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Author(s): Semiscale Program (D. J. Olson, et al)

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Responsible NRC Individual and NRC Office or Division: W. D. Lanning
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This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

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Prepared for
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INTERIM REPORT

NRC Research and Technical Assistance Report

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EG&G Idaho, Inc.

P. O. Box 1625
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August 27, 1979

Mr. R. E. Tiller, Director
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TRANSMITTAL OF SEMISCALE EOS APPENDIX SB (SEMI-TR-011) - DJO-98-79

Dear Mr. Tiller:

Attached is the Experimental Operating Specification (EOS) Appendix for Small Break Tests S-SB-2 through S-SB-5. This series of tests will be conducted to investigate thermal-hydraulic phenomena resulting from a small break loss-of-coolant accident in a pressurized water reactor. The tests were designed to be compatible with small break loss-of-coolant experiments defined for the Loss-of-Fluid Test (LOFT) Program, and with computer code calculations performed by the Code Assessment and Applications Program to predict pressurized water reactor system behavior during a small break loss-of-coolant accident.

The relatively short time frame for preparation of this document has precluded the normal review process. Therefore, as previously agreed, this document will be released without soliciting comments from the Semiscale Review Group Committee members.

Very truly yours,

D. J. Olson, Manager
Semiscale Program

EAH:ln

Attachment:
As stated

NRC Research and Technical Assistance Report

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APPENDIX SB

EXPERIMENTAL OPERATING SPECIFICATION

TESTS S-SB-2 THROUGH S-SB-5

SEMISCALE MOD-3 SMALL BREAK TEST SERIES

SEMISCALE PROGRAM

EG&G Idaho, Inc.

August 1979

Prepared for the

U. S. Nuclear Regulatory Commission

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

IDAHO OPERATIONS OFFICE UNDER CONTRACT DE-AC07-76IDO1570

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Idaho Falls, Idaho 83401

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APPENDIX SB

TO THE

SEMISCALE EXPERIMENTAL OPERATING SPECIFICATION

TESTS S-SB-2 THROUGH S-SB-5

SEMISCALE MOD-3 SMALL BREAK TEST SERIES

SEMISCALE PROGRAM

EG&G Idaho, Inc.

August 1979

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1237 098

CONTENTS

I. INTRODUCTION---------- SB-1

1. SERIES OBJECTIVES---------- SB-1

2. TEST OBJECTIVES AND BASIC DESCRIPTION--------- ---------- SB-1

2.1 Objectives and Basic Description of Test S-SB-2----- SB-3
2.2 Objectives and Basic Description of Test S-SB-3----- SB-3
2.3 Objectives and Basic Description of Test S-SB-4----- SB-4
2.4 Objectives and Basic Description of Test S-SB-5----- SB-4

II. GENERAL SYSTEM CONFIGURATION---------- SB-6

1. INTACT LOOP CONFIGURATION---------- SB-6

2. VESSEL CONFIGURATION---------- SB-6

3. BROKEN LOOP CONFIGURATION---------- SB-10

4. BREAK ASSEMBLY AND DOWNSTREAM CONFIGURATION---------- SB-10

5. COOLANT INJECTION SYSTEM CONFIGURATION---------- SB-12

6. SYSTEM HYDRAULIC AND VOLUME SPECIFICATION---------- SB-12

III. TEST CONDITIONS AND OPERATIONAL REQUIREMENTS---------- SB-16

1. SYSTEM CONFIGURATION REQUIREMENTS---------- SB-16

2. SEQUENCE OF EVENTS AND OPERATING REQUIREMENTS---------- SB-16

2.1 Water Quality---------- SB-16
2.2 Venting and Location of DP Cells---------- SB-24
2.3 Differential Pressure Cell Zeroing and Orientation---------- SB-24
2.4 System Leak Test and Pressure Test---------- SB-24
2.5 Placement of Calibration Steps in Data---------- SB-24
2.6 System Warmup---------- SB-25
2.7 Rod Thermal Behavior Repeatability Test---------- SB-25
2.8 Pump Seal Leak Test---------- SB-26
2.9 System Heat Leak Test---------- SB-26
2.10 Approach to Power---------- SB-27
2.11 Core Power Control During Transient---------- SB-27
2.12 Intact and Broken Loop Pump Speeds---------- SB-29
2.13 Makeup Pump Operation---------- SB-30
2.14 Intact and Broken Loop Steam Generators---------- SB-30
2.15 Pressure Suppression System---------- SB-32
2.16 Intact and Broken Loop Accumulators---------- SB-32

1237 099

2.17 HPIS Operation---------- SB-32
2.18 Visual Monitoring of the High Power Rod Temperature---------- SB-32
2.19 System Recovery and Test Termination---------- SB-33

IV. INSTRUMENTATION REQUIREMENTS---------- SB-34

V. REFERENCES---------- SB-42

1237 100

FIGURES

1. Semiscale Mod-3 System Cold Leg Communicative Break Configuration - Isometeric---------- SB-7

2. Semiscale Mod-3 Core - Plan View---------- SB-8

3. Semiscale Mod-3 Heater Rod Axial Power Distribution---------- SB-9

4. Break Orifices---------- SB-11

5. HPIS Flow Rate---------- SB-22

6. LPIS Flow Rate---------- SB-23

7. Core Power Decay Curves---------- SB-28

8. Normalized Pump Coastdown Curves---------- SB-31

1237 101

TABLES

I. Test Matrix for the Small Break Test Group---------- SB-2

II. Mod-3 System Resistances---------- SB-13

III. Volume Distribution for Semiscale Mod-3---------- SB-15

IV. Initial Conditions and Operational Requirements---------- SB-17

V. Sequence of Events---------- SB-20

VI. Instrument List---------- SB-35

1237 102

I. INTRODUCTION

The purpose of this document is to establish operating specifications for the Semiscale Small Break Test Series. This series of tests will be conducted in the Semiscale Mod-3 test facility to investigate the thermal-hydraulic phenomena resulting from a small break loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR). This test series was designed to be compatible with small break loss of coolant experiments defined for the Loss-of-Fluid Test (LOFT) Program and computer code calculations performed by the Code Assessment and Applications Program to predict PWR system behavior during a small break LOCA. Results of the Semiscale small break tests will be used to investigate scaling effects pertinent to LOFT and to assess analytical models used in the computer codes.

1. SERIES OBJECTIVES

The primary objectives of the small break series are to provide experimental data that can be used to assess the analytical capability of computer codes used in LOCA analysis and for comparison with compatible tests to be run in the LOFT facility.

Items of major importance include natural circulation flowrates, core uncovery heat transfer (if applicable), an assessment of certain recovery procedures and the ability of typical process instruments to provide accurate and sufficient information to operating personnel.

2. TEST OBJECTIVES AND BASIC DESCRIPTION

Four small break tests are described in this experimental operating specification (EOS). The test matrix presented in Table I lists the principal variables and specific objectives for each test.

The break size, system geometry and system initial conditions will be varied from test to test to determine their influences on system behavior.

TABLE I

TEST MATRIX FOR THE SMALL BREAK TEST GROUP

Test	Break Size	Initial Conditions	Conguration	Objectives
S-SB-2	2.5% 2.79 mm	Scaled from PWR	Semiscale Mod-3	Investigate a small break with break flow greater than HPIS flow.
S-SB-3	2.5%	Scaled from PWR	LOFT	Identify influence of LOFT geometry on system behavior
S-SB-4	2.5%	Scaled from LOFT	LOFT	Identify influence of LOFT initial conditions on system behavior
S-SB-5	0.16% 0.71 mm	Scaled from PWR	Semiscale Mod-3	Investigate a small break with break flow equal to HPIS flow at secondary side pressure.

1237 104

Each test will be a small break loss-of-coolant experiment (LOCE) with the break located at the centerline of the cold leg.

Emergency core coolant (ECC) will be provided for each test from accumulators, a high pressure injection system (HPIS) and a low pressure injection system (LPIS). The ECC flow rates and volumes will be volumetrically scaled from PWR or LOFT values assuming only one safety injection train is operating. The tests will be initiated from steady state operating conditions and will terminate after the pressure has dropped below the LPIS actuation pressure and the primary coolant loops have refilled with liquid. Test conditions are defined to simulate a loss of on-site power at the time of scram.

2.1 Objectives and Basic Description of Test S-SB-2

The primary objective of Test S-SB-2 is to provide data for a small break LOCE in which the break flow rate is greater than the high pressure safety injection rate. The initial and boundary conditions will be representative of typical PWR operating conditions.

Test S-SB-2 will be conducted in the Semiscale Mod-3 system configuration. The break size will be 0.0613 cm^2 which is volume scaled to represent an 11 cm break in the cold leg of a PWR. The break will be located in the cold leg between the pump and vessel and will be communicative in nature.

It is expected that operator actions will not be required to reduce the system pressure to the LPIS setpoint in this test.

2.2 Objectives and Basic Description of Test S-SB-3

The primary objective of Test S-SB-3 is to identify the influence of LOFT geometry and location of ECC injection on system behavior during a small break LOCE. To accomplish this, the test will be run with the same conditions as Test S-SB-2, but with the system modified to be more representative of the LOFT configuration.

1237 105

The pump suction in the intact loop will be modified so the elevation of the pump suction below the cold leg is identical to LOFT. A valve will be placed between the break and the broken loop pump. Prior to core trip, this valve will be open to establish initial conditions for the test. After the core trips the valve will be shut to simulate the non-communicative break with inactive broken loop hot leg of the LOFT configuration. The broken loop steam generator will be drained at rupture and the broken loop pump will be tripped when core power is tripped to simulate the inactive components in the LOFT broken loop hot leg.

