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APPENDIX 28

EXPERIMENTAL OPERATING SPECIFICATION TESTS S-28-1 THROUGH S-28-4 STEAM GENERATOR TUBE RUPTURE TESTS IN THE MOD-1 SYSTEM (TEST SERIES 28)

SEMISCALE PROGRAM

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EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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APPENDIX 28

to the

1-1/2-LOOP SEMISCALE MOD-1

EXPERIMENT OPERATING SPECIFICATION

Test Series 28

Tests S-28-1 through S-28-4

STEAM GENERATOR TUBE RUPTURE TESTS IN THE SEMISCALE MOD-1 SYSTEM

Semiscale Program

EG&G Idaho, Inc.

June 1977

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I. INTRODUCTION

The Semiscale Mod-1 experiment program is part of the overall Semiscale Blowdown and Emergency Core Cooling (ECC) Project conducted by EG&G Idaho Inc. to investigate the thermal and hydraulic phenomena accompanying a hypothesized loss-of-coolant accident (LOCA) in a water-cooled nuclear reactor system. The relationship of the Mod-1 Program to other ERDA-NRC sponsored experimental programs is presented in the Semiscale Mod-1 Experiment Operating Specification (EOS)(Ref. 1). The general objective of the Semiscale Program is to obtain representative integral and separate effects thermal-hydraulic response data to provide an experimental basis for analytical model development and verification. Additional Semiscale Program objectives include providing the Loss-of-Fluid Test (LOFT) facility with support in the areas of test planning, evaluation, and experiment design.

The purpose of this document is to establish the experiment specifications for the tests in Test Series 28 of the Semiscale Mod-1 program, which is designated as the steam generator tube ruptures test series. The information contained in this document is suitable for the preparation of detailed experiment operation procedures for the tests in Test Series 28 and includes:

(1) Test objectives and description
(2) System configuration
(3) Instrumentation requirements
(4) Operational requirements
(5) Initial operating conditions.

1.0 TEST SERIES OBJECTIVES

Integral tests will be performed to investigate the influence of the rupture of steam generator tubes on the core and system response during a hypothetical large break Loss-of-Coolant Accident (LOCA). The primary objectives of these tests are:

(1) To determine the sensitivity of core peak cladding temperature to the magnitude of the flowrate from the secondary side of the steam generator to the primary system (or, for scaling purposes, to the number of single ended steam generator tube ruptures).

(2) To provide data for evaluating the capability of current models to predict the thermal-hydraulic phenomena that are expected to occur during the blowdown and reflood phases of a LOCA with steam generator tube ruptures.

2.0 SPECIFICATION OF TESTS

An analysis was conducted to aid in the specification of tests which will fulfill the stated objectives for Test Series 28. The analysis was conducted to determine the effects of postulated steam generator tube ruptures on the peak rod cladding temperature experienced in the Semiscale Mod-1 system during a 200% double-ended cold leg break LOCA. The purpose of this section is to present the highlights of the analysis in order to provide a frame work for the identification of test objectives for individual tests within the series. The analysis is presented in detail in Addendum 28-A to this Appendix.

In considering the sensitivity of the peak rod cladding temperature to the number of ruptured steam generator tubes (i.e., steam generator secondary to primary flow rate) two distinct regimes occur which strongly influence the analysis approach. In the first regime, positive core flow persists despite the increased steam binding problem resulting from the secondary to primary system flow associated with the rupture of a very small number of steam generator tubes. In the second regime, negative core flow exists as a result of the larger secondary to primary system flows associated with the rupture of an increased number of steam generator tubes. Between these two regimes lies a region in which the core flow is virtually stagnated and the potential for high peak rod cladding temperatures exists.

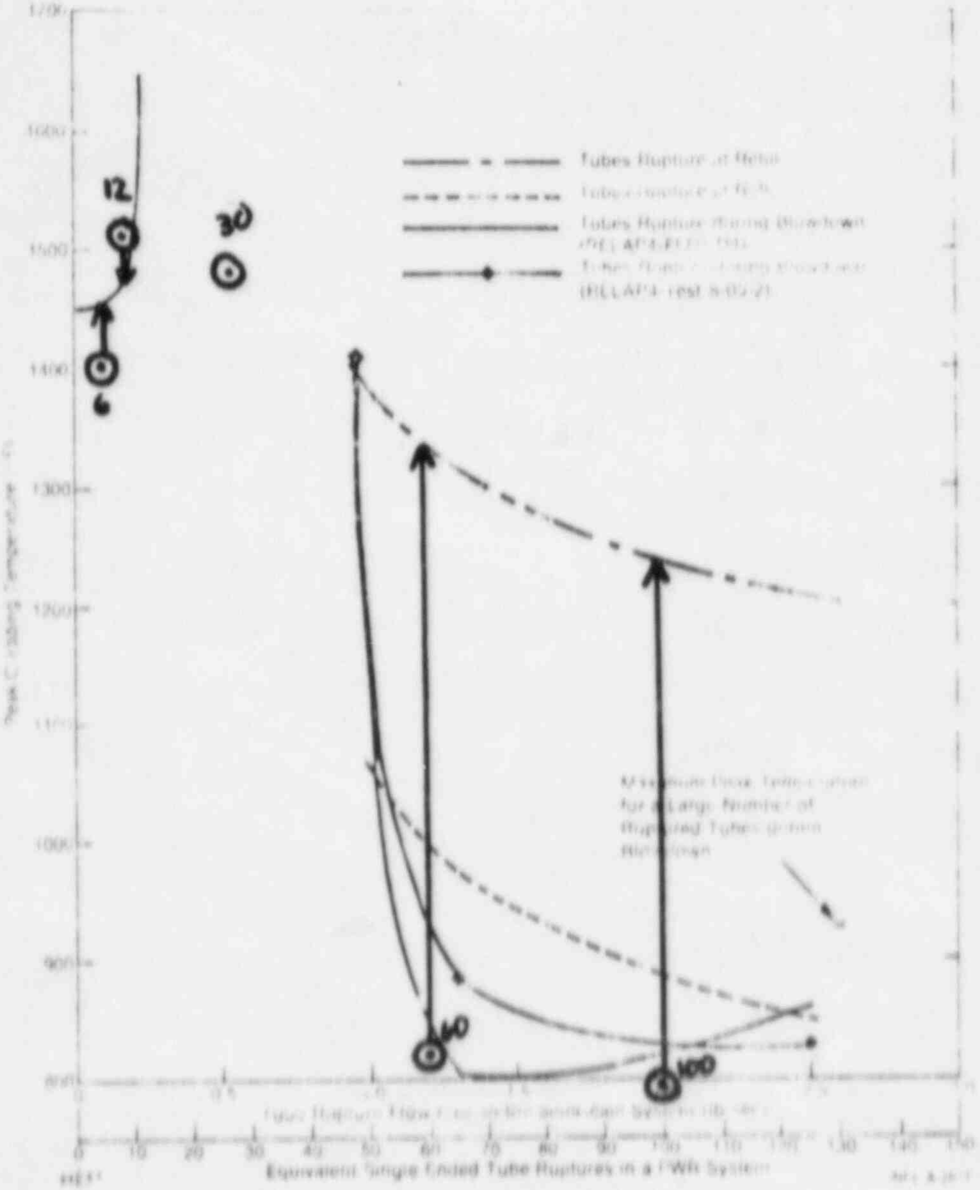
The analysis was conducted in two parts, each of which considered one of the two major regimes. The first part considered the influence of the rupture of a very small number of tubes (equivalent to less than

12 tubes in a PWR steam generator) on the peak cladding temperature in the core. The second part concerned the influence of the rupture of a relatively larger number of tubes (equivalent to more than 40 tubes in a PWR steam generator) on peak cladding temperature. The two parts of the analysis are discussed below.

2.1 Small Number of Tube Ruptures

The initial step in the analysis with a very small number of ruptured tubes was to determine the effects of the ruptures on the system response during blowdown. A RELAP4 calculation showed that a very small number of ruptured steam generator tubes (ten) would have negligible influence on the core and system thermal-hydraulic conditions throughout the blowdown period. As a result, of this insensitivity of core temperature to the rupture of a very small number of tubes, the core temperature distribution at the end of blowdown in a typical Mod-1 test, Test S-04-6, was used as the starting condition for calculations of the reflood behavior.

An investigation of the reflood process, by means of FLOOD4 calculations, indicated that the peak cladding temperature experienced during reflood increased as the number of ruptured tubes increased from zero to twelve. The increasing peak temperature, shown by the left hand curve of Figure 1, was caused by increasing steam binding which resulted in decreasing core flow. With more than twelve ruptured steam generator tubes the core flow became so small that large rod cladding temperatures were calculated.



The Influence of the Tube Rupture Flowrate or the Number of Ruptured Tubes on the Peak Cladding Temperature

2.2 Large Number of Tube Ruptures

The analysis using more than 40 ruptured steam generator tubes indicated that the peak cladding temperatures are influenced by both the number of ruptured tubes and the time in the LOCA at which the ruptures occur. As the number of ruptured tubes is increased, the increased secondary to primary system flow causes a flow from the hot leg through the upper plenum and core. This flow provides core cooling which increases as the number of ruptured tubes increases. The time at which the steam generator tube ruptures occur significantly influences the time at which the LPIS coolant enters the core ecause it controls the degree to which the lower plenum is filled at the time the steam generator secondary fluid is exhausted. Therefore, the rupture time has an effect on the peak cladding temperature. In the analysis, the steam generator ruptures were assumed to occur (1) during blowdown, (2) at the initiation of lower plenum refill and (3) at the initiation of reflood.

The major result of this analysis was that, with the tube ruptures occurring at the initiation of refill or at the initiation of reflood, the peak cladding temperature increased as the number of ruptured tubes was decreased from 120 to 50. With the tube ruptures occurring during blowdown, the RELAP4-FLOOD4 calculations indicated a slight decrease in peak temperature as the number of ruptures was decreased from 120 to 65, but indicated a significant increase in peak temperature as the number of ruptures was further decreased from 65 to 50. The increasing peak temperatures, shown by the curves on the right hand side of Figure 1, were caused by decreasing core flow during the venting of the steam

generator secondary side. With less than 50 ruptured steam generator tubes the core flow became sufficiently small and high calculated rod cladding temperatures resulted.

The analysis also demonstrated that, with more than 50 ruptured steam generator tubes, the highest peak temperatures were experienced when the tube ruptures occurred at the initiation of refill. The high peak temperatures developed because of an assumed period of adiabatic heat-up. This heat-up period was assumed to occur after the exhaustion of the steam generator, during the time required for the LPIS injection to refill the empty lower plenum. The assumption of adiabatic heatup, although conservative, does not appear to be unreasonable since results from previous Semiscale tests indicate that core flow stagnation may occur during refill. A similar period of adiabatic heat-up was assumed for the case with the tube ruptures occurring during blowdown. The core temperatures during this heat-up period were calculated by the FLOOD4 code and were also estimated from Test S-05-2 data as indicated on Figure 1. Relatively low temperatures at the start of this heat-up limited the peak temperatures achieved however.

2.3 Testing Range

The overall analysis results allow the selection of a general testing range. The combined results of the analysis indicate that the rupture of more than 12 but less than 50 steam generator tubes, during a large cold leg break LOCA, could result in high peak cladding temperatures. The tests in Series 28 will thus investigate the core and system behavior on both sides of, and within this tube rupture range, and will concentrate

in the region with the larger number of ruptured tubes. Concentration in this area allows the range of tube ruptures of interest to be defined experimentally, early in the test series. Subsequent tests can then be used to investigate the range of ruptures indicated by the calculations to result in high peak cladding temperatures. The objectives of individual tests within the test series can now be defined consistent with this range selection.

2.4 Test Objectives

The primary objective of the first test is to set an upper limit on the range of steam generator tube ruptures over which high peak cladding temperatures can result. The achievement of this objective will delineate a narrow range of tube ruptures representing the major area of interest for subsequent tests. Figure 1 shows that a test simulating 60 ruptured steam generator tubes will allow the upper limit to be set while maintaining acceptable peak cladding temperature levels. The first test will therefore be conducted to simulate 60 steam generator tube ruptures. The second objective of the first test is to provide a comparison between test data and the analysis results. The achievement of this objective will allow the specification of conditions for subsequent tests. The analysis results obtained with the tube ruptures occurring at the initiation of refill gave the highest peak cladding temperature. In the test, the injection of flow to simulate the tube ruptures will be delayed until the initiation of refill to allow a direct comparison of test results with this analytical case.

The major objectives of the second and third tests in the series are to refine the definition of the upper limit set by the first test and to probe into the range of steam generator tube ruptures indicated by the analysis to result in high peak cladding temperatures. Assumptions were made in the analysis which would bias the calculations in the direction of high peak cladding temperatures (Addendum 28-A). Therefore, the comparison between the analysis and data from the first test will probably result in the simulation of decreasing numbers of steam generator tube ruptures in the second and third tests. The time of steam generator tube rupture will be held constant at the initiation of refill so that the tests will be conducted with a single parameter variation.

The fourth, and final test in the series will be conducted to determine the effects of a very small number of ruptured steam generator tubes and will allow definition of the lower limit of the region indicated by the analysis to result in high peak cladding temperatures. Such a test would also demonstrate that operational steam generator leakage, representing less than one ruptured tube, would not cause high peak cladding temperatures during a large cold leg break LOCA. The fourth test will therefore be conducted to simulate the rupture of ten steam generator tubes. The time of the steam generator ruptures is not a major variable with a very small number of ruptured tubes but rupture at the initiation of refill will be used for consistency with the other tests in the series.

3. TEST DESCRIPTIONS

The test conditions for Test Series 28 are identical to those of the Baseline Test S-04-6 except for the introduction of secondary to primary mass flow to simulate the steam generator tube ruptures. The tube rupture flow will be simulated by a controlled injection from a heated accumulator (accumulator CI-T-3) into the inlet piping of the steam generator and the change in heat transfer potential of the steam generator will be simulated by discharging the steam generator secondary fluid over the simulated tube rupture period (Addendum 28-B). The water in accumulator CI-T-3 will be at 525°F (approximately the average temperature of the PWR steam generator secondary fluid at rated load) and 1100 psia. The total volume of water that will be injected from accumulator CI-T-3 is 5.10 ft^3, which is core area scaled from three PWR steam generators at rated load (Addendum 28-C). The injection will begin at 40 seconds after the cold leg break in each test to simulate steam generator tube ruptures at the initiation of refill. During injection the accumulator pressure will be maintained by a nitrogen supply. The injection will be terminated before the accumulator water is completely exhausted to prevent nitrogen injection into the primary system.

3.1 Test S-28-1

The primary objective of this test is to set an upper limit on the range of steam generator tube ruptures over which high peak cladding temperatures can result. The test will be run with a secondary to primary flowrate of 1.2 lbm/sec (± 0.1 lbm/sec) to simulate the ruptures of 60 steam generator tubes.

The second objective of this test is to provide a comparison between test data and the analysis results. The initiation of the vessel accumulator injection, simulating the steam generator tube rupture flow, at 40 seconds after rupture will allow comparison of test data with the analysis results with the ruptures occurring at the initiation of refill. Other test conditions and flowrates are shown in Table I.

3.2 Test S-28-2 and S-28-3

The major objectives of these tests are (1) to refine the definition of the upper limit set by Test S-28-1 and (2) to probe into the range of steam generator tube ruptures indicated by the analysis to result in high peak cladding temperatures.

Tests S-28-2 and S-28-3 will be conducted with secondary to primary flowrates initiated at 40 seconds after the cold leg break and having magnitudes determined as a result of the comparison of Series 28 test data with those of Test S-04-6 and with the analysis summarized in Figure 1. Other test conditions and flowrates are shown in Table I.

3.3 Test S-28-4

The major objective of Test S-28-4 is to determine the effects of a very small number of ruptured steam generator tubes. The test will be conducted with a secondary to primary flowrate of 0.2 lbm/sec (+ 0.0 - 0.02 lbm/sec) to simulate the rupture of 10 steam generator tubes. The flow will be initiated at 40 seconds after the cold leg break. Other test conditions and flowrates are shown in Table I.

