Zero off-sets and nonlinearities occurring during acquisition are corrected during data processing. The total probable error for thermocouples is $\pm 5^{\circ}\text{F}$ and for variable resistance devices $\pm 0.5^{\circ}\text{F}$.

2.2 Material Temperature

Material temperature measurements are made using thermocouples. Zero off-sets and nonlinearities occurring during data acquisition are corrected during data processing. The total probable error is $\pm 7^{\circ}\text{F}$ for both Type J and Type K thermocouples.

2.3 Pressure

Pressure measurements are obtained with calibrated pressure transducers. Some of the transducers are flush mounted and some are mounted in standoffs. Pressure data corrections are made for discrepancies noted between pressure measurements made with the Norwood transducers and pressure measurements made with a precision pressure gage at steady state system conditions. The total probable error is $\pm 1\%$ of transducer full scale.

2.4 Differential Pressure

The differential pressure measurements are made with calibrated differential pressure transducers. Transducer pressure sensitivity is corrected for by recording transducer voltage output as a function of pressure during pretest hydrostatic operation and then applying the resulting correction curve to the recorded test data through use of a computer program. Total probable errors vary from approximately $\pm 1.1\%$ to $\pm 20.0\%$ of transducer full scale. The average total probable error used for all differential pressure transducers used in the system is about $\pm 3.0\%$ of transducer full scale.

2.5 Volumetric Flow Rate

Volumetric flow rate measurements are made with turbine flowmeters through which all fluid within a given flow channel passes. The digital signal from the flowmeter is converted directly to volumetric flow rate through use of calibration data obtained from the manufacturer and verified by Aerojet Nuclear Company. The total probable errors, which vary with transducer range, are given in Table C-I.

2.6 Velocity

Velocity measurements are made with small turbine flowmeter probes inserted into the flow stream. These probes operate in a manner similar to that of conventional turbine flowmeters except that only a fraction of the fluid within a given flow passage passes

through them. The digital signal from the probe is converted directly to velocity through use of calibration data obtained from the manufacturer and verified by Aerojet Nuclear Company. The total probable error is $\pm 5\%$ of transducer full scale.

2.7 Momentum Flux

Momentum flux measurements are made with drag disc devices. These devices are basically strain-gaged cantilever beams with an enlarged area on one end which protrudes into a flowing fluid. The analog output is proportional to fluid density times fluid velocity squared (ρv^2). On the basis of the initial fluid density and the calibration curve, the initial voltage from the instrument is assigned a value commensurate with initial pretest steady state flow conditions. To compensate for the thermal sensitivity of the device, the voltage output as a function of temperature is recorded during pretest warmup at zero-flow conditions. The resulting correction curve, plus the hysteresis conditions and the instrument calibration curve, is applied to the recorded test data through use of a computer data conversion program. The total probable error varies from about ± 200 to ± 1000 lb/ft-sec², depending on the transducer range.

2.8 Density

Fluid density data are obtained by a gamma-attenuation technique that provides a measurement of the average fluid density across the section being monitored. A gamma source is placed on one side of the section and a gamma detector is placed on the opposite side. The gamma beam is collimated and passed through the pressure boundary and through the fluid to the photoscintillation detector. The output from the scintillation detector is amplified and recorded in volts, and is processed using a computer data conversion program based on a derived calibration factor and on the calculated initial fluid density. The total probable error is approximately ± 1.0 lb/ft³.

2.9 Liquid Level

Liquid level measurements in the vessel are made using a conductance type probe. The probe senses liquid levels at 3.85 in. intervals in the lower core barrel from 76.4 to 145.7 in. below the cold-leg centerline. Differential pressure cells are used to measure liquid level at other system locations. The total probable error associated with the differential pressure measurements is ± 1.0 in. The maximum error associated with the conductance type probe is 3.85 in.

2.10 Mass Flow Rate

Mass flow rate is not measured directly but is computed from any two of the three directly measured quantities: density, volumetric flow rate, and momentum flux. The mass flow rates within the system during the blowdown transient are calculated with a digital computer from either

$$m = [\rho (\rho v^2) A^2]^{1/2}$$

for density and momentum flux measurements, or

$$m = \rho v A$$

for density and volumetric flow rate measurements, where

m = fluid flow rate (lb/sec)

ρ = measured density (lb/ft³)

ρv^2 = measured momentum flux (lb/sec²-ft)

v = velocity (ft/sec)

A = cross-sectional flow area (ft²).

2.11 Pump Characteristics

The torque transmission to the impeller of the circulating pump is measured by use of a torque cell attached directly to the pump shaft. The total probable error is ± 4.5 in.-lb_f.

Pump speed data are obtained by the use of a gear and sensor pickup coupled with electrical frequency processing. The sensor produces a voltage signal as each gear tooth passes by the sensor. The total probable error for data above 100 rpm is ± 36 rpm; the measuring system is not capable of providing meaningful data below 100 rpm.

Pump power is measured using a halltron. This device measures the current and voltage applied to the pump motor and effectively multiplies them together to produce a voltage output proportional to the power. The total probable error is ± 0.34 kW.