2.3 Objectives and Basic Description of Test S-SB-4

The primary objective of Test S-SB-4 is to identify the effect of LOFT initial conditions on system behavior during a small break LOCE. The test will be run with the configuration of Test S-SB-3, but with initial and boundary conditions scaled to LOFT Test L3-1.

The Semiscale pumps are not large enough to produce the volume scaled LOFT flow rate, so this test will be run with the maximum flow rate attainable. In order to maintain the desired fluid temperatures, the initial core power will therefore be lower than the desired power scaled from LOFT. However, the decay power will be volume scaled to LOFT's decay power in order to achieve the desired volume to power ratio.

2.4 Objectives and Basic Description of Test S-SB-5

The primary objective of Test S-SB-5 is to provide experimental data for a small break LOCE with a break size corresponding to LOFT Test L3-2. This break size results in break flows which are approximately equal to the HPIS flow rate when the primary system pressure equals the secondary side pressure.

The conditions for Test S-SB-5 will be the same as for Test S-SB-2 except that the break area will be 0.0040 cm^2 which is volume scaled to a 2.8 cm break in the cold leg of a PWR.

1237 106

In this test, operator actions will be required to recover the system by reducing the pressure to the LPIS setpoint. System recovery will be initiated at least one hour after rupture by bleeding steam from the steam generator secondaries.

1237 107

II. GENERAL SYSTEM CONFIGURATION

The Semiscale Mod-3 system configuration, shown in Figure 1, will be used for Tests S-SB-2 and S-SB-5. The system configuration will be modified to represent LOFT, for Tests S-SB-3 and S-SB-4. Since the major components of each configuration have been discussed in EOS Appendix 7 (Reference 1), only a brief discussion of the system configuration is included herein.

1. INTACT LOOP CONFIGURATION

The intact loop for Tests S-SB-2 and S-SB-5 will be identical to that described in the EOS Appendix 7. Included in the intact loop configuration are the steam generator, primary coolant pump, and the associated loop piping which includes instrumented spool pieces.

The intact loop for Tests S-SB-3 and S-SB-4 will be modified to simulate LOFT by installing the Semiscale Mod-1 pump suction leg in place of the Semiscale Mod-3 pump suction leg. This will give the same elevation difference between the cold leg and pump suction for Semiscale and LOFT.

2. VESSEL CONFIGURATION

The basic configuration of the vessel internals will be identical to that described in the EOS Appendix 7. The Mod-3 vessel configuration consists of an upper head, upper plenum, heated core region, and lower plenum contained within a multi-section pressure vessel, and an external inlet annulus and downcomer pipe. The core configuration and the normalized axial power profile are shown in Figures 2 and 3, respectively.

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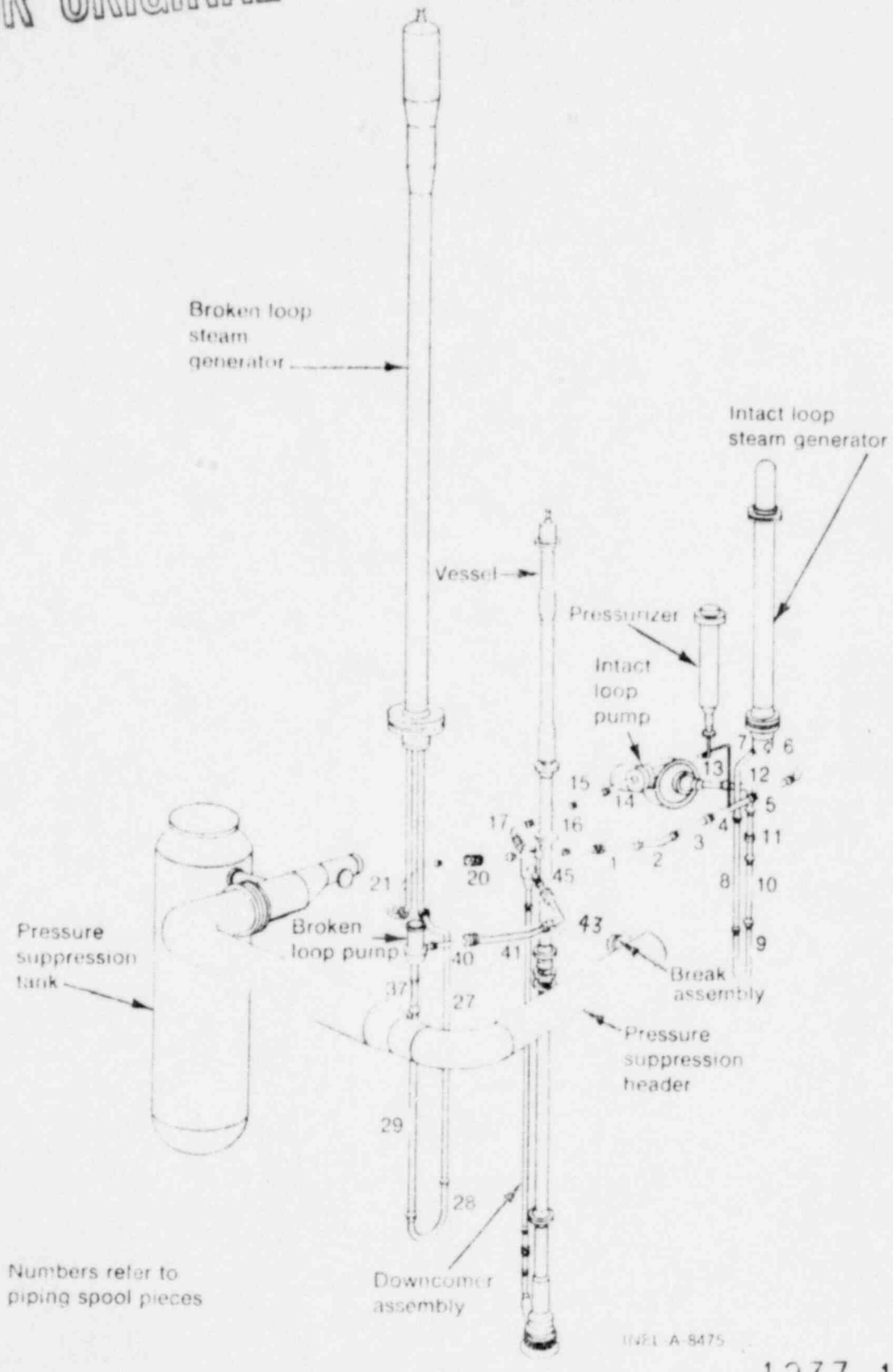

Fig. 1 Semiscale Mod-3 system cold leg communicative small break configuration isometric.

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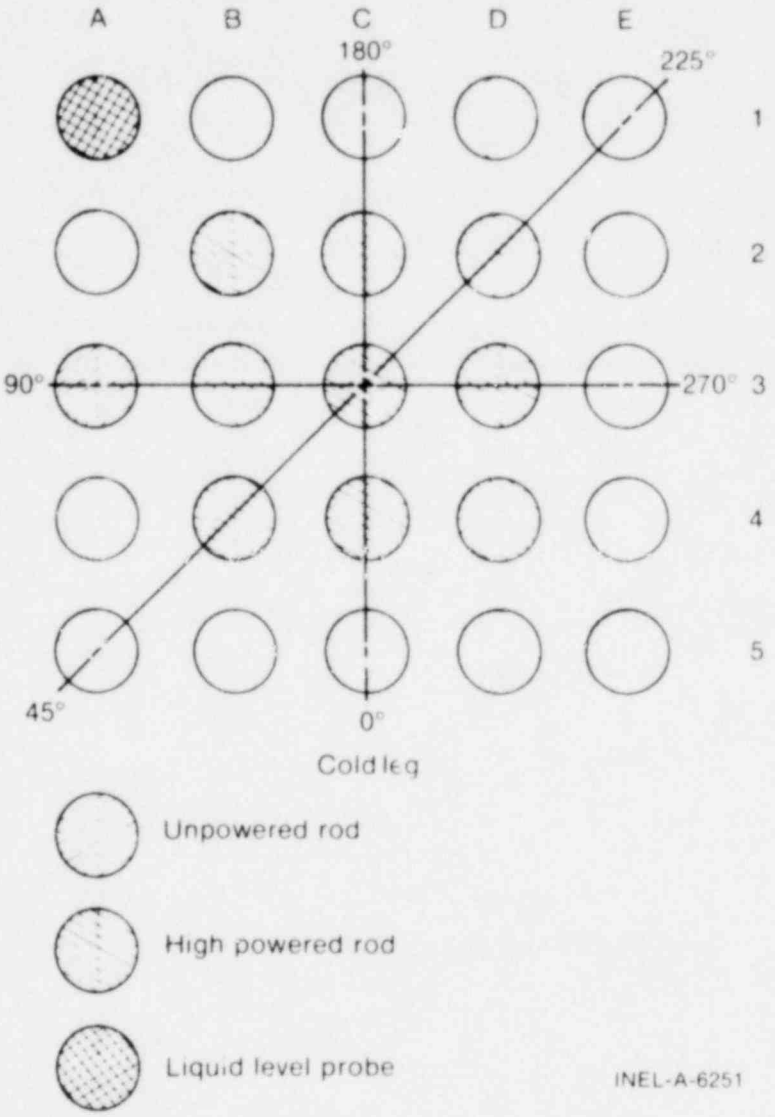

Fig. 2 Semiscale Mod-3 core - plan view.