TABLE 1

ECC AND STEAM GENERATOR SECONDARY INJECTION AND DISCHARGE PARAMETERS

ECC System	Test Number S-28-1	S-28-2	S-28-3	S-28-4
Accumulator CI-T-1				
Injection location	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)
Pressure (psig)	600	600	600	600
Liquid volume (ft^3)	2.83	2.83	2.83	2.83
Gas volume (ft^3)	1.86	1.86	1.86	1.86
Injection rate (gpm)	23.0	23.0	23.0	23.0
Line resistance $\frac{sec^2}{in.^2\text{-}ft^3}$	1229	1229	1229	1229
N_2 flow duration (sec)	24	24	24	24
Accumulator CI-T-2				
Location	Broken Loop Cold Leg (Spool Piece 42)	Broken Loop Cold Leg (Spool Piece 42)	Broken Loop Cold Leg (Spool Piece 42	Broken Loop Cold Leg (Spool Piece 42)
Pressure (psig)	600	600	600	600
Liquid volume (ft^3)	0.58	0.58	0.58	0.58
Gas volume (ft^3)	0.326	0.326	0.326	0.326
Injection rate (gpm)	7.67	7.67	7.67	7.67

TA_ I (contd)

ECC System	S-28-1	S-28-2	S-28-3	S-28-4
	Test Number			
Line resistance $\frac{sec^2}{in.^2-ft^3}$	11061	11061	11061	11061
N_2 flow duration (sec)	To Exhaustion	To Exaustion	To Exhaustion	To Exhaustion
Accumulator CI-T-3				
Injection location	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6
Temperature (°F)	525	525	525	525
Pressure (psig)	1100	1100	1100	1100
Liquid volume (ft^3)	5.1	5.1	5.1	5.1
Gas volume (ft^3)	1.7	1.7	1.7	1.7
Injection rate (gpm)	11.33 ± 1.00	TBD[a]	TBD[a]	$1.89^{+0}_{-0.19}$
N_2 flow duration (sec)	No N_2 flow allowed	No N_2 flow allowed	No N_2 flow allowed	No N_2 flow allowed
Air acutated valve				
Open (seconds after the Cold Leg Break)	40	40	40	40
Close (seconds after the Cold Leg Break)	242	TBD	TBD	Remains open.

[a] Range for these tests may vary between 0 and about 30 gpm.

TABLE I (contd)

ECC System	Test Number S-28-1	S-28-2	S-28-3	S-28-4
Steam generator secondary fluid discharge				
Initial liquid level (in.)	116	116	116	116
Flow rate (gpm)	11.33	TBD	TBD	2.89
Air actuated valve opening time (sec)[b]	40	40	40	40
Intact loop LPIS				
Location	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)
Actuation Pressure (psig)	150	150	150	150
Injection rate (gpm)	4.0	4.0	4.0	4.0
Broken loop LPIS				
Location	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)
Actuation pressure (psig)	150	150	150	150
Injection rate (gpm)	0.96	0.96	0.96	0.96
Intact loop HPIS				
Location	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)
Actuation pressure (psig)	1800	1800	1800	1800
Injection rate (gpm)	0.31	0.31	0.31	0.31

TABLE I (contd)

ECC System	Test Number			
	S-28-1	S-28-2	S-28-3	S-28-4
Broken loop HPIS				
Location	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)
Actuation pressure (psig)	1800	1800	1800	1800
Injection rate (gpm)	0.103	0.103	0.103	0.103

II. SYSTEM CONFIGURATION

The Semiscale Mod-1 system configuration for Tests S-28-1 through S-28-4 (Figure 2) will duplicate the configuration used in Test S-04-6 of the Series 4 tests, (References 2 and 3) with a 200% cold leg break. Since appendices to the Semiscale EOS (References 5 and 6), and the 1-1/2-loop Mod-1 Semiscale Program and System Descriptions (References 7 and 8) provide a detailed description of this configuration, only a brief description including modifications will be included herein.

1. INTACT LOOP SPECIFICATION

With the exception of equipment associated with the injection of fluid to represent the effect of steam generator tube ruptures, the configuration and composition of the intact loop for the Series 28 tests will be indentical to that specified in EOS Appendix 1, Section II-1 (Reference 5). Included in the intact loop configuration are the steam generator, primary coolant pump, pressurizer, and associated loop piping (instrumented spool pieces).

The steam generator tube ruptures will be represented by injecting water (at 1100 psia) through a throttle valve into spool piece 6, upstream of the steam generator inlet orifice. An accumulator (accumulator CI-T-3) containing water of primary coolant quality will be used for this purpose to avoid any possible contamination of the primary system with water treatment chemicals or crud from the secondary system fluid and to allow improved control over initial conditions and injection flow rates. The accumulator pressure will be maintained at 1100 psia throughout

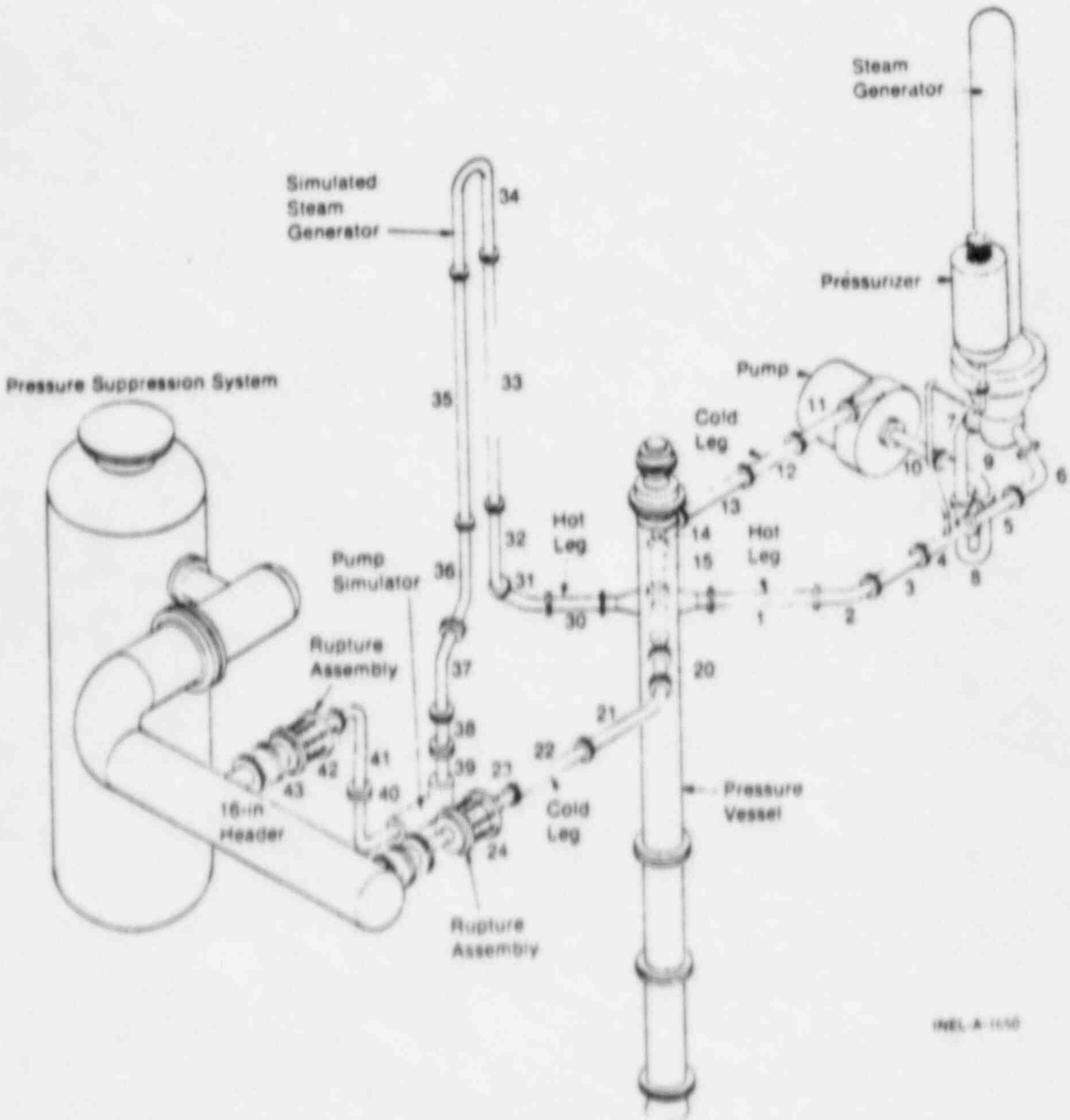


Figure 2. 1-1/2-Loop Mod-1 Semiscale Cold Leg Break Configuration - Isometric

the injection period to insure that liquid in the injection line will remain subcooled. The steam generator secondary system fluid will be discharged starting at the same time as the initiation of accumulator CI-T-3 injection. The rate of discharge of the secondary system fluid will be controlled so that the emptying time approximates the accumulator injection period. (Table 1 and Addendum 28-B).

2. VESSEL SPECIFICATION

The basic configuration of the vessel internals, including the configuration of the core, will be the same in the Series 28 tests as it was for the Series 2 tests (Reference 6), with the exception that the lower plenum will include a filler piece to duplicate the configuration for Test S-04-6. (The volume of the lower plenum with the filler piece inserted will be 40.8% smaller than the lower plenum volume of the Series 2 tests.) A brief description of the core configuration follows.

2.1 Core Configuration

The configuration of the heated core for the Series 28 tests consists of 40 electic heater rods assembled in a matrix as shown in Figure 3. In this rod bundle 4 rods (C-3, D-5, F-3, and F-6)* are unpowered and 3 of the powered rods (D-4, E-4, and E-5) have a 5% higher power level than the other powered rods to duplicate baseline Test S-04-6. Each powered heater rod has a normalized axial power

* Rod location given in Figure 10.

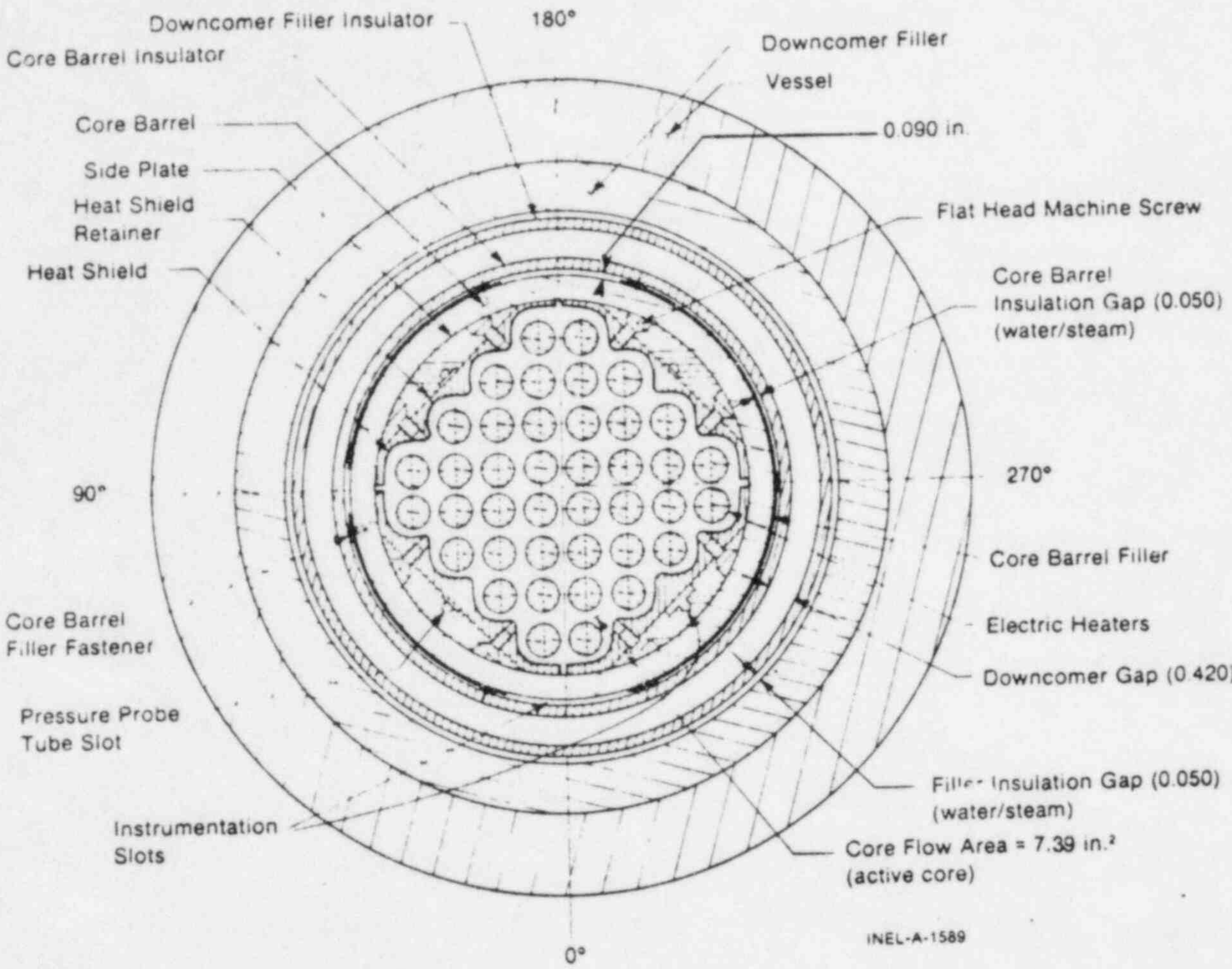


Figure 3. Electric Heater Rod Matrix for Mod-1 Core

profile as shown in Figure 4. The high powered heater rods (D-4, E-4, and E-5) will operate at about 12.1 kW/ft peak power density, while the remaining 33 powered rods will operate at about 11.5 kW/ft peak power density. The total core power for the tests conducted during Test Series 28 will be 1.44 MW. As the Semiscale Mod-1 core is designed to model the LOFT nuclear core, the heated length (66 in.) and outside diameter of the rods (0.422 in.) and fuel pin pitch (.563 in.) are identical geometrically to the nuclear fuel rods of the LOFT core.

3. BROKEN LOOP SPECIFICATION

The configuration of the broken loop is essentially identical to that specified in EOS Appendix 1 as revised (Reference 5). The reflood bypass line connected to the blowdown loop to simulate the LOFT system is removed and the connections to the broken loop piping are capped off for all tests in Series 28. All break simulations will be 200% double-ended offset shear cold leg breaks with a break flow area of 0.00262 ft^2. The Henry type break nozzles will be used to simulate the proper break flow areas. There will be ECC injection into the broken loop spool piece 42 during blowdown and reflood for all Series 28 tests.

4. PRESSURE SUPPRESSION SYSTEM SPECIFICATION

The pressure suppression system will be configured as outlined in EOS Appendix 1 (Reference 5).

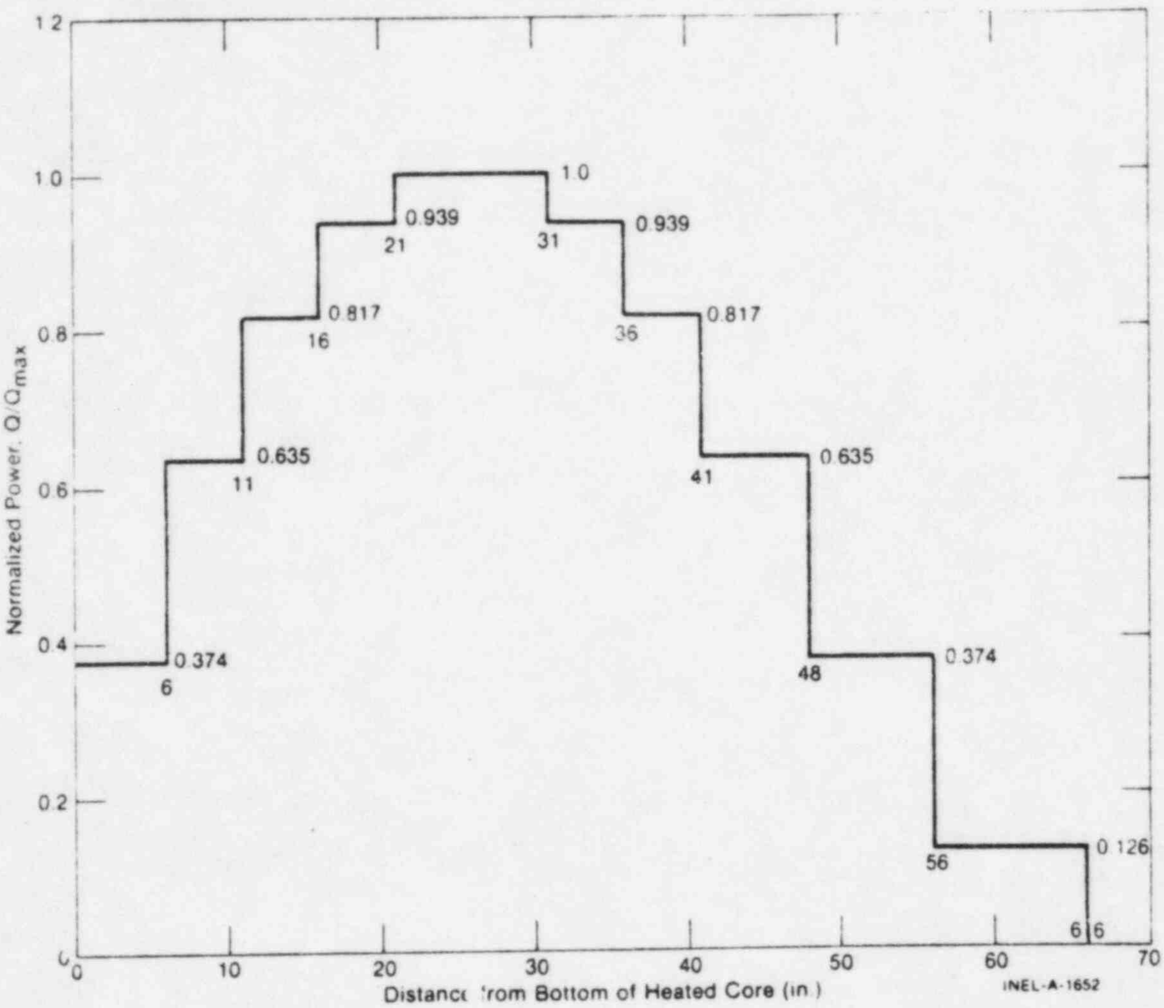


Figure 4. Semiscale Mod-1 Axial Power Profile

5. PRESSURE SUPPRESSION STEAM SUPPLY SYSTEM SPECIFICATION

The pressure suppression steam supply is designed as an auxiliary part of the pressure suppression system. Steam is injected into the pressure suppression system to maintain the header pressure within ± 2 psi of a specified constant value within the range of 20 to 80 psia. The system is capable of supplying up to 0.5 lb/sec of steam at 60 psia and 0.3 lb/sec at 20 psia. The design of the pressure suppression steam supply system is described in Sections 1.16 and 2.15 of the System Design Description (SDD) (Reference 9.)

For Test Series 28, the pressure suppression steam supply system will be used to maintain the header pressure at 35 psia during the reflood phase of these tests. This pressure is to be achieved by setting the initial pressure suppression tank water level at 47.5 in., which results in a downcomer submergence of about 10 in. The initial pressure and temperature should be 35 psia and ambient, respectively. Once blowdown has commenced the steam supply system should maintain the specified 35 psia header pressure within the ± 2 psi limit through the complete test.

6. COOLANT INJECTION SYSTEM SPECIFICATION

Section 1.2.4.2 of the SDD describes the coolant injection system capabilities in detail. Table I presents the coolant injection requirements for the Series 28 tests.

7. SYSTEM HYDRAULIC RESISTANCES AND VOLUME DISTRIBUTION

The hydraulic resistances for the intact loop and core will remain as reported in EOS Appendix 5 (Reference 4). The values were calculated from pressure differentials as measured by ΔP transducers during Semiscale Mod-1 Tests S-02-3 and S-02-4 before the break and are presented in Table II. These data were obtained with a core comprised of active heater rods and an intact loop resistance based on core area scaling. The hydraulic resistances for the broken loop will be as specified in EOS Appendix 2 (Reference 6). The values for the broken loop hydraulic resistances are also presented in Table II. The system volume has been determined directly through measurement with the results as presented in Table III.

TABLE II

MEASURED FORWARD FLOW HYDRAULIC RESISTANCES WITH ACTIVE CORE

INTACT LOOP

	Measurement[a]	R' $(sec^2/ft^3\text{-}in.^2)$[b] from Test S-02-3	R' $(sec^2/ft^3\text{-}in.^2)$[c] from Test S-02-4
A)	DPU-UP-1	0.419	0.438
B)	DPU-UP-3	0.416	0.435[h]
C)	DPU-1-3	0.026[h]	0.024[i]
D)	DPU-3-6	0.071	0.076
E)	DPU-6-7 (steam generator)	2.077	2.03
F)	DPU-SGOP-7 (included in E)	0.894	0.96
G)	DPU-7-10	0.252	0.255
H)	DPU-12-10[d] (pump)	4.91	4.94
I)	DPU-12-15	0.539	0.553
J)	DPU-15-1	1.677	1.722
K)	DPU-15-IAN	0.319	0.320
L)	DPV-9-UP (DPV-9+10)	0.887	0.875[h]
M)	DPV-9-180	0.18	0.159
N)	DPV-LP-UP (DPV-166+10)	0.815	0.804
	Total system resistance (excluding pump)	4.64[e]	4.66[e]
		4.59[f]	4.54[f]
		4.70[g]	4.66[g]

BROKEN LOOP

	Measurement	R' $(sec^2/ft^3\text{-}in.^2)$[j]
O)	DPB-30-32V	12.45
P)	DPB-32V-36L	25.83
Q)	DPB-SGOR	2.09
R)	DPB-38-40	210 (with 9 plates)
S)	DPB-30-38	52.4
T)	DPB-42-43	4.23
U)	DPB-42-HNI	17.52[k]
V)	DPB-23-24	5.14
W)	DPB-23-CNI	17.29[k]
X)	DPB-21-23	.48

See footnotes (a) through (k) at end of the table.

FOOTNOTES for TABLE II

(a) Location and elevation of measurement differential pressure taps be found in Section III of this document.

(b) Core power = 1.2 MW Average intact loop flow = 12.5 lb/sec Hot leg fluid temperature = 604°F Cold leg fluid temperature = 538°F.

(c) Core power = 1.6 MW Average intact loop flow = 16.42 lb/sec Hot leg fluid temperature = 609°F Cold leg fluid temperature = 544°F.

(d) Differential pressure across the intact loop pump.

(e) Using DPU-15-1 across vessel and nozzles, Σ(C+D+E+G+I+J)

(f) Using DPV-9-UP across vessel, Σ(B+D+E+G+I+K+L)

(g) Using DPV-9-180 and DPV-LP-UP across vessel, Σ(A+C+D+E+G+I+K+M+N)

(h) Determined by scaling similar R' values from these tests.

(i) Calculated.

(j) Documented in Table V of EOS Appendix 2.

(k) Pressure apparently not recovered in the nozzle because the hydraulic resistance over the entrance is much larger than the total nozzle resistance (DPB-42-43 or DPB-23-24).

TABLE III

MEASURED LIQUID VOLUME DISTRIBUTION

FOR SEMISCALE MOD-1 SYSTEM

Component	Liquid Volume (ft^3)
Vessel[(a)]	3.114
Intact loop[(b)]	2.238
Pressurizer (to nozzle flange)	0.960
Pressurizer surge line (including nozzles)	0.032
Broken loop	
Cold leg break configuration (calculated)	
Hot leg side to break	0.883
Cold leg side to break	0.213
System total liquid volume	7.440

(a) The vessel volume is with the lower plenum filler piece inserted and includes the volumes of the six vessel nozzles.

(b) Excluding pressurizer and pressurizer surge line volumes.

III. MEASUREMENT CAPABILITIES AND INSTRUMENT LOCATION DESCRIPTION

The instrumentation locations and measurement capabilities are described in detail in this section. Included is a discussion of the Mod-1 data acquisition system and a set of tables listing Mod-1 measurements and the measurement requirements for the tests of Test Series 28. There are approximately 500 measurement locations available in the Mod-1 system. However, because of data acquisition limitations, only about 220 measurements will be recorded for each test. To meet experiment objectives, the Mod-1 system incorporates the following types of measurements: momentum flux (FD), volumetric flow (FT), fluid temperature (TF), resistance bulb temperature (RB), shielded fluid thermocouples (TS), liquid level (LL), material temperature (TM), metal insulation temperature (TI), heater pin temperature (TH), fluid density (G), differential pressure (DP), pressure (P), power (PWR), voltage (VOL), current (CUR), and pump speed (RPM). Where required, a dual measurement capability has been specified. Available instrument locations are shown in Figures 5 through 10. Instrumentation associated with the Mod-1 system configuration for steam generator tube rupture simulation tests, discussed in Addendum 28-B, is indicated on Figure 6.

1. DATA ACQUISITION SYSTEM (DAS)

The data acquisition system (DAS) consists of two hardware systems designed to accumulate Mod-1 data: (1) the digital data acquisition processing system (DDAPS); and (2) the analog data acquisition system (ADAS). The DDAPS system is an "on line" system (i.e., hard copy data can be

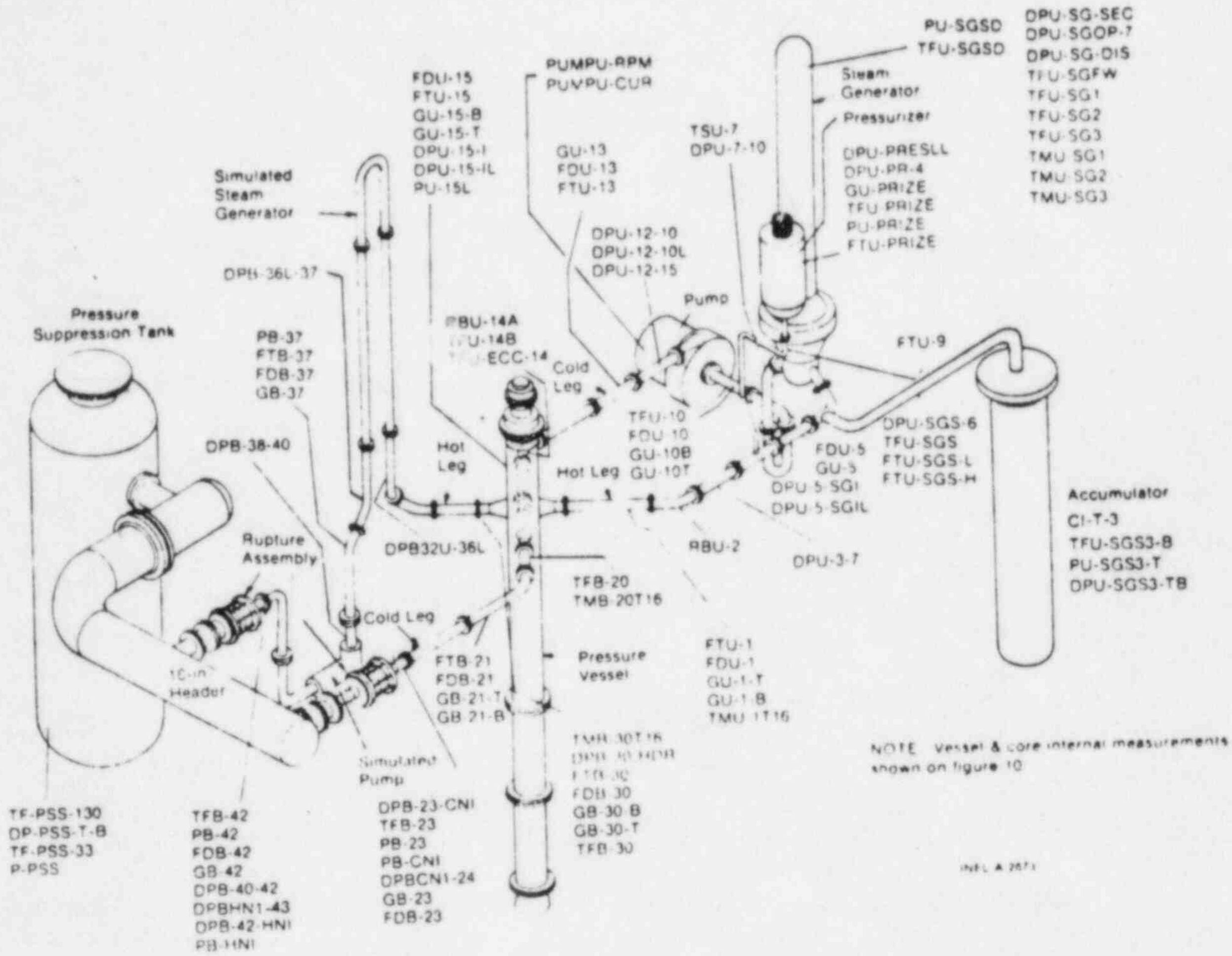


Figure 5. Semiscale Mod-1 System and Instrumentation for Cold Leg Break Configuration - Isometric

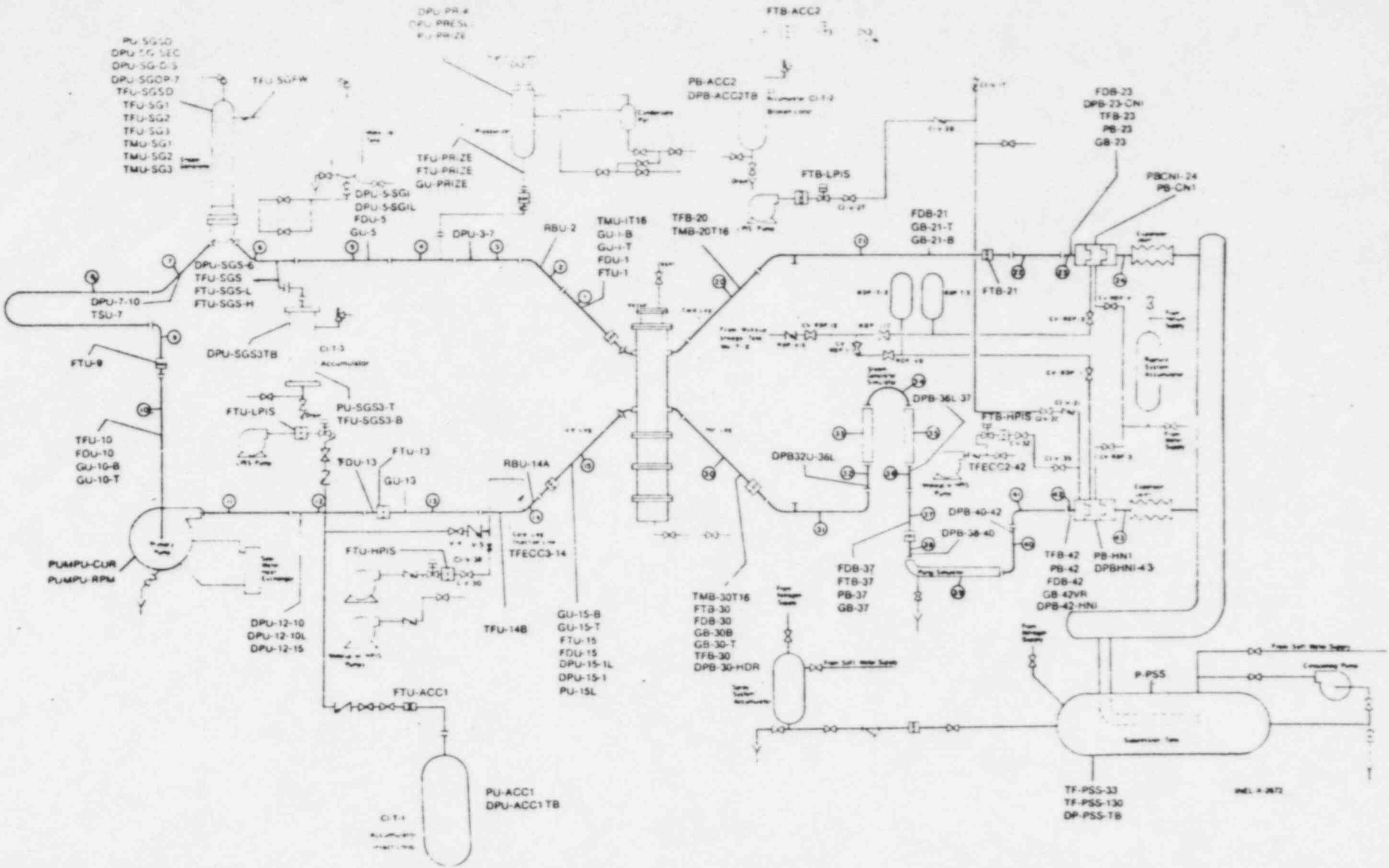


Figure 6. Semiscale Mod-1 System and Instrumentation for Cold Leg Break Configuration - Schematic