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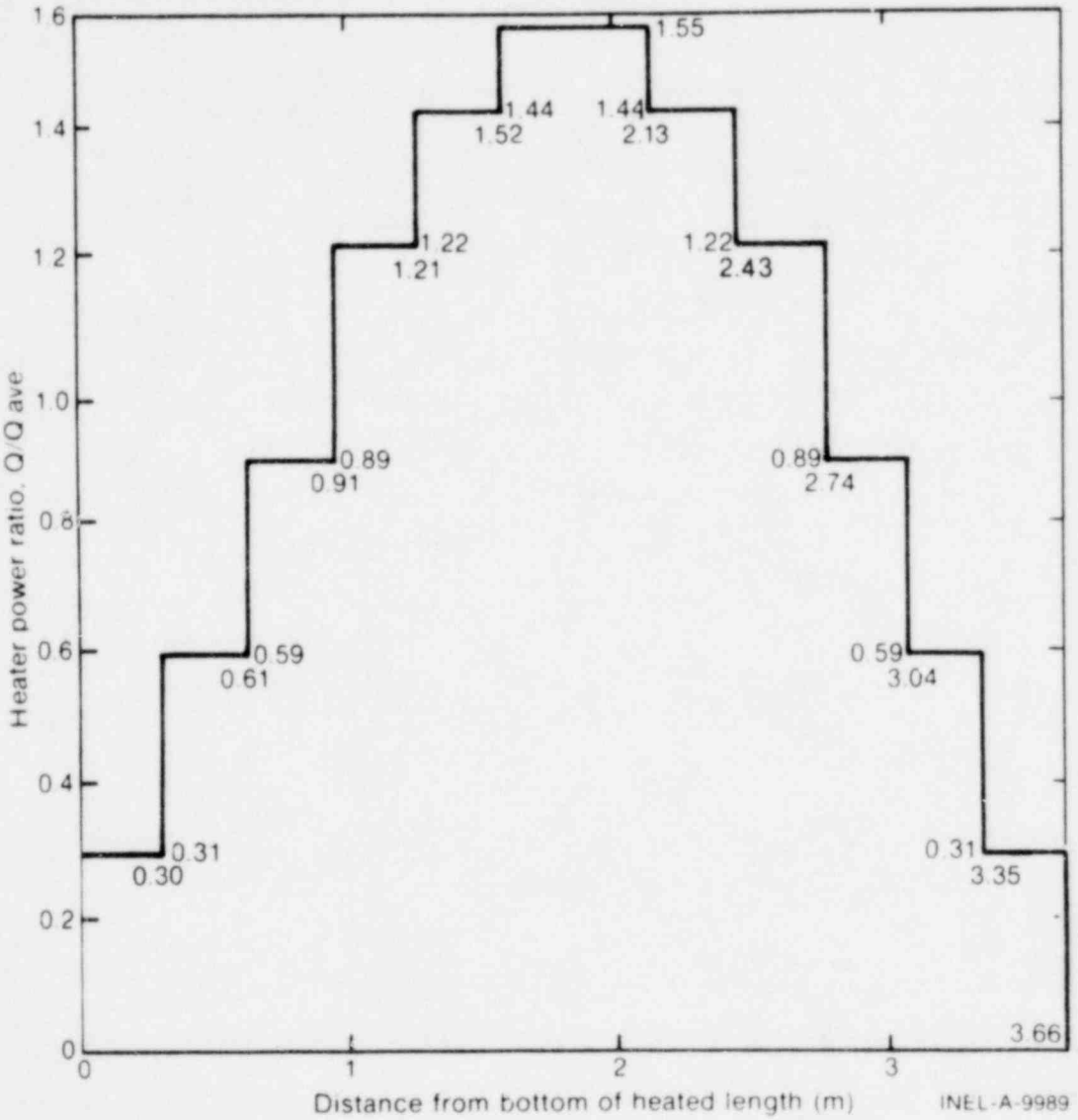

Fig. 3 Semiscale Mod-3 heater rod axial power distribution.

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3. BROKEN LOOP CONFIGURATION

The broken loop for Tests S-SB-2 and S-SB-5 will be the same as that described in EOS Appendix 7, except that it will be configured for a communicative break instead of noncommunicative. An active steam generator and pump are included in the broken loop.

The broken loop will be modified to simulate the LOFT broken loop configuration for Tests S-SB-3 and S-SB-4. The LOFT broken loop will consist of a non-communicative break assembly, an inactive hot leg, and pump and steam generator simulators. A valve will be installed in place of spool piece 40 in the Mod-3 configuration. When this valve is closed, the break will be non-communicative and the broken loop hot leg will be inactive. This valve will be open prior to core trip to obtain the desired initial conditions. The broken loop steam generator will be drained at rupture and the broken loop pump will be tripped when core power is tripped to represent the inactive LOFT components.

4. BREAK ASSEMBLY AND DOWNSTREAM CONFIGURATION

The break assembly will include a bell mouthed orifice and an instrumented spool piece. The break orifices to be used in the small break test series are shown in detail in Figure 4.

The pressure suppression system (PSS), described in EOS Appendix 7, will be used in Tests S-SB-2, S-SB-3, and S-SB-4 to control the backpressure at the break.

In Test S-SB-5, the break flow will bypass the PSS and pass through a condensing system. This system will be used to measure the low break flow rates which will occur in this test. The condensing system will consist of coil heat exchangers to condense the break discharge fluid, with instrumentation and a tank to collect and measure the liquid.

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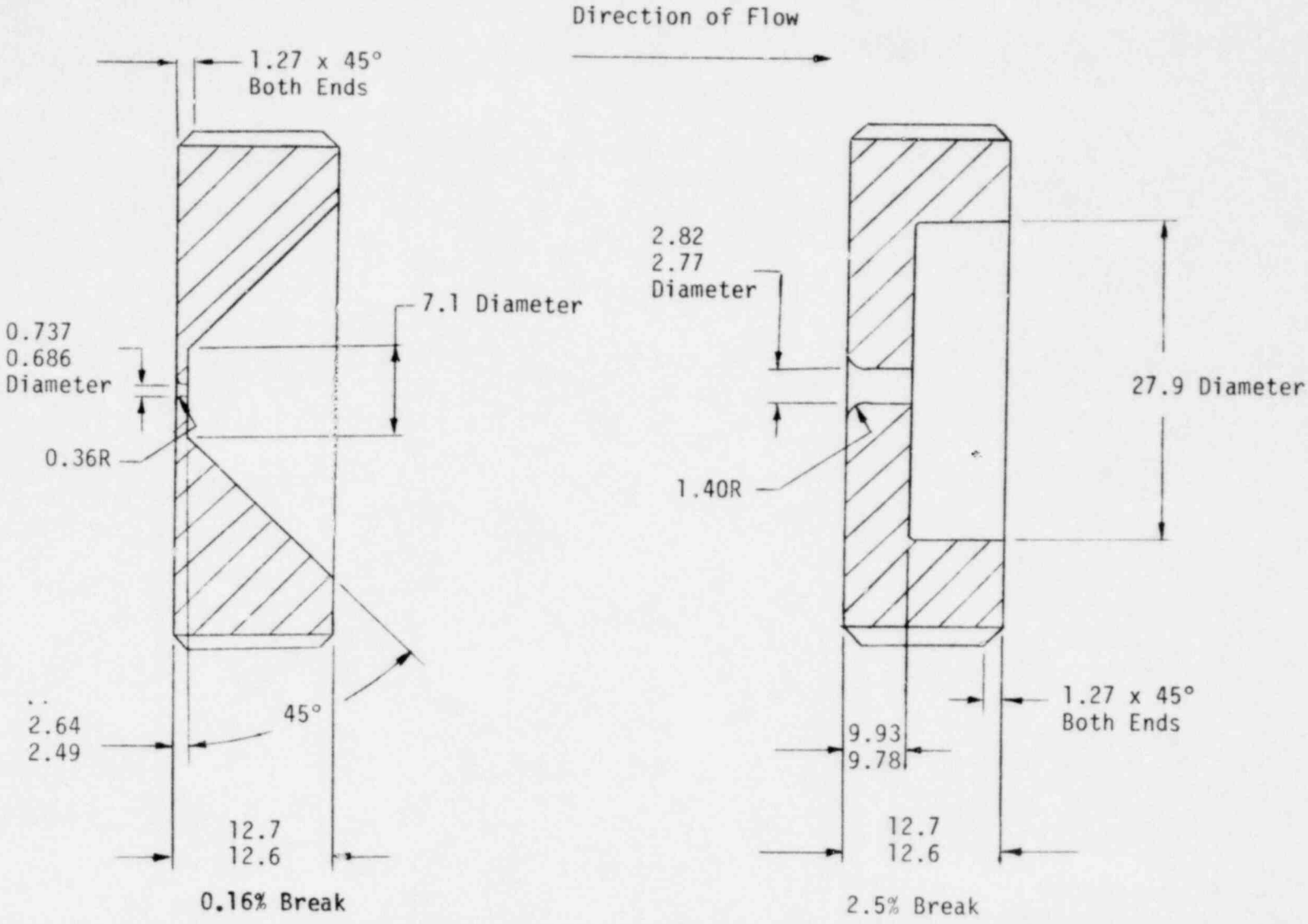


Fig. 4 Break orifice configurations.

5. COOLANT INJECTION SYSTEM CONFIGURATION

The cold leg coolant injection systems to be used in this series of tests include accumulator systems, high pressure injection systems, and low pressure injection systems. Each of these systems is described in the SDD for the Mod-1 system (Reference 2).