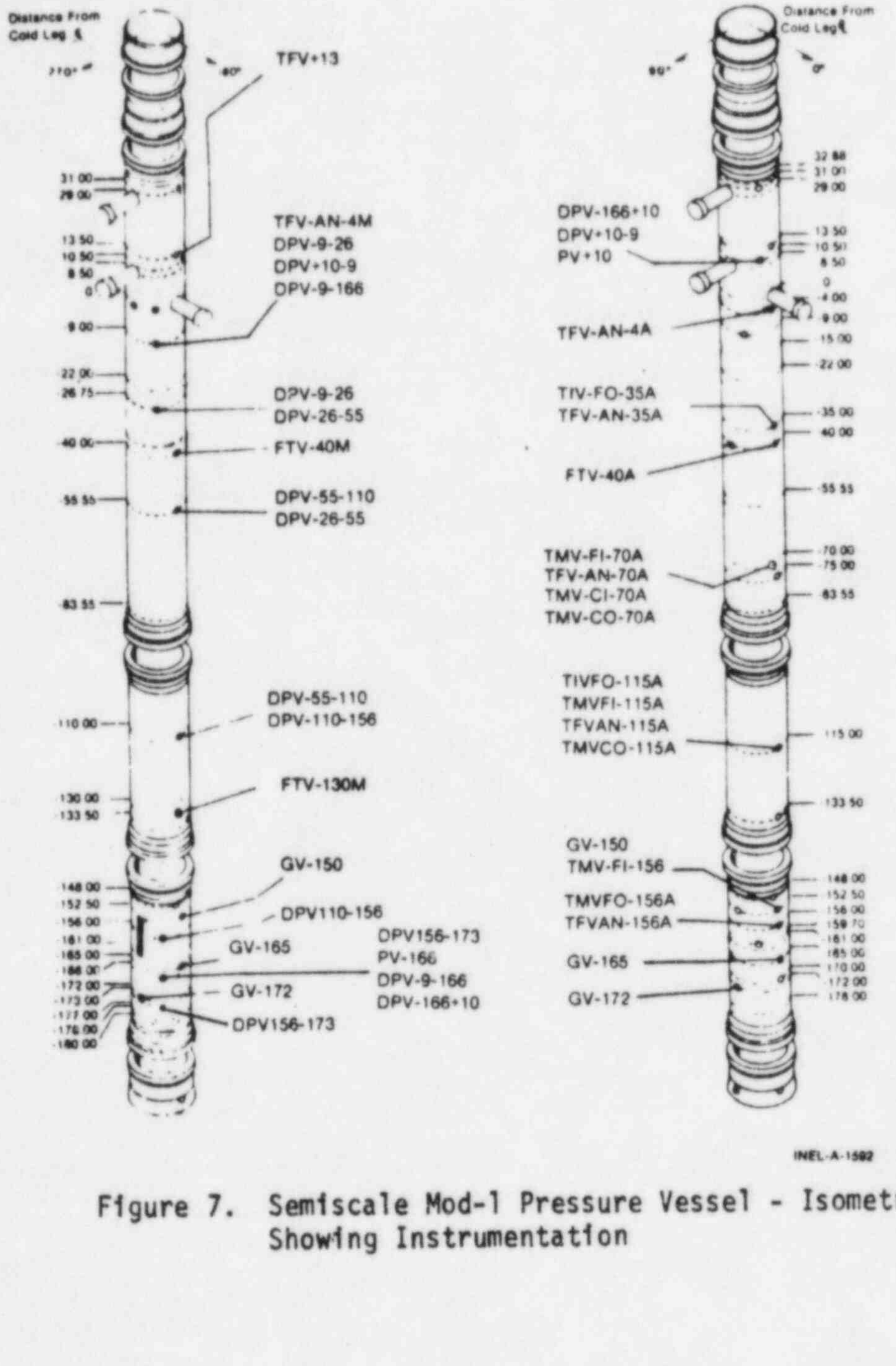


Figure 7. Semiscale Mod-1 Pressure Vessel - Isometric Showing Instrumentation

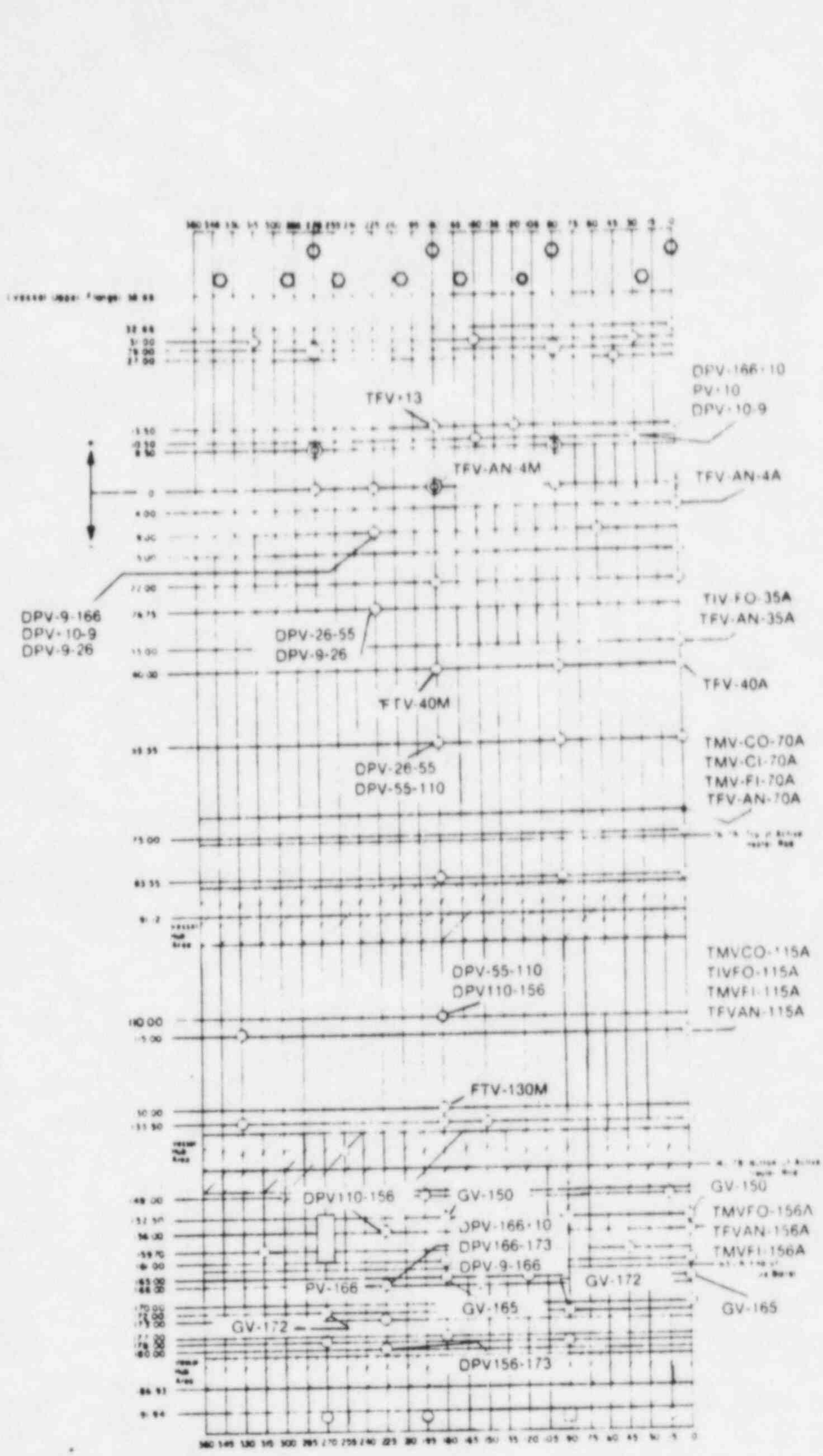


Figure 8. Semiscale Mod-1 Pressure Vessel - Penetrations and Instrumentation

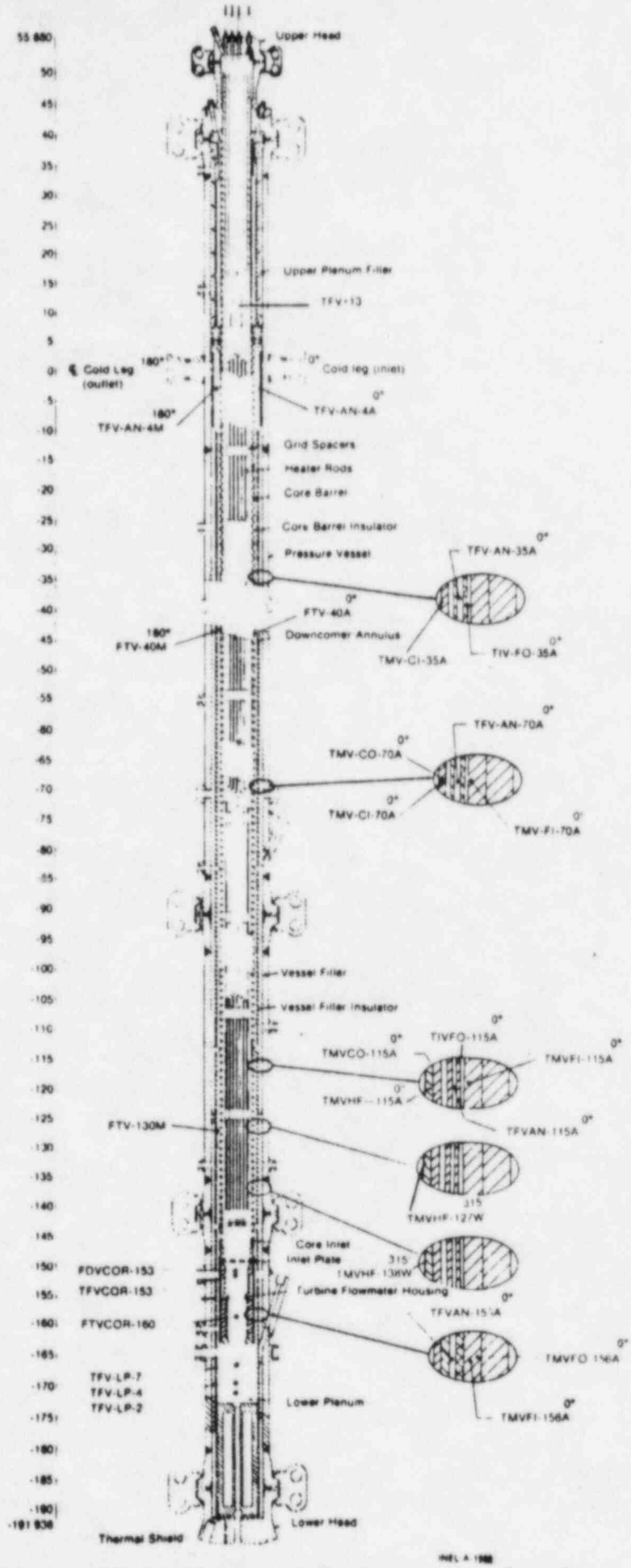


Figure 9. Semiscale Mod-1 Pressure Vessel - Cross Section Showing Instrumentation

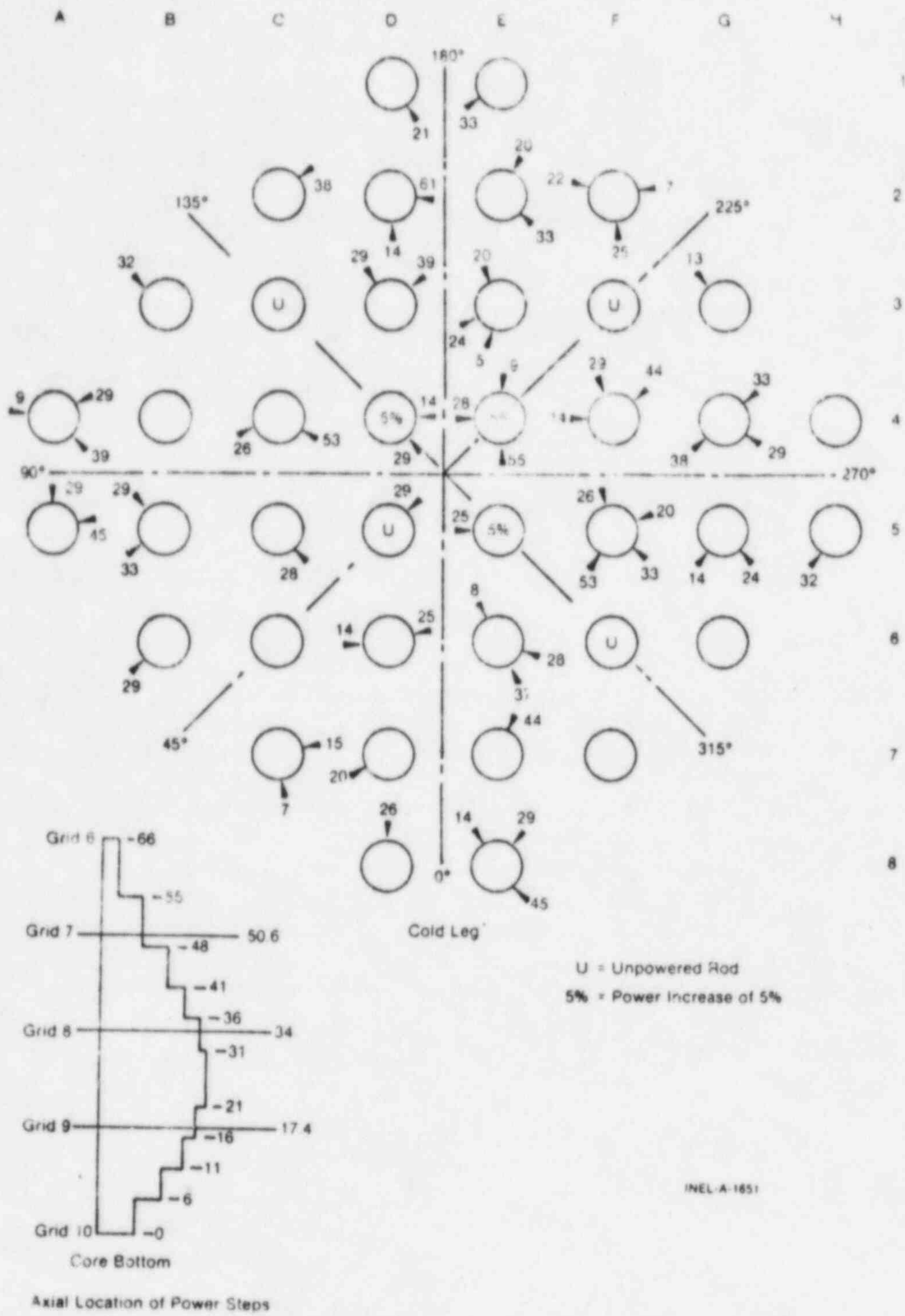


Figure 10. Semiscale Mod-1 Core - Plan View with Thermocouple Locations

obtained immediately following a test). A multiplex system allows the sampling of 256 data channels but the current software imposes a limit of 240 channels. For the purpose of generating 8-inch-plots, 920 data points are recorded for each data channel for a given recording period. If higher resolution of on-line data is needed, sequential blocks of 920 data points can be obtained over the required time period. The maximum sampling frequency of the DDAPS is 25,000 samples/sec; however the current software sets the DDAPS sampling rate at 13,800 samples/sec which results in 57.5 samples/sec for each of the available 240 data channels. Of these 240 data channels 230 are currently used. A total of 205 channels of low level amplifiers and preconditioners are available, allowing flexibility in the measurements assigned to these channels. In addition, 15 channels of single-beam gamma densitometers and 10 channels of two-beam gamma densitometers are also available. The ADAS has the capability of recording 80 data channels. The minimum frequency response is approximately 0-250 Hz with some of the channels having much higher frequency limits. The ADAS is used for higher response measurements.

The following engineering units will be used for various measurements and for the derived flow rates.

Measurement	Units
TF, TM, TI, TH	°F
DP	psid
P	psig
FT	gpm
G	lb_m/ft^3

	Drag disc volts (uncorrected)
	Drag disc volts (corrected)
FD-G combined (flow calculations)	ft/sec (velocity)
	lb_m/sec ft^2 (mass flux)
FT-G combined (flow calculations)	lb_m/sec (mass flow rate)
	lb_m (integrated mass)
	$lb_m/ft\text{-}sec^2$ (momentum flux)
	gpm (volumetric flow rate)
Power	KW
Volts	Volts
current	amps
Pump speed	rpm
Liquid level	in.

The DDAPS will be used to monitor instrument output during warmup of the Mod-1 system. At each warmup point, data required to analyze instrument and system performance will be sampled. The data for the tests will be recorded from -20 seconds to 640 seconds after LOCA rupture.

2. MEASUREMENT CAPABILITY AND TEST DATA REQUIREMENTS

Tables IV through VIII give a detailed description of Mod-1 measurement capabilities. The following information is included in the Tables:

(1) Detector ID and Descriptive Title. The detector ID consists of an alphanumeric group that will appear on the plots received from the "on-line" DDAPS. This ID describes the type of measurement and general location in various parts of the Mod-1 system (intact loop hot leg, etc.). The descriptive title details the instrument location. The location is described as : (a) the distance from a reference point; and/or, (b) angular displacement; and/or (c) elevation from a reference point.

(2) Range/Response/Accuracy. This part of the table will reflect the range, response (rise time), and accuracy of the instruments installed in the Mod-1 system.

(3) Location/Comments. Included are any comments that help describe the location of the measurements.

(4) Tests Used On. The four tests of Test Series 28 are listed.