6. SYSTEM HYDRAULIC AND VOLUME SPECIFICATION

Table II presents centerline elevation changes and hydraulic resistances for the Mod-3 system. Most of the resistances listed in the table are based on measurements from a pressure drop test conducted at isothermal conditions of 550 K and 15.5 MPa. The hydraulic resistances were obtained from measured values for the pressure drop, fluid density, and mass flow rate using the following equation:

$$R' = \frac{\rho \Delta P}{\dot{m}^2}$$

where ρ = Fluid density, kg/m^3

ΔP = Pressure drop, Pa

$\dot{m}$ = Mass flow rate, kg/sec

Where measurements were not available, the hydraulic resistances were calculated as follows:

$$R' = \frac{\Sigma(K_L + fL/D)}{2\ A_f^2}$$

where K_L = Loss coefficient

f = Friction factor

L = Length of pipe, m

D = Diameter of pipe, m

A_f = Flow area, m^2

1237 114

TABLE II

MOD-3 SYSTEM RESISTANCES
(Measured Values at 550 K)

Between Instrument Sections	Measurement	Resistance ($\times 10^5/m^4$)	Elevation Change(m)
Intact Loop			
Vessel upper plenum to spool 1A	DV-LUP-1A	1.77	0.35
Spool 1A to 6	DI-1-	1.37	0.00
Steam generator (Spool 6 to 7)**	DI-6-7	32.46	-0.47
Spool 7 to 13	DI-7-13	1.18	0.00 (-2.67)+
Spool 13 to 15 (exclusive of pump)		0.09*	0.25
Locked rotor pump		16.18*	-
Spool 15 to 17A	DI-15-17	1.77	0.00
Spool 17A to downcomer inlet annulus	DI-17-DIA	0.20	0.29
Broken Loop			
Vessel lower upper plenum to spool 20B	DB-13V-20B	13.73	0.35
Spool 20B to 21	DB-20B-21	8.92	0.00
Steam generator (Spool 21 to 27A)**	DB-21-27	271.63	-0.01
Spool 27A to 37A	DB-27-37A		-0.86 (-2.91)+
Spool 37A to 40B (exclusive of pump)		2.94*	0.65
Locked rotor pump		1249.80*	-
Spool 40B to 45A	DB-40-45	62.66	0.00
Spool 45A to DC inlet annulus		8.83	0.29
Vessel			
DC inlet annulus to bottom of lower plenum	DD-DIA-578	5.49	-6.07
Bottom of lower plenum to bottom of core		1.57	0.77
Bottom of core to above core	DV-501-105	7.26	3.96
Above core to lower upper plenum	DV-105-13	1.57	0.92
Bypass line		3824.4	
Support column A	DV-154Q-105	8335.3	
Support column B	DV-154D-105	8139.1	
Guide tube	DV+331-105	4412.8	

* - Calculated values.
\+ - Value in parentheses denotes maximum elevation change in section.
** - Intact loop U-tube bend is 253 cm above bottom of tube sheet.
Broken loop U-tube bend is 978 cm above bottom of tube sheet.

1237 115

Table III presents a detailed tabulation of the design volume distribution for the Mod-3 system for the cold leg break configuration.

1237 116

TABLE III

VOLUME DISTRIBUTION FOR SEMISCALE MOD-3
(COLD LEG BREAK)

	Desired Volume Scaled from PWR m^3	Design m^3	Desired Volume Scaled from LOFT (m^3)
1.0 Vessel			
1.1 Downcomer Region			
Distribution annulus	0.0071	0.0077	0.0048
Downcomer pipe	0.0074	0.0145	0.0145
Core bypass	0.0039	--	0.0006
TOTAL DOWNCOMER VOLUME	0.0184	0.0222	0.0199
1.2 Upper Head Region			
Above top of guide tube	0.0044	0.0046	--
Below top of guide tube	0.0087	0.0094	--
TOTAL UPPER HEAD VOLUME	0.0131	0.0140	--
1.3 Upper Plenum	0.0103	0.0112	0.0252
1.4 Core Region	0.0107	0.0106	0.0082
1.5 Lower Plenum	0.0161	0.0157	0.0199
1.6 Control Rod Guide Tube	0.0050	0.0015	--
1.7 Core Support Tubes	0.0007	0.0004	--
TOTAL VESSEL VOLUME	0.0743	0.0756	0.0732
2.0 Intact Loop			
2.1 Hot Leg	0.0039	0.0103	0.0105
2.2 Pressurizer (Liquid Volume)	0.0215	0.0215[1]	0.0247
2.3 Surge Line	--	0.0004	0.0003
2.4 Steam Generator	0.0536	0.0421	0.0392
2.5 Pump Suction Leg	0.0063	0.0243[1]	0.0093
2.6 Pump	0.0040	0.0041	0.0056
2.7 Cold leg	0.0042	0.0088	0.0108
TOTAL INTACT LOOP VOLUME	0.0935	0.1115	0.1000
3.0 Broken Loop			
3.1 Hot Leg	0.0013	0.0025	0.0046
3.2 Steam Generator	0.0179	0.0176	0.0155
3.3 Pump Suction Leg	0.0021	0.0056	0.0003
3.4 Pump	0.0013	0.0013	0.0018
3.5 Cold Leg	0.0014	0.0016	0.0059
TOTAL BROKEN LOOP VOLUME	0.0240	0.0286	0.0281
TOTAL SYSTEM LIQUID VOLUME	0.192	0.215[1]	0.205

1 For Tests S-SB-3 and S-SB-4 the pressurizer liquid volume will be 0.0247 m^3, the pump suction leg volume will be 0.0111, and the total liquid system volume will be 0.205 m^3.

1237 117

III. TEST CONDITIONS AND OPERATIONAL REQUIREMENTS

The initial conditions and operational requirements for the small break test series are listed in Table IV. Supplementary information and a sequence of events are provided in the following sections.

1. SYSTEM CONFIGURATION REQUIREMENTS

The general system configuration will be as described in Section II. In Tests S-SB-3 and S-SB-4, a valve will be installed between the broken loop pump discharge and the break assembly. This valve will be open, permitting full flow until the initiation of core power decay. At that time it will close, isolating the hot leg from the cold leg for the remainder of the test.

2. SEQUENCE OF EVENTS AND OPERATING REQUIREMENTS

The sequence of events prior to and during the tests is defined in Table V. This sequence is to serve as a guide for the preparation of detailed test procedures. The following text describes in more detail the events listed in Table V.

2.1 Water Quality

For each test the system will be filled and vented with water conforming to the following water chemistry requirements:

pH	9.0 - 10.5
Conductivity	3-70 mhos/cm
Lithium	0.3 - 2.2 g/m^3
Chloride	0.15 g/m^3 (maximum)
Flouride	0.10 g/m^3 (maximum)
Oxygen	1.0×10^{-4} cc/l (maximum)
Total gas	100 cc/l (maximum)

1237 118

TABLE IV

INITIAL CONDITIONS AND OPERATIONAL REQUIREMENTS

	SB-2	SB-3	SB-4	SB-5
Initial Conditions				
Pressurizer Pressure (MPa)	15.51	15.51	14.86	15.51
Hot Leg Fluid Temperature (K)	583.3	583.3	576.2	583.3
Cold Leg Fluid Temperature (K)	550.0	550.0	556.8	550.0
Core Inlet Flow Rate (kg/s)	11.7	11.7	11.7	11.7
Total Core Power (MW)	2.1	2.1	1.2(1)	2.1
Radial Power Profile	Flat	Flat	Flat	Flat
Pressurizer Liquid Volume (m^3)	0.0215	0.0247	0.0247	0.0215
S. G. Secondary Pressure (MPa)	5.86	5.86	5.86	5.86
S. G. Feedwater Temperature (K)	495	495	495	495
S. G. Secondary Water Level				
Intact Loop (m)	2.95	2.95	2.95	2.95
Broken Loop (m)	9.98	(2)	(2)	9.98
Configuration				
Break Size	2.5%	2.5%	2.5%	0.16%
Break Type	Communicative	Noncommunicative	Noncommunicative	Communicative
Break Location	Cold Leg	Cold Leg	Cold Leg	Cold Leg
System Modification	No	(3)	(3)	No
Pressurizer Location	Intact Loop	Intact Loop	Intact Loop	Intact Loop
Pressurizer Line Resistance (m^{-4})	5.9×10^8	5.9×10^8	5.9×10^8	5.9×10^8
Intact Loop ECC Injection Location (all systems)	Cold Leg	Cold Leg	Cold Leg	Cold Leg
Broken Loop ECC Injection Location (all systems)	Cold Leg	Not Used	Not Used	Cold Leg
Intact Loop Accumulator Line Resistance (m^{-4})	8.59×10^8	4.4×10^8	4.4×10^8	8.59×10^8
Broke Loop Accumulator Line Resistance (m^{-4})	7.73×10^9	----	---	7.73×10^9

1237 119

TABLE IV (contd)

ECC Injection	SB-2	SB-3	SB-4	SB-5
Intact Loop Accumulator				
Actuation Pressure (MPa)	4.24	4.24	4.24	4.24
Liquid Volume (m^3)	0.04480	0.05973	0.05973	0.04480
Nitrogen Volume (m^3)	0.02635	0.03514	0.03514	0.02635
Temperature (K)	300	300	300	300
Intact Loop HPIS				
Actuation Pressure (MPa)	12.41	12.41	12.41	12.41
Delay (s)	25	25	0	25
Injection Rate (kg/s)	see Fig. 5	see Fig. 5	see Fig. 5	see Fig. 5
Temperature (K)	300	300	300	300
Intact Loop LPIS				
Actuation Pressure (MPa)	0.883	0.883	0.883	0.883
Injection Rate (kg/s)	see Fig. 6	see Fig. 6	see Fig. 6	see Fig. 6
Temperature (K)	300	300	300	300
Broken Loop Accumulator				
Actuation Pressure (MPa)	4.24	Not	Not	4.24
Liquid Volume (m^3)	0.01493	Used	Used	0.01493
Nitrogen Volume (m^3)	0.00878			0.00878
Temperature (K)	300			300
Broken Loop HPIS				
Actuation Pressure (MPa)	12.41			12.41
Delay	25	Not	Not	25
Injection Rate (kg/s)	see Fig. 5	Used	Used	see Fig. 5
Temperature(K)	300			300
Broken Loop LPIS				
Actuation Pressure (MPa)	0.883	Not	Not	0.883
Injection Rate (kg/s)	see Fig. 6	Used	Used	see Fig. 6
Temperature (K)	300			300

1237 120

TABLE IV (contd)

Transient Conditions	SB-2	SB-3	SB-4	SB-5
SCRAM (power decay)	1.2 ANS	1.2 ANS	LOFT Scaled	1.2 ANS
Pressure Setpoint (MPa)	12.58	12.58	--	12.58
Time Delay (s)	3.4	3.4	0	3.4
Steam Generator Secondaries(4)				
Steam Valve Relief Pressure (MPa)	7.7	7.7	7.03	7.7
Steam Valve Isolation	12 s after SCRAM	12 s after SCRAM	At SCRAM	12 s after SCRAM
Main Feedwater Isolation	5 s after SCRAM	5 s after SCRAM	At SCRAM	5 s after SCRAM
Auxiliary Feedwater Initiation	60 s after SCRAM	60 s after SCRAM	Low level 2.44 m	60 s after SCRAM
Auxiliary Feedwater Flow Rate (kg/s)				
Intact Loop	0.0296	0.0395	0.0147	0.0296
Broken Loop	0.0099	0	0	0.0099
Auxiliary Feedwater Temperature (K)	300	300	300	300

SB-19

1. The initial core power for Test S-SB-4 will be determined by obtaining the required hot and cold leg temperatures at full flow.

2. The broken loop steam generator secondary water level for Tests S-SB-3 and S-SB-4 will be the lowest level which will produce the desired cold leg temperature at the desired flow rate.

3. In Tests S-SB-3 and S-SB-4 the system will be modified to represent LOFT's characteristics as closely as possible. The configuration is described in Section II.

4. In Tests S-SB-3 and S-SB-4 the broken loop steam generator will be drained at the time the pumps are tripped and the hot leg is valved off from the cold leg.

1237 121

TABLE V

SEQUENCE OF EVENTS
SMALL BREAK TEST GROUP

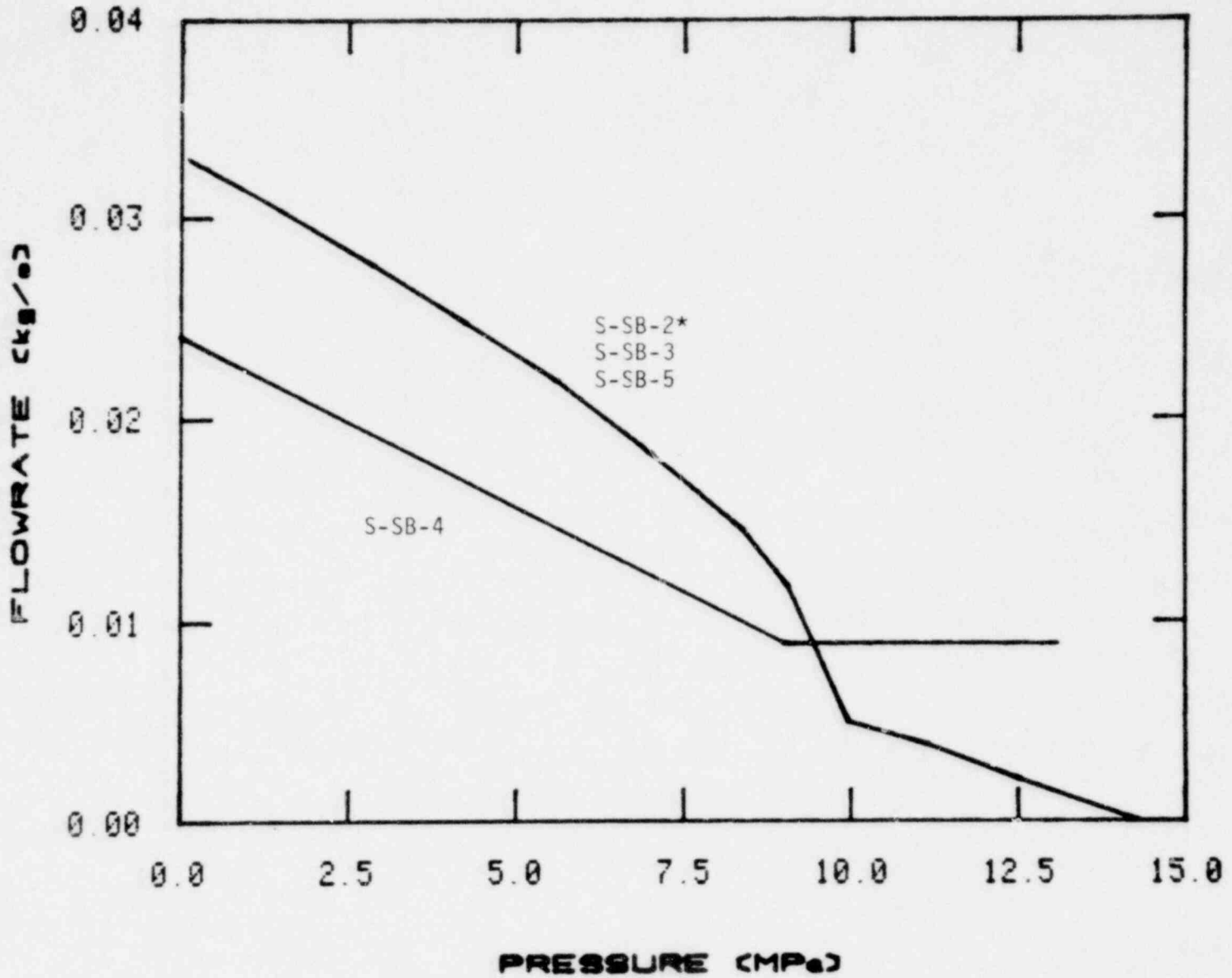
Event	Time of Application
1. Fill and vent primary system and establish water chemistry.	Several hours before blowdown
2. Fill suppression tank.	
3. Fill intact and broken loop steam generator secondaries.	
4. Fill intact and broken loop accumulators.	
5. Electronically zero DP cells.	
6. Perform pretest leak test.	
7. Perform instrumentation systems warmup and checkout.	
8. Perform system warmup and rod thermal behavior repeatability test (at 450 K).	Flow and no-flow DDAPS data at RFI-2 = 300 K, 350 K, 400 K 450 K, 500 K.
9. Perform pump seal leak tests and system heat loss test (at 550 K).	At 527 K, 4.5 MPa; 550 K, 9.0 MPa; 550 K, 12.5 MPa.
10. Establish core power level at full power and stabilize.	Approximately 10 - 30 minutes before blowdown.
11. Take primary system water sample.	When RFI-2 indicates desired hot leg temperature.
12. Verify that the specified system initial conditions exist.	At specified core power before blowdown.
13. Adjust core flow rate to achieve required core ΔT.	
14. Reverify that the specified initial system conditions exist prior to blowdown.	Up to 20 seconds before rupture.
15. Start DDAPS recording initiation.	20 seconds before rupture.

1237 122

TABLE V (contd)