Although the level of detector reliability is quite good because of the large number of measurements being taken, some instrument failures are anticipated prior to each test. During the system warmup, a committee consisting of representatives from the Semiscale Operations and Analysis Sections will evaluate the impact of any instrument failure with respect to test objectives and determine whether or not the test should proceed.

2.1 Discussion of Instrument Tables

The following is a discussion of Tables IV through VIII The columns on the right side of the tables indicate which measurements will be made for each test. The letter "A" means the data will be taken on both the analog system and the digital system, the letter "D" signifies that the data will be taken on the digital system only. Dashes indicate the measurement will be omitted.

2.1.1 Measurement Selection Rationale. The measurements specified for Series 28 tests have been selected to provide a general coverage of the phenomena occurring throughout the system with some emphasis on measuring the phenomena near the core and break and the temperature response of the heater rods. Much of the instrumentation for these tests duplicates the measurements taken during the baseline ECC test S-04-6 and the Series 5 tests to allow a direct comparison of results.

2.1.2 Table IV. This table includes a description of the measurement capabilities in the intact loop. Spool pieces are numbered starting with the hot leg vessel outlet spool as "1" and continuing through the loop (excluding the steam generator and pump) to the cold leg vessel inlet spool, number 15 (see Figure 2). The steam generator measurements include several differential pressure, fluid temperature, and pressure measurements. The letters "SG" refer to the steam generator. SG1 is located 12.25 in. above the bottom of the tube sheet; SG2 is 24.25 in. above the bottom of the tube sheet; SG3 is 48.25 in. above the bottom of the tube sheet; and SG4 is 96.75 in. above the bottom of the tube sheet. The tube sheet is approximately 3.5 in. thick. In the intact loop spool

pieces, the detector ID references the spool piece number and the descriptive title references the distance from the center of the vessel along either the hot leg (H) or cold leg (C) to the measurement location (e.g., (H100) means the measurement is 100 in. from the vessel center along the hot leg piping center line.). In the case of differential pressure measurements, the detector ID and the descriptive title include the spool piece number and the distance from the vessel center respectively for both taps of a given measurement. At all locations the descriptive title for differential pressure measurements also gives elevation between taps (e.g., DPU-3-7 (EL18) means the DP tap on spool 3 is 18 in. above the tap on spool 7). An "L" on the detector ID indicates a low range instrument and distinguishes between the high and low range measurements for the same location. For metal temperature measurements and fluid density measurements the following additional alphabetics at the end of the detector ID indicate the relative positions of the measurements:

T = Top;

B = Bottom; and

S = Side of the pipe cross section.

2.1.3 Table V. This table describes instrumentation in the Mod-1 broken loop with the cold leg break configuration. The broken loop includes a cold leg and a hot leg both terminating in blowdown nozzles. (Refer to Figure 2 for broken loop spool piece numbering system.) The broken loop descriptive titles are similar to those of the intact loop. When there are elevation changes between differential pressure taps, the descriptive titles contain the designation "EL", meaning elevation.

2.1.4 Table VI. This table includes instrumentation in the vessel and core. Numbers in the detector ID's define the vertical distance (in.) of the measurement from the centerline of the cold leg. A plus (+) preceding the numbers refers to the distance above the cold leg centerline whereas all other numbers refer to distances below the cold leg centerline. Angular displacement using the intact loop cold leg as the reference and rotating clockwise as viewed from the top, is denoted by the following alphameric designation:

A = 0°, G = 90°, M = 180°, T = 270°, W = 315°

For example, the differential pressure cell titled DPV-9-26 means the vessel pressure tap 9 in. below the cold leg centerline is connected to the pressure tap 26 in. below the cold leg centerline; the vessel filler metal thermocouple title TMV-FI-70A indicates that the measurement location is 70 in. below the cold leg center line at an angle of 0°. The descriptive titles indicate the angular positions and elevation differences between taps if applicable.

The following key describes the system used for vessel instrumentation identification:

TI	=	Insulation surface temperature
CO	=	Core outside diameter (TM's located 1/16 in. from OD of core barrel, OD = 5.505 in.)
CI	=	Core barrel inside diameter or core barrel insulation inside diameter (TM's located 1/16 in. from core barrel ID)

FI = Vessel filler inside diameter (TM's located 1/16 in. from vessel filler ID, ID = 7.050 in.)

G = Core grid

TF-AN = Fluid temperature in downcomer annulus - extend 0.200 in. out from filler insulator ID in flow stream

FO = Vessel filler outside diameter or filler insulator outside diameter (TM's located 0.65 in. from vessel filler ID, ID = 7.050 in.) (TI's located on surface of filler insulation OD)

IAN = Inlet annulus

AN = Downcomer annulus

VI = Vessel inside diameter (TM's located 1/16 in. from vessel ID, ID = 8.585 in.)

LH = Vessel lower head (TM located 1/8 in. from bottom face of lower plenum)

LP = Lower Plenum (TF's on vertical rack in lower plenum)

TH = Core heater rod temperature

HF = Core housing filler, TM's located 0.200 in. from outer surface

CIG = Core barrel insulation gap; TF is in center of gap

FIG = Filler insulation gap, TF is in the center of the gap.

The heater rod thermocouples and core fluid thermocouples are identified in a manner that is different from the other vessel instrumentation.

As indicated on Figure 10, any heater rod in the core can be described by two coordinates in terms of the columns (letter) and rows (number). The two digit numbers refer to elevation above the bottom of the core. For example, TH-C4-33 refers to coordinates C-4, 33 in. above the bottom of the heated length.

The core fluid thermocouples are located on the grid spacers between rods. There are five grid spacers located in the heated core region. These are numbered consecutively from 6 through 10, with grid number 6 at the top of the heated length. The grids are spaced approximately at equal distance from each other. The first number in the designation represents the number of the grid spacer while the two pairs of letter and numbers give the four adjacent rod positions. For example, TFG-6GH-45 means a thermocouple located on Grid 6 in the space between Columns G and H and Rows 4 and 5. The grid spacer fluid thermocouple axial positions are indicated in Figure 10.

2.1.5 Table VII. This table includes pressure suppression system (PSS) instrumentation. All elevations in the descriptive title refer to distance from the bottom of the PSS tank.

2.1.6 Table VIII. This table describes the coolant injection system instrumentation. The following key describes the instrumentation numbering system:

ACC	=	Accumulator
TB	=	Top to bottom connection
LPIS	=	Low pressure injection system
HPIS	=	High pressure injection system

TABLE IV

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pressure						
PU-5 (H 100)	0-3000 psi 10 msec 1% F.S.	Spool 5	---	---	---	---
PU-7 (C 240)	0-3000 psi 10 msec 1% F.S.	Spool 7	---	---	---	---
PU-13 (C 54)	0-3000 psi 10 msec 1% F.S.	Spool 13	---	---	---	---
PU-PRIZE	0-3000 psi 10 msec 1% F.S.	Pressurizer steam dome	D	D	D	D
PU-SGSD	0-3000 psi 10 msec 1% F.S.	Steam generator steam dome secondary	D	D	D	D
PU-SGIP (EL 13)	0-3000 psi 10 msec 1% F.S.	Elevation is below tube sheet, inlet plenum	---	---	---	---
PU-SGOP (EL 13)	0-3000 psi 10 msec 1% F.S.	Elevation is below tube sheet, outlet plenum	---	---	---	---
PU-15L (C 16)	0-500 psi 20 msec 1% F.S.	Cold leg	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pressure (cont'd)						
PU-SGS3-T	0-1000 psi 20 msec 1% F.S.	Accumulator (CI-T-3), above water level	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure						
DPU-UP-3 (H4V+10.5(30)H69EL2)	50" H_2O 20 msec 1% F.S.	Vessel outlet plenum to hot leg; upper plenum tap approximately 2" above Spool 3	---	---	---	---
DPU-UP-1L (H4V+10.5(30)H69EL2)	20" H_2O 20 msec 1% F.S.	Low range measurement, outlet plenum to hot leg	---	---	---	---
DPU-1-3 (EL 2)	50" H_2O 20 msec 1% F.S.	Spool 1 to Spool 3	---	---	---	---
DPU-1-3L (EL 2)	20" H_2O 20 msec 1% F.S.	Spool 1 to Spool 3, low range	---	---	---	---
DPU-3-7 (H62-C231EL18)	500" H_2O 20 msec 1% F.S.	Across steam generator; spool 3 is about 18" higher than spool 7	D	D	D	D
DPU-SG-DIS	0-500" H_2O 20 msec 1% F.S.	Steam generator secondary side; across venturi tube, 66 in. downstream from steam generator discharge	D	D	D	D
DPU-PR-4	0-1000 psid 20 msec 1% F.S.	Pressurizer top to spool 4. Elevation difference between tops is 105 in. Spool 4 top is 55 in. below pressurizer exit.	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (Cont'd.)						
DPU-SGS3TB	3 psi 20 msec 1% F.S.	Top to bottom on accumulator (CI-T-3)	D	D	D	D
DPU-3-7L (H62-C231EL18)	50" H_2O 20 msec 1% F.S.	Low range measurement across steam generator	---	---	---	---
DPU-5-SGI (EL 18)	500" H_2O 20 msec 1% F.S.	Across inlet orifice of steam generator Spool 5 is lower than steam generator inlet plenum.	D	D	D	D
DPUSGIPSG1 (EL 24)	200" H_2O 20 msec 1% F.S.	From steam generator inlet plenum to SG1	---	---	---	---
DPUSG1-SG2 (EL 12)	20" H_2O 20 msec 1% F.S.	Primary side tubes of steam generator	---	---	---	---
DPUSG2-SG3 (EL 24)	50" H_2O 20 msec 1% F.S.	Primary side tubes of steam generator	---	---	---	---
DPUSG3-SG4 (El 49)	100" H_2O 20 msec 1% F.S.	Primary side tubes of steam generator	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (Cont'd.)						
DPU-SGOP-7 (EL 35)	500" H_2O 20 msec 1% F.S.	From steam generator outlet plenum to Spool 7 including orifice	D	D	D	D
DPU6-SGIPL (EL 18)	100" H_2O 20 msec 1% F.S.	Low range across steam generator inlet orifice	D	D	D	D
DPU-7-10 (C 231-141)	50" H_2O 20 msec 1% F.S.	231 is outlet of steam generator, 141 is pump inlet ΔP tap	D	D	D	D
DPU-8C-7 (C 197-231 EL 32)	50" H_2O 20 msec 1% F.S.		---	---	---	---
DPU-8C-8D (C 197-185 EL 10)	20" H_2O 20 msec 1% F.S.	DP in pump trap; tap 8C lower than tap 8D	---	---	---	---
DPU-8D-8E (C 185-175 EL 10)	20" H_2O 20 msec 1% F.S.	DP in pump trap; tap 8D lower than tap 8E	---	---	---	---
DPU-8E-10 (C 175-141 EL 12)	20" H_2O 20 msec	Pump inlet covers elbow and turbine; tap 8E lower than Spool 10	---	---	---	---
DPU-12-10 (C 141-75 EL 10)	50 psid 20 msec 1% F.S.	Pump inlet to pump outlet; Spool 10 is lower than Spool 12	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			[illegible] 1	S-[illegible]-2	[illegible]-3	-28-4
Differential Pressure (Cont'd.)						
DPU-12-10L (C 141-75 EL 10)	100" H_2O 20 msec 1% F.S.	Low range pump inlet to pump outlet	D	D	D	D
DPU-12-15 (C 75-16)	100" H_2O 20 msec 1% F.S.	Across cold leg injection point	D	D	D	D
DPU-12-15L (C 75-16)	20" H_2O 20 msec 1% F.S.	Low range across cold leg injection	---	---	---	---
DPU-15-1 (H 31-C16 EL 8.5)	500" H_2O 20 msec 1% F.S.	Cold leg to hot leg; Spool 1 is higher than Spool 15	D	D	D	D
DPU-15-1L (H31-C16 EL 8.5)	100" H_2O 20 msec 1% F.S.	Cold leg to hot leg low range; Spool 1 is higher than Spool 15	D	D	D	D
DPU-15-IAN (C4V9(225)C16EL9)	100" H_2O 20 msec 1% F.S.	Cold leg to inlet annulus. Inlet annulus tap is 9 in. below the cold leg centerline at 225°	---	---	---	---
DPU-SGS-5	1000 psid 20 msec 1% F.S.	Instrumented spool piece in accumulator CI-T-3 injection line to spool piece 5.	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (Cont'd.)						
DPU-SG-SEC (EL 81)	100" H_2O 20 msec 1% F.S.	Existing process instrumentation - steam generator secondary side liquid level - DP taps at 48.54" and 129.62" above tube sheet	D	D	D	D
DPU-PRESLL	150" H_2O 20 msec 1% F.S.	Existing process instrumentation - pressurizer water level	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature						
TFU-1 (H 31)	650°F 100 msec .5% F.S.	In Spool 1	---	---	---	---
RBU-2 (H 46)	650°F 250 msec ±°F	In Spool 2 Resistance bulb	D	D	D	D
TSU-2 (H 52)	650°F 100 msec .5% F.S.	In Spool 2	---	---	---	---
TFU-PRIZE	650°F 100 msec .5% F.S.	In surge line, near pressurizer exit between turbine flowmeter and pressurizer	D	D	D	D
TSU-5 (H 104)	650°F 100 msec .5% F.S.	In Spool 5, shielded thermocouple	---	---	---	---
TSU-6 (H 114)	650°F 100 msec .5% F.S.	In Spool 6, shielded thermocouple	---	---	---	---
TFU-7 (C 249)	650°F 100 msec .5% F.S.	In Spool 7	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature (Cont'd)						
TSU-7 (C 243)	650°F 100 msec .5% F.S.	In Spool 7, shielded thermocouple	D	D	D	D
TFU-8 (C 197)	650°F 100 msec .5% F.S.	In Spool 8	---	---	---	---
TFU-10 (C 144)	650°F 100 msec .5% F.S.	In Spool 10	D	D	D	D
TSU-12 (C 80)	650°F 100 msec .5% F.S.	In Spool 12, shielded thermocouple	---	---	---	---
TFU-13 (C 51)	650°F 100 msec .5% F.S.	In Spool 13	---	---	---	---
TFU-14B (C 39)	650°F 100 msec 0.5% F.S.	In Spool 14 downstream of cold leg injection point	D	D	D	D
TFU-14A (C 44)	650°F 100 msec .5% F.S.	In Spool 14 upstream of cold leg injection point	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature (cont'd)						
RBU-14A (C 43)	650°F 250 msec ±1°F	In Spool 14, resistance bulb	D	D	D	D
TFU-15 (C 16)	650°F 100 msec .5% F.S.	In Spool 15	---	---	---	---
TFU-SGFW ----	650°F 100 msec .5% F.S.	In feedwater line leading to steam generator	D	D	D	D
TFU-SGSD ----	650°F 100 msec .5% F.S.	In steam dome of steam generator	D	D	D	D
TFU-SG1 (EL 12)	650°F 100 msec .5% F.S.	In steam generator secondary side. Numbers refer to elevation above the tube sheet	D	D	D	D
TFU-SG2 (EL 24)	650°F 100 msec .5% F.S.	In steam generator secondary side. Numbers refer to elevation above the tube sheet	D	D	D	D
TFU-SG3 (EL 48)	650°F 100 msec .5% F.S.	In steam generator secondary side. Numbers refer to elevation above the tube sheet	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			[illegible]	[illegible]	[illegible]	-28-4
Fluid Temperature (cont'd)						
TFU-SG4 (EL 96)	650°F 100 msec .5% F.S.	In steam generator secondary side. Numbers refer to elevation above the tube sheet	---	---	---	---
TFU-SGS	↓	In instrumented spool piece in accumulator CI-T-3 injection line	D	D	D	D
TFU-SGS3-B	↓	Located in accumulator CI-T-3, submerged in water near tank bottom below but not close to heater element.	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Metal Temperature						
TMU-1T4 (H 25)	0-650°F 100 msec 1% F.S.	In Spool 1 on top 1/4" from pipe ID	---	---	---	---
TMU-1T16 (H 25)		Spool 1 on top 1/16" from pipe ID	D	D	D	D
TMU-1S16 (H 25)		Spool 1 on side 1/16" from pipe ID	---	---	---	---
TMU-1B16 (H 25)		Spool 1 on bottom 1/16" from pipe ID	---	---	---	---
TMU-5B4 (H 103)		Spool 5 on bottom 1/4" from ID	---	---	---	---
TMU-5B16 (H 102)		Spool 5 on bottom 1/16" from ID	---	---	---	---
TMU-7S4 (C 242)		Spool 7 vertical pipe 1/4" from ID	---	---	---	---
TMU-7S16 (C 243)		Spool 7 vertical pipe 1/16" from ID	---	---	---	---
TMU-8S4 (C 195)		Spool 8, in pump trap 1/4" from pipe ID rotated 25° from bottom DP tap	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd.)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Metal Temperature (contd.)						
TMU-8S16 (C 195)	0-650°F 100 msec 1% F.S.	Spool 8, in pump trap 1/16" from pipe ID rotated 25° from bottom DP tap	---	---	---	---
TMU-10T4 (C 144)	↓	Spool 10 on top 1/4" from ID	---	---	---	---
TMU-10T16 (C 144)		Spool 10 on top 1/16" from ID	---	---	---	---
TMU-10S16 (C 144)		Spool 10 on side 1/16" from ID	---	---	---	---
TMU-10B16 (C 144)		Spool 10 on bottom 1/16" from ID	---	---	---	---
TMU-13T4 (C 56)		Spool 13, 1/4" from ID top	---	---	---	---
TMU-13T16 (C 56)		Spool 13, 1/16" from ID top	---	---	---	---
TMU-13S16 (C 56)		Spool 13, 1/16" from ID side	---	---	---	---
TMU-13B16 (C 56)		Spool 13, 1/16" from ID bottom	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Metal Temperature (contd.)						
TMU-15T4 (C 14)	0-650°F 100 msec 1% F.S.	Spool 15, 1/4" from ID top	---	---	---	---
TMU-15T16 (C 14)	↓	Spool 15, 1/16" from ID top	---	---	---	---
TMU-15S16 (C 14)	↓	Spool 15, 1/16" from ID side	---	---	---	---
TMU-15B16 (C 14)	↓	Spool 15, 1/16" from ID bottom	---	---	---	---
TMU-SG1 (EL 12)	↓	On steam generator tubes. Numbers refer to elevation above tube sheet. TM located near OD of tube	D	D	D	D
TMU-SG2 (EL 24)	↓	↓	D	D	D	D
TMU-SG3 (EL 48)	↓	↓	D	D	D	D
TMU-SG4 (EL 96)	↓	↓	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used [illegible]			
			[illegible]	[illegible]	[illegible]	-28-4
Momentum Flux						
FDU-1 (H 28)	+10 to +11,500 lbm/ft-sec^2 (initial 5000) 20 msec 5% of reading	Spool 1	D	D	D	D
FDU-5 (H 100)	+1 to +2,000 lbm/ft-sec^2 20 msec 5% of reading	Spool 5	D	D	D	D
FDU-10 (C 137)	+10 to +23,750 lbm/ft-sec^2 20 msec 5% of reading	Spool 10	D	D	D	D
FDU-13 (C 54)	+10 to +14,500 lbm/ft-sec^2 20 msec 5% of reading	Spool 13	D	D	D	D
FDU-15 (C 19)	+10 to +14,500 lbm/ft-sec^2 20 msec 5% of reading	Spool 15	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Volumetric Flow						
FTU-1 (H 18)	20-1200 gpm 10 msec 1% F.S.	Spool 1 bi-directional	A	A	A	A
FTU-9 (C 154)	↓	Spool 9 bi-directional	A	A	A	A
FTU-13 (C 64)	↓	Spool 13 Bi-directional	A	A	A	A
FTU-15 (C 29)	10-800 gpm 10 msec 1% F.S.	Spool 15 bi-directional	A	A	A	A
FTU-PRIZE	5-100 gpm 10 msec 1% F.S.	Surge line	D	D	D	D
FTU-SGFEED	1-20 gpm 10 msec 1% F.S.	Steam generator feedwater line	---	---	---	---
FTU-SGS-L	0.5-5 gpm 10 msec 0.5% F.S.	In the instrumented spool piece of accumulator CI-T-3 injection line (low range)	---	TBD	TBD	D
FTU-SGS-H	3-30 gpm 10 msec 0.5% F.S.	In the instrumented spool piece of accumulator CI-T-3 injection line (high range)	D	TBD	TBD	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Density						
GU-1-T (H 24)	.1-100 lbm/ft^3 20 msec .5% F.S.	Spool 1 dual beam densitometer, top 270/360 degrees	A	A	A	A
GU-1-B (H 24)		Spool 1 dual beam densitometer, bottom 30/330 degrees	A	A	A	A
GU-5 (H 96)		Spool 5 vertical	A	A	A	A
GU-10-B (C 141)		Spool 10 bottom	A	A	A	A
GU-10-T (C 141)		Spool 10 top	A	A	A	A
GU-13 (C 58)		Spool 13 vertical	D	D	D	D
GU-15-B (C 20)		Spool 15 dual beam densitometer, bottom 30/330 degrees	A	A	A	A
GU-15-T (C 20)		Spool 15 dual beam densitometer, top 270/360 degrees	A	A	A	A
GU-PRIZE		In pressurizer surge line	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE IV (Cont'd)

UNBROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pump Measurements						
PUMPU-POW	0-20 KW .5 s ±0.5 KW	Pump motor power	---	---	---	---
PUMPU-RPM	200-3600 rpm 10 msec ±25rpm	Pump rpm	D	D	D	D
PUMPU-CUR	0-25 amp	Pump current	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pressure						
PB-21 (C 49)	0-3000 psi 1 msec 5% F.S.	Broken loop cold leg pressure	---	---	---	---
PB-23 (C 92)	0-3000 psi 1 msec 1% F.S.	Upstream of nozzle (tee of DP tap)	A	A	A	A
PB-CN1 (C 94)	0-3000 psi 1 msec 1% F.S.	Nozzle throat - cold leg, tee of DP tap precision pressure transducer	A	A	A	A
PB-CN2 (C 96), 315°	0-3000 psi 1 msec 1% F.S.	Nozzle throat, cold leg	---	---	---	---
PB-CN3 (C 97), 0°	0-3000 psi 1 msec 1% F.S.	Nozzle throat, cold leg	---	---	---	---
PB-CN4 (C 101), 0°	0-3000 psi 1 msec 1% F.S.	Nozzle throat, cold leg	---	---	---	---
PB-24 (C 103)	0-3000 psi 1 msec 5% F.S.	Downstream of nozzle	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Test Series [illegible]			
			[illegible]-28-1	[illegible]	[illegible]	-28-4
Pressure (contd.)						
PB-30 (H 18)	0-3000 psi 1 msec 1% F.S.	Broken loop hot leg pressure, tee of DP tap	---	---	---	---
PB-37 (H 281)	0-3000 psi 1 msec 5% F.S.	Downstream of steam of steam generator, upstream of pump	D	D	D	D
PB-42 (H 415)	0-3000 psi 1 msec 1% F.S.	Upstream of nozzle pump side, tee of DP tap	A	A	A	A
PB-HN1 (H 417)	0-3000 psi 1 msec 1% F. S.	Hot leg nozzle throat, tee of DP tap	A	A	A	A
PB-43 (H 425)	0-3000 psi 1 msec 5% F.S.	Upstream of rupture discs	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Contd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure						
DPB-21-23 (C 49-92)	800" H_2O 20 msec 1% F.S.	Spool 21 to 23	---	---	---	---
DPB-23-CN1 (C 92-97)	0-1000 psid 20 msec 1% F.S.	Spool 23 to CN1 (in nozzle throat)	D	D	D	D
DPBCN1-CN4 (C 96-101)	0-200" H_2O 20 msec 1% F.S.	Throat to nozzle divergent section cold leg	---	---	---	---
DPU-23-24 (C 92-103)	0-1000 psid 20 msec 1% F.S.	Across blowdown nozzle	---	---	---	---
DPB-30-HDR (H18-89)	0-1000 psid 20 msec 1% F.S.	From broken hot leg Spool 30 to the suppression tank header	D	D	D	D
DPB-30-32 (H18-73EL10)	0-50" H_2O 20 msec 1% F.S.		---	---	---	---
DPB32U-36L (H73-242EL16)	0-200 psid 20 msec 1% F.S.	Across simulated steam generator orifice assembly, Spool 32 upper tap is higher than Spool 36 lower tap	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	[illegible]			
			[illegible]	[illegible]	[illegible]	-28-4
Differential Pressure (contd.)						
DPBCN1-24 (C96-89)	0-1000 psid 20 msec 1% F.S.	Hot leg blowdown nozzle to Spool 24 calibrated to be zero under empty condition	A	A	A	A
DPB32L-32U (H63-73EL10)	0-20" H_2O 20 msec 1% F.S.	Spool 32 lower tap to 32 upper tap	---	---	---	---
DPB36L-42 (H242-415EL14)	0-100 psid 20 msec 1% F.S.	Across simulated pump	---	---	---	---
DPB32U36LL (H73-242EL10)	0-800" H_2O 20 msec 1% F.S.	Across simulated steam generator orifice assembly low range	---	---	---	---
DPB-SGOR (H84-90EL6)	0-500" H_2O 20 msec 1% F.S.	Across first orifice plate of simulated steam generator	---	---	---	---
DPB-38-40 (H304-347ELØ)	0-1000 psid 20 msec 1% F.S.	Across simulated pump broken loop	D	D	D	D
DPB-38-40L (H304-347ELØ)	0-500" H_2O 20 msec 1% F.S.	Across simulated pump broken loop low range	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (cont'd)						
DPB-30-38 (H18-3Ø4EL4Ø)	0-100 psid 20 msec 1% F.S.	Covers entire steam generator assembly plus instrument spool downstream of steam generator; Spool 30 is higher than Spool 38	---	---	---	---
DPB-40-42 (H363-415EL40)	0-50" H_2O 20 msec 1% F.S.	Covers elbow leading into spool just upstream of blowdown nozzle; Spool 40 is lower than Spool 42	D	D	D	D
DPB-42-43 (H415-425ELØ)	0-1000 psid 20 msec 1% F.S.	Across blowdown nozzle	---	---	---	---
DPB-HN4-43 (H423-425ELØ)	0-50 psid 20 msec 1% F.S.	From nozzle divergent section to spool just downstream	---	---	---	---
DPB-42-HN1 (H415-417ELØ)	1000 psid 20 msec 1% F.S.	From spool just upstream of nozzle to nozzle throat.	D	D	D	D
DPBHN1-HN4 (H417-423ELØ)	0-1000 psid 20 msec 1% F.S.	From nozzle throat to nozzle divergent section	---	---	---	---
DPB-IAN-21 (C4V9(225)C23ELØ)	0-100" H_2O 20 msec 1% F.S.	From vessel inlet annulus at 9 in. below the cold leg centerline to broken loop cold leg	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN [illegible]OP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location [illegible]	[illegible]	[illegible]	[illegible]	-28-4
Differential Pressure (cont'd)						
DPB-UP-30 (H4V+10.5(30)H18EL2)	100" H_2O 20 msec 1% F.S.	From vessel upper plenum 10.5 in. above the cold leg centerline to broken loop hot leg	---	---	---	---
DPBHN1-43 (H417-89)	1000 psid 20 msec 1% F.S.	From nozzle throat to spool 43	D	D	D	D
DPB-37-38 (H281-304EL25)	0-50" H_2O 20 msec 1% F.S.	Completes DP increments in loop - across the turbine meter, drag disk; Spool 37 is higher than Spool 38	---	---	---	---
DPB-36L-37 (H242-281EL39)	0-50 psid 20 msec 1% F.S.	Across nozzle assembly between Spools 36 and 37; Spool 36 is higher than Spool 37	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature						
TFB-20 (C 21)	650°F 100 msec .5% F.S.	Cold leg just out of vessel	D	D	D	D
TFB-23 (C 91)	↓	Upstream of nozzle "cold leg"	D	D	D	D
TFB-24 (C 103)	↓	Downstream of nozzle "cold leg"	---	---	---	---
TFB-30 (H 17)	↓	Hot leg broken loop	D	D	D	D
TFB-37 (H 275)	↓	Discharge of steam generator	---	---	---	---
TSB-37 (H 272)	↓	Shielded thermocouple Spool 37	---	---	---	---
TFB-40 (H 367)	↓	Discharge of simulated pump	---	---	---	---
TFB-42 (H 414)	↓	Upstream of nozzle "hot leg"	D	D	D	D
TFB-43 (H 425)	↓	Downstream of nozzle "hot leg"	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Contd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Metal Temperature						
TMB-20T4 (C 21)	650°F 100 msec 1% F.S.	Cold leg broken loop, 1/4" from pipe ID on top	---	---	---	---
TMB-20T16 (C 21)	↓	Cold leg broken loop, 1/16" from pipe ID on top	D	D	D	D
TMB-20S16 (C 21)		Cold leg broken loop, 1/16" from pipe ID on side	---	---	---	---
TMB-20B16 (C 21)		Cold leg broken loop, 1/16" from pipe ID on bottom	---	---	---	---
TMB-30T4 (H 17)		Hot leg broken loop, 1/4" from pipe ID on top	---	---	---	---
TMB-30T16 (H 17)		Hot leg broken loop, 1/16" from pipe ID on top	D	D	D	D
TMB-30S16 (H 17)		Hot leg broken loop, 1/16" from pipe ID on side	---	---	---	---
TMB-30B16 (H 17)		Hot leg broken loop, 1/16" from pipe ID on bottom	---	---	---	---
TMB-40S4 (H367)		Simulated pump discharge vertical section, 1/4" from pipe ID	---	---	---	---
TMB-40S16 (H367)	↓	Simulated pump discharge vertical section, 1/16" from pipe ID	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Contd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Momentum Flux						
FDB-21 (C 53)	±100 to ±30,000 lbm/ft-sec^2 20 msec 5% F.S.	Cold leg spool 21	A	A	A	A
FDB-23 (C 93)	±100 to ±100,00 lbm/ft-sec-^{2} 20 msec 5% F.S.	Just upstream of blowdown nozzle Spool 23	A	A	A	A
FDB-30 (H 21)	±100 to ±10.000 lbm/ft-sec^2 20 msec 5% F.S.	Hot leg spool 30	A	A	A	A
FDB-37 (H 284)	±100 to ±50,000 lbm/ft-sec^2 20 msec 5% F.S.	Steam generator outlet vertical pipe	A	A	A	A
FDB-42 (H 416)	±100 to ±50.000 lbm/ft-sec^2 20 msec 5% F.S.	Just upstream of blowdown nozzle Spool 42, downstream of injection point	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Cont'd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location [illegible]	[illegible]			
			[illegible]	[illegible]	[illegible]	-28-4
Volumetric Flow						
FTB-21 (C 58)	+20 to +1200 gpm 10 msec 1% F.S.	Cold leg spool 21,3" pipe, Sch. 160	A	A	A	A
FTB-30 (H 25)	+20 to +1200 gpm 10 msec 1% F.S.	Hot leg spool 30, 3" pipe, Sch. 160	A	A	A	A
FTB-37 (H 290)	+20 to +1200 gpm 10 msec 1% F. S.	Hot leg spool 37, 2" pipe, Sch. 160	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE V (Contd)