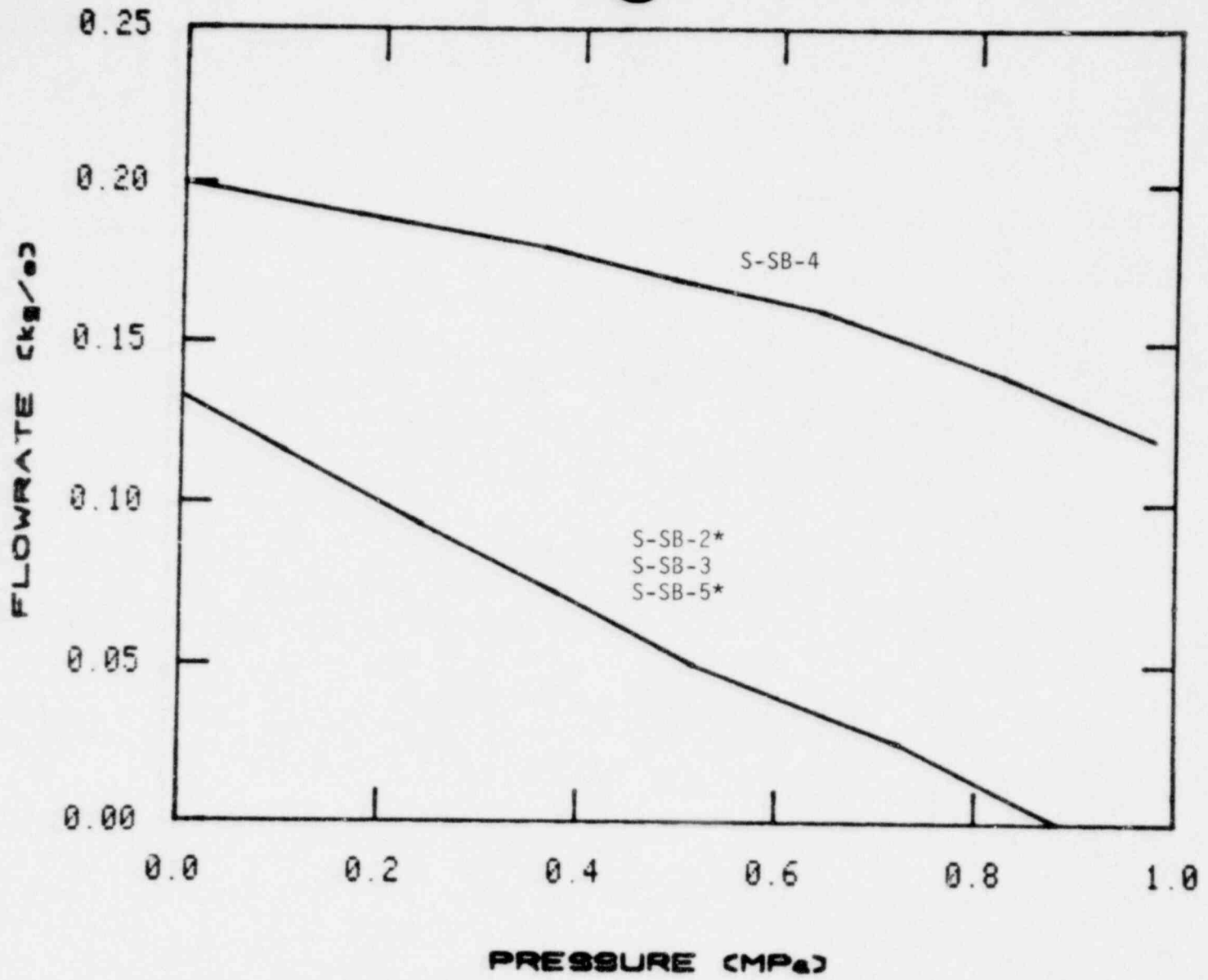
Event	Time of Application
16. Initiate transient by opening break.	t = o
17. Enable ECC systems.	t = 1 s
18. Initiate trip sequence. 18.1 Initiate core power decay. 18.2 Initiate pump coastdown. 18.3 (S-SB-3 and S-SB-4 only) Close BL hot leg isolation valve and drain BL steam generator. 18.4 Close feedwater valves. 18.5 Close steam valves. 18.6 Initiate HPIS injection. 18.7 Initiate auxiliary feedwater injection.	Time as specified in Table IV.
19. Reduce PSS tank pressure to 300 kPa (except S-SB-5).	300 s
20. Begin bleeding steam from steam generator secondaries (S-SB-5).	3600 s
21. Initiate accumulator injection	When system pressure drops to 4.24 MPa.
22. Reduce PSS tank pressure to 100 kPa (except S-SB-5).	When system pressure drops to 1.20 MPa.
23. Initiate LPIS injection.	When system pressure drops to 0.883 MPa.
24. Terminate test. 24.1 Trip core power. 24.2 Terminate ECC injection. 24.3 Terminate feedwater flow.	After the system has refilled with liquid.
25. Drain system from low points.	

1237 123



* Total injection rate is shown. For Tests S-SB-2 and S-SB-5, the flow will be split 75% into the intact loop and 25% into the broken loop.

Fig. 5 HPIS flow rates.



* Total injection rate is shown. For Tests S-SB-2 and S-SB-5, the flow will be split 75% into the intact loop and 25% into the broken loop.

Fig. 6 LPIS flow rates.

1237 125

A water sample will be taken just prior to blowdown and analyzed posttest for content. The results of this analysis will be reported in the experimental data report.

2.2 Venting and Location of DP Cells

It is required that all differential pressure (DP) cells and connecting lines be free of air bubbles prior to warmup. The DP cells must be lower than any system ports that connect to the cell.

2.3 Differential Pressure Cell Zeroing and Orientation

With the system full of cold water, all DP cells should read zero prior to each warmup. Wherever practical, the DP cells will be oriented with the high side tap connected to the first number in the instrument identification so that a positive DP will be obtained during normal flow. For example, DI-3-6 should have the high side tap connected to spool 3 and the low side tap connected to spool 6.

2.4 System Leak Test and Pressure Test

In the system leak test, the system is brought from 250 to 15,513 kPa in five equal pressure increments. At each pressure point, DDAPS data will be taken. The leak test should be accomplished at no-flow conditions with the system cold and full of water.

2.5 Placement of Calibration Steps in Data

It is required that calibration steps do not occur on the data during or within 2 s of the following events: rupture, ECC initiation, and system drain.

1237 126

2.6 System Warmup

In the system warmup, the system is brought from ambient conditions to the operating cold leg fluid temperature. All data should be recorded and displayed on the DDAPS at intervals specified in Table V. The intact and broken loop pumps must have the capability of starting at the specified system pressure and temperature. It is required that the system be maintained at the operating temperature for approximately 10 minutes prior to approach to power to ensure that system piping and fluid temperatures are stabilized.

2.7 Rod Thermal Behavior Repeatability Test

The Mod-3 heater rod thermal characteristics will possibly change over a period of operational cycling. It is therefore necessary to have information on the possible changes in the thermal behavior of the rods from test to test. This information will provide a basis for anticipating a critical situation, such as rod overheating, and possibly provide data for modifying analytical conduction models. Below is an outline of test procedures to be followed in step 8 of the sequence of events, for evaluation of the rod thermal behavior.

(1) The temperature level for switching the core power off will be set at 950 K to ensure no core damage will result from this test.

(2) The system will be heated at 100% flow rate until the core inlet temperature reaches 450 K $\pm$ 5 K. There will be no flow in the secondary of either the intact or broken loop steam generators.

(3) The core power will be maintained constant (for longer than 5 minutes) until the core inlet temperature stabilizes within 1 K.

1237 127

(4) When the core inlet temperature stabilizes, the core power will be step increased to 25% of full power (0.50 MW) for 10 s and then returned to its original level.

(5) The DDAP data system will record heater rod cladding temperatures, fluid temperatures, flow rates, and pump power for each individual power pulse test, and a magnetic tape will be generated.

2.8 Pump Seal Leak Test

Due to the small break sizes in these tests, the pump seal leak rate could be significant when compared to the break flow rate. It is therefore desirable to use the makeup pump to match the leak rate as nearly as possible to maintain repeatability. In order to determine the leak rate, a leak test will be performed during system warmup. Data will be taken at the following conditions:

Pressure	Temperature	Pump Speed
4.5 MPa	527 K	0
9.0 MPa	550 K	0
12.5 MPa	550 K	full

Pressurizer level and makeup line flow rate measurements are required. System temperatures should be allowed to stabilize at each condition.

2.9 System Heat Leak Test

The Semiscale system, because of its small size, has a heat leak rate which is not typical of a large PWR. In a slow transient this heat leak could affect system response. In the small break test series an attempt will be made to account for the atypical heat leak by increasing the decay power. A heat leak test will be performed to measure the heat leak rate as follows.

1237 128

With the system at nominal conditions of 550 K and 10 MPa with full flow, the system will be stabilized for approximately 10 minutes. The core power required to maintain this condition will be recorded. Then both pump speeds will be reduced to approximately 10% of full speed, for approximately 10 minutes. Measurements of fluid temperatures, metal temperatures and core power are required.

2.10 Approach to Power

The maximum core power for the small break tests will be 2.1 MW. The approach to power will be accomplished as follows:

> Ramp the core power up in successive, discrete steps, permitting sufficient time between steps for the steam generator secondary steam temperature to stabilize. The maximum core power will be attained in the following sequence with data recorded at each step.
>
> 0.5 MW - record data
> 1.2 MW - record data
> full power - record data

In Test S-SB-4, the maximum core power is approximately 1.2 MW. For this test, approach to power will be obtained in following sequence.

0.4 MW - record data
0.8 MW - record data
full power - record data

2.11 Core Power Control During Transient

Core power will be maintained at 100% until 3.4 s after the pressure reaches 12.58 MPa, when control will be switched to a predetermined power decay, shown in Figure 7. An additional amount of