BROKEN LOOP

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Density						
GB-21-T (C 49)	.1-100 lb/ft^3 20 msec 5% F.S.	Top beam of the dual beam densitometer at Spool 21, 270/260°	A	A	A	A
GB-21-B (C 49)	↓	Bottom beam of the dual beam densitometer at Spool 21, 30/330°	A	A	A	A
GB-23 (C 92)	↓	Vertical orientation spool 23	A	A	A	A
GB-30-T (H 18)	↓	Top beam of the dual beam densitometer at Spool 30, 270/260°	A	A	A	A
GB-30-B (H 18)	↓	Bottom beam of the dual beam densitometer at Spool 30, 30/330°	A	A	A	A
GB-37 (H 278)	↓	Across vertical pipe steam generator discharge	A	A	A	A
GB-42 (H 415)	↓	Vertical orientation Spool 42	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pressure						
PV-165 (225DEG)	3000 psi 1 msec 1% F.S.	In upper part of lower plenum approximately 26" from lower plenum bottom - mounted on standoff	A	A	A	A
PV+10 (180DEG)	0-3000 1 msec 1% F.S.	In vessel upper plenum 10 in. above unbroken loop cold leg centerline - mounted on standoff, 30°	A	A	A	A
PV-HEISE+10 (30DEG)	0-3000 psi .5 sec ±5 psi	Heise gauge at Spool 4, ~ 10" above unbroken loop cold leg centerline recorded in log just prior to reflood	---------HAND RECORD----			
PV-9 (225DEG)	0-3000 psi 1 msec 1% F.S.	In vessel inlet annulus, 9" below cold leg centerline - mounted on standoff	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure						
DPV-166+10 (225-30EL177)	300" H_2O 20 msec 1% F.S.	Lower plenum 166" below cold leg centerline; to upper plenum 10.5" above cold leg centerline; DP taps 225° -30°, respectively	D	D	D	D
DPV+10-166 (225-30EL177)	50" H_2O 20 msec 1% F.S.	Upper plenum to lower plenum, low range	---	---	---	---
DPV+10-9 (225-30EL10)	300" H_2O 20 msec 1% F.S.	Upper plenum 10.5" above cold leg centerline to inlet annulus at 9" below cold leg centerline; DP taps 30°-225° respectively	D	D	D	D
DPV-0-9 (90-225EL9)	50" H_2O 20 msec 1% F.S.	Inlet annulus cold leg centerline to just ahead of downcomer entrance (9" below cold leg centerline; DP taps 90°-255°, respectively	---	---	---	---
DVP-9-166 (225-225EL171)	300" H_2O 20 msec 1% F.S.	Inlet annulus (9" below cold leg centerline) to lower plenum (approximately 26" above lower plenum bottom and 166" below cold leg centerline); DP taps 225°	D	D	D	D
DPV-9-26 (225-225EL17)	50" H_2O 20 msec 1% F.S.	Inlet annulus (9" below cold leg centerline) to downcomer gap (approximately 26" below cold leg centerline); DP taps 225°	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (Cont'd.)						
DPV-26-55 (225-180EL29)	50" H_2O 20 msec 1% F.S.	Across part of downcomer 26" to 55" below centerline to cold leg; DP taps 225° - 180°	D	D	D	D
DPV-55-55 (0-180EL0)	20" H_2O 20 msec 1% F.S	Covers any angular DP at 55" below, cold leg centerline; DP taps 180° - 180°, respectively	---	---	---	---
DPV-55-110 (0-180EL55)	100" H_2O 20 msec 1% F.S.	Across part of downcomer 55" to 110" below centerline of cold leg; DP taps 180° - 180°, respectively	D	D	D	D
DPV110-156 (180-225EL46)	100" H_2O 20 msec 1% F.S.	Across part of downcomer 110" to 156" below centerline of cold leg; DP taps 180° - 225°F, respectively	D	D	D	D
DPV156-173 (225-225EL17)	20" H_2O 20 msec 1% F.S.	Across downcomer exit (7" above exit to 19" below exit): taps at 156 and 173" below cold leg centerline, respectively	D	D	D	D
DPV166-192 (225-27EL26)	50" H_2O 20 msec 1% F.S.	Across most of lower plenum; DP taps at 225° - 270°, respectively, and at 166" and 192" below cold leg centerline	---	---	---	---
DPV166-173 (225-225EL7)	20" H_2O 20 msec 1% F.S.	Across part of lower plenum 19 to 26" above lower plenum bottom; DP taps at 225° - 225°, respectively, and at 166 and 173" below cold leg centerline	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Differential Pressure (contd.)						
DPV180-192 (225-270EL12)	20" H_2O 20 msec 1% F.S.	Across part of lower plenum 12" above lower plenum bottom to lower plenum bottom (horizontal tap)1 DP taps at 225° - 270°, respectively	---	---	---	---
DPC-89-106 (315-225EL17)	50" H_2O 20 msec 1% F.S.	In core active region pressure tubes at 315° and 225°, respectively, and at 89 and 106" below cold leg centerline	---	---	---	---
DPC-106-122 (225-135EL16)	100" H_2O 20 msec 1% F.S.	In core active region, pressure tubes at 225° and 135°, respectively, and at 106 and 122" below cold leg centerline	---	---	---	---
DPC-122-140 (135-45EL18)	100" H_2O 20 msec 1% F.S.	In core active region, pressure tubes at 135° and 45°, respectively	---	---	---	---
DPC-133-191 (270-225EL58)	100" H_2O 20 msec 1% F.S.	In core entrance across turbine and flow mixer box	---	---	---	---
DPC-89+10 (315-30EL100)	500" H_2O 20 msec 1% F.S.	From top of active core region to upper plenum (+10.5) core tube at 315° upper plenum tap at 30°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Downcomer Fluid Temperature						
TFV-AN-4A (0DEG)	650°F 100 msec .5% F. S.	4" below cold leg centerline in inlet annulus 0°	D	D	D	D
TFV-AN-4M (180DEG)	↓	4" below cold leg centerline in inlet annulus 180°	D	D	D	D
TFV-AN-15A (Failed) (9DEG)	↓	In downcomer 15" below cold leg centerline approx. 5" below downcomer entrance	---	---	---	---
TFV-AN-15M (180DFG)	↓	In downcomer 15" below cold leg centerline approx. 5" downcomer entrance 180°	---	---	---	---
TFV-AN-15T (270DEG)	↓	In downcomer 15" bellow cold leg centerline approx. 5" below downcomer entrance 270°	---	---	---	---
TFV-AN-35A (0DEG)	↓	In downcomer 35" below cold leg centerline 0° approx. 25" below downcomer entrance	D	D	D	D
TFV-AN-35M (180DEG)(Failed)	↓	In downcomer 35" below cold leg centerline 180° approx. 25" below downcomer entrance	---	---	---	---
TFV-AN-35T (270DEG)	↓	In downcomer 35" below cold leg centerline 270° approx. 25" below downcomer entrance	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Downcomer Fluid Temperature						
TFV-AN-70A (ODEG)	650°F 100 msec .5% F.S.	In downcomer ~60" below downcomer entrance and 70" below cold leg centerline 0°	D	D	D	D
TFVAN-115A (ODEG)	↓	In downcomer ~105" below downcomer entrance and 115" below cold leg centerline 0°	D	D	D	D
TFVAN-115M (1800DEG)	↓	In downcomer ~105" below downcomer entrance and 115° below cold leg centerline 180°	---	---	---	---
TFVAN-156A (ODEG)	↓	In downcomer ~7" from bottom of downcomer and 156° below cold leg centerline 0°	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature (Core)						
TFG-5CD-45 (55.5 CL)	650°F 100 msec .5% F.S.	On core grid spacer number 5, 55.5" below cold leg centerline	D	D	D	D
TFG-6AB-45 (75.75 CL)	↓	On core grid spacer number 6, 75.75" below cold leg centerline	---	---	---	---
TFG-6BC-45 (75.75 CL)		On core grid spacer number 6, 75.75" below cold leg centerline	---	---	---	---
TFG-6CD-45 (75.75 CL)		On core grid spacer number 6, 75.75" below cold leg centerline	D	D	D	D
TFG-6DE-45 (75.75 CL)		On core grid spacer number 6, 75.75" below cold leg centerline	---	---	---	---
TFG-6FG-45 (75.75 CL)		On core grid spacer number 6, 75.75" below cold leg centerline	---	---	---	---
TFG-6CD-56 (75.75 CL)		On core grid spacer number 6, 75.75" below cold leg centerlin	---	---	---	---
TFG-8DE-34 (108.78CL)		On core grid spacer number 8, 108.78" below cold leg centerline	---	---	---	---
TFG-8AB-45 (108.78CL)		On core grid spacer number 8, 108.78" below cold leg centerline	---	---	---	---
TFG-8CD-45 (108.78CL)		On core grid spacer number 8, 108.78" below cold leg centerline	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature (Core) (cont'd)						
TFG10AB-45 (141.98CL)	650°F 100 msec .5% F.S.	On core grid spacer number 10, 141.98" below cold leg centerline	---	---	---	---
TFG10BC-45 (141.98CL)	↓	On core grid spacer number 10, 141.98" below cold leg centerline	---	---	---	---
TFG10CD-45 (141.98CL)	↓	On core grid spacer number 10, 141.98" below cold leg centerline	D	D	D	D
TFG10DE-45 (141.98CL)	↓	On core grid spacer number 10, 141.98" below cold leg centerline	---	---	---	---
TFG10FG-45 (141.98CL)	↓	On core grid spacer number 10, 141.98" below cold leg centerline	---	---	---	---
TFG10CD-56 (141.98CL)	↓	On core grid spacer number 10, 141.98" below cold leg centerline	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location [illegible]	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature-Filler and Core Barrel Insulator Gaps						
TFVCIG-70A (ODEG)	650°F 100 msec	Core barrel insulation gap, 70" below cold leg centerline, 0°	---	---	---	---
TFVCIG11A (ODEG)	↓	Core barrel insulation gap, 115" below cold leg centerline, 0°	---	---	---	---
TFVFIG-70A (ODEG)	↓	Filler insulation gap, 70" below cold leg centerline, 0°	---	---	---	---
TFVFIG156A (ODEG)	↓	Filler insulation gap, 156" below cold leg centerline, 0°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Fluid Temperature Upper Plenum - Lower Plenum						
TFV+13 (150DEG)	650°F 100 msec .5% F.S.	In upper plenum 13.5" above cold leg centerline at 180°	D	D	D	D
TFV-LP-2 ----	↓	In lower plenum fluid TC rack, 2.0" from bottom of lower plenum filler block, on centerline	D	D	D	D
TFV-LP-4 ----	↓	In lower plenum fluid TC rack, 4.0" from bottom of lower plenum filler block, on centerline	D	D	D	D
TFV-LP-7 ----	↓	In lower plenum fluid TC rack, 7.0" from bottom of lower plenum filler block, on centerline	D	D	D	D
TFV-LP-22 ----	↓	In lower plenum fluid TC rack, 21.5" from bottom of vessel, 45°	---	---	---	---
TFV-LP-28 ----	↓	In lower plenum fluid TC rack, 27.5" from bottom of vessel, 45°	---	---	---	---
TFVCOR-153	650°F 100 msec 1% F.S.	Core entrance	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Metal Temperature - Vessel Wall						
TMV-VI-15A (ODEG)	650°F 100 msec 1% F.S.	In vessel 15" below unbroken loop cold leg centerline, 0°	---	---	---	---
TMV-VI-35A (ODEG)	↓	In vessel ~25" below downcomer entrance and 35" below cold leg centerline, 0°	---	---	---	---
TMVVI-156A (ODEG)		In vessel ~7" above downcomer exit and 156" below cold leg centerline, 0°	---	---	---	---
TMVVI-177M (180DEG)		In vessel ~15" above lower plenum bottom and 177" below cold leg centerline, 180°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Vessel Filler Metal Temperatures						
TMV-FI-4M (180DEG)	650°F 100 msec 1% F.S.	In vessel filler 4" below cold leg centerline, 180°	---	---	---	---
TMV-FI-15A (0DEG)		In vessel filler ~5" below downcomer entrance and 15" below cold leg centerline, 0°	---	---	---	---
TMV-FI-15M (180DEG)		In vessel filler ~5" below downcomer entrance and 15" below cold leg centerline, 180°	---	---	---	---
TMV-FI-35A (0DEG)		In vessel filler ~25" below downcomer entrance, 35" below cold leg centerline, 0°	---	---	---	---
TMV-FI-35M (180DEG)		In vessel filler ~25" below downcomer entrance, 35" below cold leg centerline, 180°	---	---	---	---
TMV-FO-35A (Failed) (0DEG)		In vessel filler ~25" below downcomer entrance, 1/2" from filler ID, 0°	---	---	---	---
TMV-FI-70A (0DEG)		In vessel filler ~60" below downcomer entrance, 70" below cold leg centerline, 0°	D	D	D	D
TMV-FI-115A (0DEG)		In vessel filler ~105" below downcomer entrance, 155" below cold leg centerline, 0°	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Vessel Filler Metal Temperatures (Cont'd.)						
TMVFI-156A (ODEG)	650°F 100 msec 1% F.S.	In vessel filler ~7" above downcomer entrance, 156" below cold leg centerline, 0°	D	D	D	D
TMVFI-156M (Failed) (180DEG)		In vessel filler ~7" above downcomer entrance, 156" below cold leg centerline, 180°	---	---	---	---
TMVFO-156A (ODEG)		In vessel filler 156" below cold leg centerline or ~7" above downcomer exit, 1/2" from filler ID, 0°	D	D	D	D
TMVFI-177M (180DEG)		In vessel filler 177" below cold leg centerline or 15" from lower plenum bottom, 180°	---	---	---	---
TMVFO-177M (180DEG)		In vessel filler 177" below cold leg centerline or ~15" from lower plenum bottom, 1/2" from filler ID, 180°	---	---	---	---
TMVFI-184M (180DEG)		In vessel filler 184" below cold leg centerline or 8" from lower plenum bottom, 180°	---	---	---	---
TMVLH (Bottom Head)		In vessel bottom head, 1/8" from surface (90°)	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)
VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Vessel Filler Insulator Temperature						
TIV-FO-4A (ODEG)	0-650F 100 msec 1% F.S.	On surface of filler insulator OD 4" below cold leg centerline, 0°	---	---	---	---
TIVFO-115M (180DEG)	↓	On surface of filler insulator OD 115" below cold leg centerline or ~5" below downcomer entrance, 180°	---	---	---	---
TIV-FO-35A (ODEG)	↓	On surface of filler insulator OD 35" below cold leg centerline or 25" below downcomer entrance, 0°	D	D	D	D
TIV-FO-35M (180DEG)	↓	On surface of filler insulator OD 35" below cold leg centerline or 25" below downcomer entrance, 180°	---	---	---	---
TIV-FO-70A (ODEG)	↓	On surface of filler insulator OD 70" below cold leg centerline or 60" below downcomer entrance, 0°	---	---	---	---
TIVFO-115A (ODEG)	↓	On surface of filler insulator OD 115" below cold leg centerline or 105" below downcomer entrance, 0°	D	D	D	D
TIVFO-156A (Failed) (ODEG)	↓	On surface of filler insulator OD 156" below cold leg centerline or 7" above downcomer exit, 0°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Vessel Filler Insulator Temperature (contd.)						
TIV-FO-177M (180DEG)	0-650°F 100 msec 1% F.S.	On surface of filler insulator OD 177" below cold leg centerline or 15" above lower plenum bottom, 180°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Barrel Metal Temperatures						
TMV-CO-4A (ODG)	650°F 100 msec 1% F.S.	In core barrel 4" below cold leg centerline in inlet annulus region, 0°	---	---	---	---
TMV-CO-4M (180DEG)		In core barrel 4" below cold leg centerline in inlet annulus region, 0°	---	---	---	---
TMV-CO-15A (ODEG)		In core barrel 15" below cold leg centerline or ~5" below downcomer entrance, 0°	---	---	---	---
TMV-CO-35A (ODEG)		In core barrel 35" below cold leg centerline or ~25" below downcomer entrance, 0°	---	---	---	---
TMV-CI-35A (ODEG)		In core barrel 35" below cold leg centerline or ~25" below downcomer entrance, 0°	---	---	---	
TMV-CO-70A (ODEG)		In core barrel 70" below cold leg centerline or ~60" below downcomer entrance, 0°	D	D	D	D
TMV-CI-70A (ODEG)		In core barrel 70" below cold leg centerline or ~60" below downcomer entrance, 0°	D	D	D	D
TMV-CI-95M (180DEG)		In core barrel 95" below cold leg centerline or ~85" from downcomer entrance, 180°	---	---	---	---
TMVCO-115M (180DEG)		In core barrel 115" below cold leg centerline or ~105" from downcomer entrance, 180°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Barrel Metal Temperature (contd).						
TMVCO-115A (ODEG)	650°F 100 msec 1% F.S.	In core barrel 115" below cold leg centerline or ~105" from downcomer entrance, 0°	D	D	D	D
TMVCI-115A (ODEG)	↓	In core barrel 115" below cold leg centerline or ~105" from downcomer entrance, 0°	---	---	---	---
TMVCO-127A (ODEG)	↓	On core barrel 127" below cold leg centerline ~117" from downcomer entrance, 0°	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Housing Filler						
TMVHF-115W (315DEG)	650°F 100 msec 1% F.S.	On core housing filler, 115" below cold leg centerline, 315°, 0.200" from outer surface	D	D	D	D
TMVHF-127W (315DEG)	↓	On core housing filler, 127" below cold leg centerline, 315°, 0.200" from outer surface	D	D	D	D
TMVHF-138W (315DEG)	↓	On core housing filler, 138" below cold leg centerline, 315°, 0.200" from outer surface	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures						
TH-D1-21 (330DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-D1-44 (315DEG)	↓	↓	---	---	---	---
TH-D1-60 (135DEG)	↓	↓	---	---	---	---
TH-E1-33 (60DEG)	↓	↓	D	D	D	D
TH-E1-27 (Failed) (195DEG)	↓	↓	---	---	---	---
TH-E1-54 (0DEG)	↓	↓	---	---	---	---
TH-C2-28 (135DEG)	↓	↓	---	---	---	---
TH-C2-33 (45DEG)	↓	↓	---	---	---	---
TH-C2-8 (Failed) (345DEG)	↓	↓	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperature (Cont'd.)						
TH-C2-38 (225DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-D2-14 (0DEG)	↓	↓	D	D	D	D
TH-D2-29 (Failed) (90DEG)	↓	↓	---	---	---	---
TH-D2-45 (180DEG)	↓	↓	---	---	---	---
TH-D2-61 (270DEG)	↓	↓	D	D	D	D
TH-E2-33 (315DEG)	↓	↓	D	D	D	D
TH-E2-20 (215DEG)	↓	↓	D	D	D	D
TH-F2-25 (0DEG)	↓	↓	D	D	D	D
TH-F2-22 (100DEG)	↓	↓	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Test Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Cont'd.)						
TH-F2-21 (Open) (270DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	---	---	---	---
TH-F2-07 (260DEG)			D	D	D	D
TH-B3-52 (195DEG)			---	---	---	---
TH-B3-20 (90DEG)			---	---	---	---
TH-B3-32 (135DEG)			D	D	D	D
TH-C3-28 (0DEG)			---	---	---	---
TH-C3-13 (Failed) (270DEG)			---	---	---	---
TH-C3-60 (135DEG)			---	---	---	---
TH-D3-33 (Failed) (45DEG)			---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Contd)						
TH-D3-29 (155DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-D3-39 (205DEG)	↓	↓	D	D	D	D
TH-E3-5 (20DEG)			D	D	D	D
TH-E3-20 (160DEG)			D	D	D	D
TH-E3-24 (80DEG)			D	D	D	D
TH-F3-6 (315DEG)			---	---	---	---
TH-F3-25 (30DEG)			---	---	---	---
TH-F3-15 (240DEG)			---	---	---	---
TH-F3-22 (105DEG)			---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			[illegible]-28-1	[illegible]-20-[illegible]	[illegible]-3	[illegible]-28-4
Core Heater Temperatures (Cont'd.)						
TH-G3-13 (145DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-A4-9 (105DEG)	↓	↓	D	D	D	D
TH-A4-29 (235DEG)			D	D	D	D
TH-A4-33 (135DEG)			---	---	---	---
TH-A4-39 (305DEG)			D	D	D	D
TH-B4-5 (Failed) (135DEG)			---	---	---	---
TH-B4-24 (Failed) (180DEG)			---	---	---	---
TH-B4-20 (Failed) (300DEG)			---	---	---	---
TH-C4-20 (150DEG)			---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Cont'd.)						
TH-C4-26 (75DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-C4-53 (300DEG)	↓	↓	D	D	D	D
TH-D4-21 (open) (225DEG)			---	---	---	---
TH-D4-29 (315DEG)			D	D	D	D
TH-D4-14 (265DEG)			D	D	D	D
TH-E4-9 (180DEG)			D	D	D	D
TH-E4-28 (270DEG)			---	---	---	---
TH-E4-28 (90DEG)			D	D	D	D
TH-E4-55 (0DEG)			D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-1
Core Heater Temperatures (Cont'd.)						
TH-F4-29 (160DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-F4-44 (210DEG)	↓	↓	D	D	D	D
TH-F4-14 (90DEG)	↓	↓	D	D	D	D
TH-G4-29 (305DEG)	↓	↓	D	D	D	D
TH-G4-38 (35DEG)	↓	↓	D	D	D	D
TH-G4-33 (225DEG)	↓	↓	D	D	D	D
TH-H4-60 (45DEG)	↓	↓	---	---	---	---
TH-A5-29 (180DEG)	↓	↓	D	D	D	D
TH-A5-45 (260DEG)	↓	↓	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Cont'd.)						
TH-A5-60 (345DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	---	---	---	---
TH-B5-9 (345DEG)	↓	↓	---	---	---	---
TH-B5-33 (45DEG)	↓	↓	D	D	D	D
TH-B5-29 (155DEG)	↓	↓	D	D	D	D
TH-B5-38 (235DEG)	↓	↓	---	---	---	---
TH-C5-28 (320DEG)	↓	↓	D	D	D	D
TH-D5-39 (135DEG)	↓	↓	---	---	---	---
TH-D5-9 (45DEG)	↓	↓	---	---	---	---
TH-D5-29 (225DEG)	↓	↓	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (contd.)						
TH-E5-25 (90DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-E5-21 (180DEG)	↓	↓	---	---	---	---
TH-F5-26 (165DEG)			D	D	D	D
TH-F5-33 (315DEG)			D	D	D	D
TH-F5-53 (30DEG)			D	D	D	D
TH-F5-20 (255DEG)			D	D	D	D
TH-G5-24 (335DEG)			D	D	D	D
TH-G5-14 (45DEG)			D	D	D	D
TH-H5-8 (315DEG)			---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (contd.)						
TH-H5-32 (45DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-B6-14 (0DEG)	↓	↓	---	---	---	---
TH-B6-29 (45DEG)			D	D	D	D
TH-B6-61 (210DEG)			---	---	---	---
TH-C6-53			---	---	---	---
TH-C6-32 (225DEG)			---	---	---	---
TH-D6-25 (255DEG)			D	D	D	D
TH-D6-14 (90DEG)			D	D	D	D
TH-E6-37 (335DEG)			D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location/Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Contd)						
TH-E6-8 (150DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-E6-28 (285DEG)	↓	↓	D	D	D	D
TH-F6-28 (215DEG)			---	---	---	---
TH-F6-9 (0DEG)			---	---	---	---
TH-F6-28 (Failed) (150DEG)			---	---	---	---
TH-G6-33 (135DEG)			---	---	---	---
TH-C7-15 (250DEG)			D	D	D	D
TH-C7-7 (350DEG)			D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd.)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (Cont'd.)						
TH-D7-20 (65DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-E7-44 (195DEG)	↓	↓	D	D	D	D
TH-E7-13 (45DEG)			---	---	---	---
TH-F7-29 (open) (150DEG)			---	---	---	---
TH-F7-33 (Failed) (45DEG)			---	---	---	---
TH-F7-39 (210DEG)			---	---	---	---
TH-D8-26 (180DEG)			D	D	D	D
TH-D8-33 (255DEG)			---	---	---	---
TH-D8-57 (0DEG)			---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Core Heater Temperatures (contd.)						
TH-E8-14 (155DEG)	2300°F 100 msec 1% F.S.	Heater pin metal temperature	D	D	D	D
TH-E8-45 (305DEG)	↓	↓	---	---	---	---
TH-E8-29 (225DEG)			D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			[illegible]	[illegible]	[illegible]	-28-4
Momentum Flux (Core)						
FDVCOR-153 (90° EL 152.5)	10-1000 lbm/ft-sec2 20 msec 5% F. S.	In core flow mixer box	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Test Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Flow Velocity or Volumetric Flow Downcomer Core						
FTV-22M (180DEG)	75 ft/sec 10 msec 1% F.S.	In downcomer gap 22" below cold leg centerline or ~12" below downcomer entrance, 180°	---	---	---	---
FTV-40A (0DEG)		In downcomer gap 40" below cold leg centerline or ~30" below downcomer entrance, 0°	D	D	D	D
FTV-40G (90DEG)		In downcomer gap 40" below cold leg centerline or ~30" below downcomer entrance, 90°	---	---	---	---
FTV-40M (180DEG)		In downcomer gap 40" below cold leg centerline or ~30" below downcomer entrance, 180°	D	D	D	D
FTV-83A (0DEG)	36 ft/sec 10 msec 1% F.S.	In downcomer gap 83" below cold leg centerline or ~73" below downcomer entrance, 0°	---	---	---	---
FTV-83G (90DEG)		In downcomer gap 83" below cold leg centerline or ~73" below downcomer entrance, 90°	---	---	---	---
FTV-83M (180DEG)		In downcomer gap 83" below cold leg centerline or ~73" below downcomer entrance, 180°	---	---	---	---
FTV-130M (180DEG)		In downcomer gap 130" below cold leg centerline or ~120" below downcomer entrance, 180°	D	D	D	D
FTVCOR-160 (315DEG EL 159.7)	10-500 gpm 10 msec 1% F.S.	Entrance to core	A	A	A	A