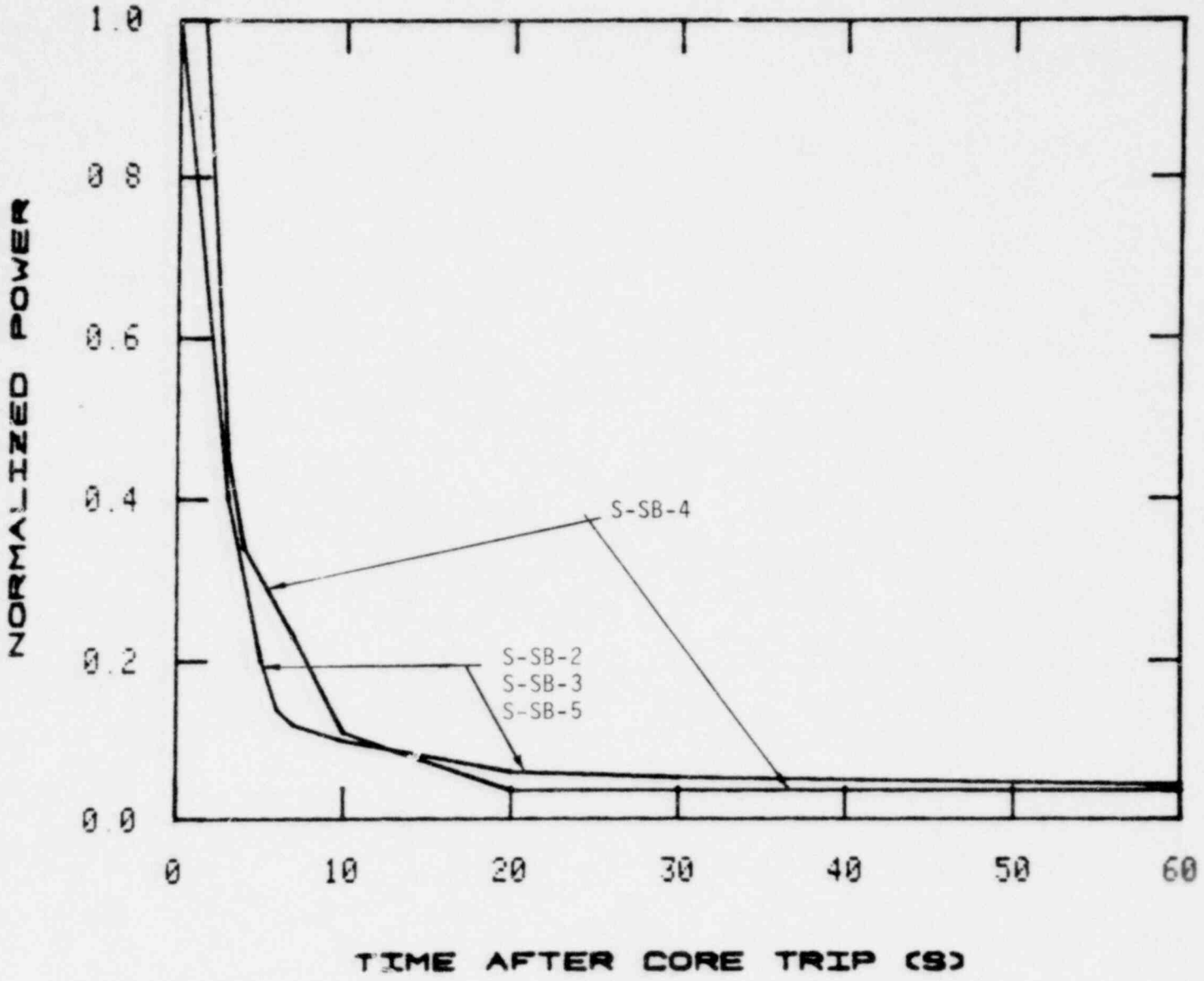


Fig. 7 Core power decay curves.

1237 130

power will be added to that determined from Figure 7 to account for the system heat leak rate, which will be determined as mentioned in Section III, 2.9.

A heater rod protection circuit causes the core power to trip on high temperature. The heater rod trip point temperatures are specified as a linear function of core power defined by the following points.

Core Power (%)	Core Trip Temperature (K)
2.0 MW	950
0.12 MW	1255

If the core power is tripped by a high heater rod temperature indication, the core power will be tripped to 0.10 MW as long as the hottest heater rod temperature is less than 1255 K. At an indicated temperature of 1255 K, core power will be tripped to zero.

2.12 Intact and Broken Loop Pump Speeds

During system heating to isothermal conditions and approach to power, the intact and broken loop pumps will operate together to produce the desired core flow rate, indicated by FV+1. Operation and control of the two pumps prior to rupture is such that the initial flow split between the two pumps will result in 25% of the total core flow passing through the broken loop, and 75% of the core flow passing through the intact loop. The core flow will then be brought up to initial conditions with the intact loop pump, and the broken loop pump speed will be controlled by monitoring the loop flow rates to maintain the desired flow split.

System warmup will continue until the final value of steady-state core power is achieved. The intact loop pump speed may then require adjustment (with the broken loop pump following) to produce the

required value of vessel temperature differential. The required fluid temperature differential (hot leg to cold leg T = RFI-2 minus RFI-17) can be achieved by reducing pump speed to increase the temperature differential and by increasing the pump speed to reduce the temperature differential.

During the test, both pumps will operate at prerupture speed until 3.4 s after the pressure reaches 12.58 MW, at which time the pump speed will be controlled to follow the coastdown curve in Figure 8. In Tests S-SB-3 and S-SB-4, the broken loop pump will be shutoff concurrently with the closing of the hot leg isolation valve.

2.13 Makeup Pump Operation

A measurement of the pump seal leak rate will be made prior to each test. The leak rate will be determined as a function of system pressure and cold leg temperature as described in Section III, 2.8. The makeup pump will be controlled so as to match the leak rate as nearly as possible throughout the test. Makeup water will be injected at approximately the cold leg temperature.

2.14 Intact and Broken Loop Steam Generators

During steady-state operation preceding the blowdown experiments, the intact and broken loop steam generators function independently of each other to maintain the desired vessel inlet temperature of both loops within the temperature range specified in Table IV. Each of the steam generators is equipped with discharge and feedwater valves which are positioned by automatic controllers and control primary cold leg fluid temperature and steam generator secondary water level, respectively.

Following the initiation of core power decay, the steam generator feedwater valves will close, the main steam valves will close, and auxiliary feedwater will be initiated. The time or setpoints for these events are listed in Table IV. The steam relief valve setpoint and auxiliary feedwater flow rate are also listed in Table IV.

1237 132

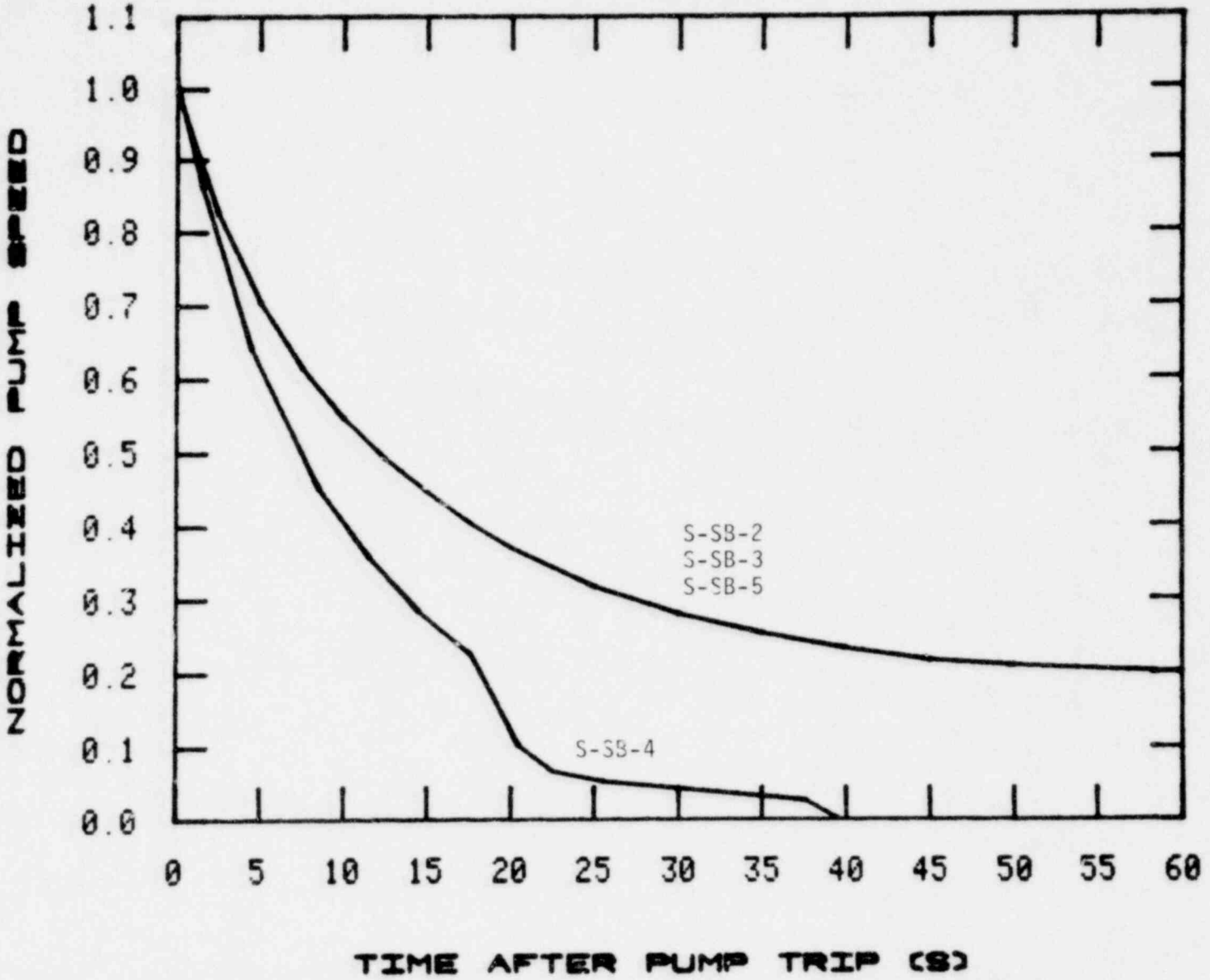


Fig. 8 Normalized pump coastdown curves.

1237 133

2.15 Pressure Suppression System

The suppression tank pressure will be controlled to avoid the occurrence of high Mach numbers at the drag screeen downstream of t' break, while maintaining critical flow at the break orifice. To accomplish this, the suppression tank pressure will initially be set to 650 kPa. At 300 s after rupture, this pressure will be reduced to 300 kPa. It will be maintained at this pressure unitl the primary system pressure (PV-11) reaches 1200 kPa. The suppression tank pressure will then be dropped to 100 kPa for the remainder of the test.

2.16 Intact and Broken Loop Accumulators

The intact and broken loop accumulators will be filled with water to a level corresponding to accumulator liquid volumes specified in Table IV. The intact loop accumulator will inject into cold leg spool 17 for all tests. The broken loop accumulator will inject into spool 40, but will not be used in Tests S-SB-3 and S-SB-4. The accumulator water is to be injected at ambient temperature (≈300 K). The intact and broken loop set point pressures will be 4240 kPa for the small break tests.

2.17 HPIS Operation

The HPIS flow rate will be automatically controlled by the on-line computer. The system pressure will be sampled by the on-line computer which will calculate the required HPIS flow rate based on Figure 5.

2.18 Visual Monitoring of the High Power Rod Temperatures

Regardless of the automatic trip function built into Mod-3 core power control, visual readout of the high powered rod temperatures most likely to experience departure from nucleate boiling (DNB) should be supplied with a high speed chart recorder. During the approach to

1237 134

power, an observer with the capability for manual override on core power control should monitor the visual readout for indication of prerupture DNB as a backup to the automatic power control system. If, during steady-state operation at full power, any one of these thermocouples indicates a temperature above the trip temperature of 950 K without the automatic power trip, the manual override should be implemented.

2.19 System Recovery and Test Termination

After one hour has passed since rupture, the Experiment Specification and Analysis representative may decide to begin operator actions to reduce the system pressure. This is expected to be necessary only in Test S-SB-5. The recovery procedure will be to bleed steam from the steam generator secondary to reduce secondary and primary system pressures at a rate which produces a 50 K/hr cooldown.

The tests will be terminated after the LPIS is operating and the primary coolant loops have refilled with liquid.

1237 135

IV. INSTRUMENTATION REQUIREMENTS

The Semiscale Mod-3 data aquisition system, instrument identification, and measurement capabilities are described in EOS Appendix 7 (Reference 1) and will not be described in detail here. The types of measurements available include the following: pressure, differential pressure, volumetric flow rate, momentum flux, fluid temperature, metal temperature, heater rod cladding temperature, fluid density, liquid level, power, voltage, current, pump speed, and pump torque. Approximately 800 measurements are available, and the data aquisition system is currently capable of recording approximately 275 of these.

Table VI lists the instruments and ranges to be used in Tests S-SB-2 through S-SB-5.

1237 136

TABLE VI

INSTRUMENTATION FOR TESTS S-SB-2 THRU S-SB-5

Instrument ID	Range
Pressure	(MPa)
PI-17AL	3.45
PI-PRIZE	17.24
PI-SD	10.34
PI-ACC3	6.90
PB-45	17.24
PB-41L	0.69
PB-RDP	17.24
PB-SD	10.34
PB-ACC2	6.90
PV-13	17.24
Differential Pressure	(kPa)
DI-13V-1	12.4
DI-1-6	12.4
DI-6-7	344.7
DI-6-SGI	12.4
DI-SGI-SGO	12.4
DI-SGO-7	12.4
DI-SGI-SG4	74.7
DI-SGO-SG4	74.7
DI-SGI-SG1	12.4
DI-SG1-SG2	12.4
DI-SG2-SG4	12.4
DI-SG3-SG4	12.4
DI-7-13	24.9
DI-7-9	24.9
DI-9-13	24.9
DI-13-15	689.5
DI-15-17	24.9
DI-17-DIA	12.4
DI-PR-LL	12.4
DI-PR-4	74.7
DI-SGFEED	0.9 kg/s
DI-SG-LL	124.5
DI-SGOUT	0.9 kg/s
AI-ACC3-LL	24.9
DB-13V-20	24.9
DB-20-21	12.4
DB-21-27A	344.7
DB-21-SGI	12.4
DB-SGI-SGO	12.4
DB-SGO-27A	12.4
DB-SGI-SG3	124.5
DB-SGO-SG3	124.5

1237 137

TABLE VI (contd)

Instrument ID	Range
Differential Pressure (contd)	(kPa)
DB-SGI-SG1	74.7
DB-SG1-SG2	74.7
DB-SG2-SG3	74.7
DB-27A-37	24.9
DB-27A-28	24.9
DB-28-37	24.9
DB-37-40	689.5
DB-40-45	74.7
DB-45-DIA	12.4
DB-SGFEED	0.3 kg/s
DB-SG-LL	344.7
DB-SGOUT	0.3 kg/s
DB-ACC2-LL	24.9
DB-41-PT01	24.9
DB-41-PT02	24.9
DB-41-PT03	24.9
DD-DIA-578	74.7
DD-DIA-170	24.9
DD-170-435	74.7
DD-435-578	24.9
DD-81-13V	344.7
DV-578-501	12.4
DV-501-105	124.5
DV-501-442	24.9
DV-442-278	74.7
DV-278-154	74.7
DV-154-105	24.9
DV-105-13	24.9
DV-13+135	24.9
DV-154+154	74.9
DV+154+429	74.7
Volumetric Flow	(l/s)
FI-1	12
FI-11	12
FI-16	12
FI-17	12
FI-PRIZE	2
FI-ACC3	0.5
FI-HPIS	0.05
FI-LPIS	0.5
FB-20	4
FB-37	4
FB-40	4

1237 138

TABLE VI (cont'd)

Instrument ID	Range
Volumetric Flow (contd)	(l/s)
FB-45	4
FB-ACC2	0.5
FB-HPIS	0.005
FB-LPIS	0.5
FV+1	16
Momentum Flux	($kg/m\ s^2$)
NB-20	15,000
NB-37	15,000
NB-40	15,000
NB-45	15,000
NB-41	60,000
NV-9	18,000
NV-499	18,000
MGV+330	18,000
MSV+153D	18,000
MSV+153Q	18,000
Pumps	
SI-PUMP	377 rad/s
SB-PUMP	3665 rad/s
WB-PUMP	25 kW
Heater Rods	
AH-HI	2500 A
AH-LO	2000 A
VH-HI	400 V
VH-LO	400 V
Resistance Bulb Temperature	(K)
RFI-2	617
RFI-17	617
RFB-20	617
RFB-45	617

1237 139

TABLE VI (contd)

Instrument ID	Range
Fluid Temperature	(K)
TFI-1	617
TFI-6	617
TFI-7	671
TFI-11	617
TFI-17	617
TFI-SD	617
TFI-SGFW	617
TFI-SS30	617
TFI-SS61	617
TFI-SS114	617
TFI-SS244	617
TFI-ECC-17	617
TFB-20	617
TFB-SGIL	617
TFB-SGOL	617
TFB-40	617
TFB-45	617
TFB-SS32	617
TFB-SS81	617
TFB-SS429	617
TFB-SS734	617
TFB-SS949	617
TFB-SD1149	617
TFB-SGD762	617
TFB-ECC40	617
TFB-41	617
TFD-18F	617
TFD-152	617
TFD-294	617
TFD-364	617
TFD-435	617
TFV+343Q	617
TFV-63R	617
TFV-572W	617
TSFV+148D	617
TGFV+144W	617
TFG-1AB-45	320
TFG-5AB-45	820
TFG-6DE-34	820
TFG-7DE-45	820
TFG-8DE-23	820
TFG-9DE-12	820
TFG-10DE-12	820

1237 140

TABLE VI (contd)

Instrument ID	Range
Metal Temperature	(K)
TMI-1T	617
TMI-11T	617
TMI-17T	617
TMB-20T	617
TMB-40T	617
TMB-45T	617
TMD-18F	617
TIMD-18F	617
TMD-294	617
TIMD-294	617
TMD-364	617
TIMD-364	617
TIMV+343Q	617
TMV+160F	617
TIMV+160F	617
TIMV-572W	617
Heater Rod Cladding Temperatures	(K)
TH-D1-5	1366
TH-C2-8	1366
TH-D2-10	1366
TH-D5-11	1366
TH-A4-40	1366
TH-E4-41	1366
TH-C3-49	1366
TH-D3-71	1366
TH-E3-72	1366
TH-A4-108	1366
TH-E4-109	1366
TH-C3-115	1366
TH-D1-131	1366
TH-D3-132	1366
TH-D2-134	1366
TH-D5-137	1366
TH-D3-153	1366
TH-E3-155	1366
TH-D1-163	1366
TH-B3-179	1366
TH-E2-180	1366
TH-A4-181	1366
TH-C3-184	1366
TH-B2-189	1366
TH-E2-190	1366
TH-E5-191	1366
TH-C3-194	1366

1237 141

TABLE VI (contd)

Instrument ID	Range
Heater Rod Cladding Temperatures (contd)	(K)
TH-D3-206	1366
TH-E3-207	1366
TH-A3-208	1366
TH-E3-223	1366
TH-D3-226	1366
TH-A4-227	1366
TH-A3-229	1366
TH-C3-230	1366
TH-D1-251	1366
TH-A5-252	1366
TH-E1-252	1366
TH-D2-254	1366
TH-C2-277	1366
TH-A3-291	1366
TH-E3-291	1366
TH-A5-321	1366
TH-B1-321	1366
TH-C2-321	1366
TH-E1-321	1366
TH-D5-322	1366
TH-D2-323	1366
TH-B3-353	1366
TH-E2-353	1366
TH-E5-353	1366
TH-E4-354	1366
Density	(kg/m^3)
GI-1T	1000
GI-1B	1000
GI-5 VR	1000
GI-13T	1000
GI-13B	1000
GI-16 VR	1000
GI-17T	1000
GI-17B	1000
GI-PRIZE	1000
GB-20 VR	1000
GB-37	1000
GB-40 VR	1000
GB-45 VR	1000
GV+339	1000
GV+174	1000
GV-11	1000

1237 142

TABLE VI (contd)

Instrument ID	Range
Density (contd)	(kg/m^3)
GV-154-23	1000
GV-164-AB	1000
GV-243-23	1000
GV-313-23	1000
GV-323-23	1000
GV-323-AB	1000
GV-383-23	1000
GV-483-23	1000
GV-502-AB	1000
GV-528-588	1000
GD-72B	1000
GD-260B	1000
GD-456B	1000
GXB-41T	1000
GXB-41M	1000
GXB-41B	1000
Liquid Level	
All	

1237 143

V. REFERENCES

1. Semiscale Program. Appendix 7 to the Semiscale Experimental Operating Specification - Mod-3 Baseline Test Series (Test Series 7), WR-S-78-002, EG&G Idaho, Inc. (March 1978).

2. System Design Description for the 1-1/2-Loop Mod-1 Semiscale System (June 1975).

1237 144