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Cont'd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Locat'on [illegible]	[illegible]	[illegible]	[illegible]	28-4
Density (Vessel)						
GV-150 (0-180DEG)	.1-100 lb/ft^3 20 msec .5 F.S.	In core flow mixer box horizontal shot 150" below cold leg centerline	A	A	A	A
GV-165		In upper part of lower plenum 165" below cold leg centerline or 1.724" below downcomer exit horizontal shot	D	D	D	D
GV-172 (90-270DEG)		In lower plenum 172" below cold leg centerline or 8.729" below downcomer exit horizontal shot	D	D	D	D
GV-178 (90-270DEG)		In lower plenum 178" below cold leg centerline or 14.724" below downcomer exit horizontal shot	---	---	---	---
GV161/192 (270-90DEG)	.1-100 lb/ft^3 20 msec .5% F.S.	Lower plenum diagonal density shot 31" vertical distance; 32.2" diagonal distance	---	---	---	---

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VI (Contd)

VESSEL AND CORE

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Test Used On			
			L-28-1	L-28-2	L-28-3	L-28-4
Power						
PWRCOR-T1 (Total power)	1.45 MW 20 msec 1% F.S.	Core heater pin total power	D	D	D	D
PWRCOR-T2 (Total power)	1.45 MW 20 msec 1% F.S.	Core heater pin total power	D	D	D	D
VOLTCOR-T	200 Vac 1% F.S.	Voltage to total core	D	D	D	D
AMPCOR-T	10,000 A 1% F.S.	Current to total core	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VII

PRESSURE SUPPRESSION SYSTEM

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Pressure						
P-PPS (top of tank)	0-250 psi 10 msec. 1% F.S.	Pressure suppression tank top	D	D	D	D
Differential Pressure						
DP-PSS-TB (EL 130)	0-100 in. H_2O 20 msec. 1% F.S.	From near top of tank (129.54" from bottom) to bottom	D	D	D	D
Fluid Temperature						
TF-PPS-0 (EL 0)	650°F 100 msec .5% F.S.	Elevation in parentheses is from bottom of PSS tank	---	---	---	---
TF-PSS-17 (EL 17)	↓	↓	---	---	---	---
TF-PPS-33 (EL 33)			D	D	D	D
TF-PPS-48 (EL 48)			---	---	---	---
TF-PPS-63 (EL 63)			---	---	---	---
TF-PPS-130 (EL 130)			D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VIII

COOLANT INJECTION SYST[illegible]M

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location [illegible]	Tests Used On [illegible]			
			[illegible]	[illegible]	[illegible]	-28-4
Pressure						
PU-ACC1	750 psi 10 msec 1% F.S.	In accumulator (CI-T-1) connecting to the unbroken loop cold leg (Spool 14)	D	D	D	D
PB-ACC2		In accumulator (CI-T-2) connecting to the broken loop cold leg (Spool 42)	D	D	D	D
Differential Pressure						
DPB-ACC2-TB	5 psi 20 msec 1% F.S.	Top to bottom of accumulator CI-T-2 (broken loop)	D	D	D	D
DPU-ACC1-TB	5 psi 20 msec 1% F.S.	Top to bottom of accumulator CI-T-1 (intact loop)	D	D	D	D
Fluid Temperature						
TFECC1-14	0-150°F 100 msec .5% F.S.	Intact loop cold leg ECC injection fluid temperature in line leading to spool 14	D	D	D	D
TFECC2-42	0-150°F 100 msec .5% F.S.	Broken loop ECC fluid temperature in line leading to spool 42	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

TABLE VIII (Cont'd)

COOLANT INJECTION SYSTEM

Detector ID Descriptive Title	Range, Response* Accuracy** (F.S.=Full Scale)	Location Comments	Tests Used On			
			S-28-1	S-28-2	S-28-3	S-28-4
Volumetric Flow						
FTU-ACC1	0-75 gpm 10 msec 1% F.S.	In accumulator line connecting to the unbroken loop cold leg (Spool 14)	D	D	D	D
FTB-ACC2	0-35 gpm 10 msec 1% F.S.	Broken loop accumulator	D	D	D	D
FTU-LPIS	0-5 gpm 10 msec 1% F.S.	In line leading either to unbroken loop or vessel	D	D	D	D
FTB-LPIS	0-2 gpm 10 msec 1% F.S.	In line leading from LPIS to broken loop	D	D	D	D
FTU-HPIS		In line to vessel or unbroken loop, immediately after HPIS	D	D	D	D
FTB-HPIS		In line to broken loop, immediately after HPIS pump	D	D	D	D

*Response means the rise time (for a step input from 10 to 90% of the full scale).

**Accuracy is referenced to the steady state full scale.

IV. OPERATIONAL REQUIREMENTS AND INITIAL CONDITIONS

The operational requirements and initial conditions specified in this section are based on reproducing in so far as possible the pre-blowdown conditions and controlled component activities expected to occur in a simulated LOCA.

The operational requirements described in this section include pre-experiment system and instrumentation preparations, operational requirements during system heatup and approach to power, and operational requirements relative to the component control activities associated with the blowdown and reflood experiments. The component control activities that affect blowdown behavior and are therefore specified as operational requirements are:

(1) Core power versus time.

(2) Coolant pump speed versus time.

(3) Steam generator steam discharge valve closing.

(4) Simulated break characteristics.

The specified core power versus time following break initiation is based on producing the same heat flux at the local peak power area of the core as is predicted to occur in a typical nuclear core. Power control will be identical to that specified for Series 4 tests (Reference 2); the rationale for selecting the electrical power decay rate is given in Reference 2. The initial power level was selected to permit continual operation throughout the experiment without occurrence of a high temperature trip.

The coolant pump speed requirements following blowdown initiation are based on modeling the predicted reference plant coolant pump coastdown transient assuming pump power is tripped at break time. The Mod-1 pump has disproportionately high friction torque relative to the reference plant pump, hence power must be reapplied when the pump speed coasts down to 61% of the initial speed to provide a modeled reference plant pump coastdown behavior.

The steam generator steam discharge valve will be operated so as to approximate the behavior of a pressurized water reactor. The valve will be tripped closed 1 second after break initiation and will close in the order of 0.6 to 1 second. In the Mod-1 system, the steam valve closure will be controlled by the experiment sequence controller. The steam generator feedwater valve will be closed simultaneously with the steam valve.

The break simulation will provide simultaneous rupture of the two Mod-1 burst disc assemblies to simulate a double-ended break LOCA.

The initial (i.e., preblowdown) operating conditions that affect blowdown behavior and are therefore equated to the corresponding reference plant initial conditions are:

(1) Fluid temperature differential across core.

(2) Fluid temperature in operating loop cold leg.

(3) Steam generator level and steam generator tube rupture water source (accumulator) level, temperature and pressure.

(4) Pressure in pressurizer.

(5) Liquid to steam vo' ıme ratio in pressurizer.

(6) Pressure suppression system conditions (pressure, temperature, and water level).

(7) The conditions of the accumulators as specified in Table I.

The core heater power level is an initial condition that is related to the corresponding reference plant parameters by the ratio of primary system volumes.

1. OPERATIONAL REQUIREMENTS

1.1 Water Quality

The system shall be filled and vented with water conforming to the following water chemistry requirements (the specified values are standard temperature and pressure conditions).

pH	9.0 - 10.5
Conductivity	3-70 μmhos/cm
Lithium	0.3 - 212 ppm
Chloride	0.15 ppm (maximum)
Fluoride	0.10 ppm (maximum)
Oxygen	0.10 ppm (maximum)
Total gas	100 cc/kg (maximum)

Water samples will be taken prior to blowdown and analyzed posttest for content. The results of this analysis will be given in the test report.

1.2 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.

1.3 Differential Pressure Cell Zeroing and Orientation

All air should be bled from the pressure transducers and lines. With the system full of cold water, all DP cells should read zero prior to each warmup. The various cells should be oriented with high side tap connected to the first number in the instrument list (e.g., DPU-15-1 would have the high side tap connected to spool 15 and the low side tap connected to spool 1).

1.4 Order of Testing

The tests for Test Group 28 will be conducted in the following order: S-28-1, S-28-2, S-28-3, and S-28-4.

1.5 Placement of Calibration Steps in Data

It is required that calibration steps do not occur on the data during or within 2 seconds of the following events: blowdown, ECC injection, core quench during reflood, and system drain.

1.6 Visual Monitoring of High Power Rod Temperatures

In spite of the automatic trip functions built-in to the Mod-1 core power control, it is suggested that a visual readout of the high power rod temperatures most likely to experience DNB be supplied. The visual readout could simply be a high speed chart recorder. During the approach to power, prior to blowdown, an observer with capability for manual override of core power control, should monitor the visual readout for indication of prerupture DNB as a backup to the automatic power control system. The rod thermocouples which should be monitored are given below:

TH-D4-29	TH-B6-29	TH-D8-26
TH-E4-28	TH-E5-20	TH-D1-21

If, during steady state operation at full power, any one of these thermocouples indicates a temperature in excess of the trip temperature of 1250°F without automatic power trip, the manual override should be implemented.

2. SEQUENCE OF EVENTS

Table IX shows the sequence of events prior to, during, and after rupture. Included in this table is the system hydro and warmup. The actual operations associated with performing the events specified in Table IX are discussed in the following section. Additional events associated with representation of the steam generator tube ruptures are dealt with in Addendum 28-B.

2.1 System Leak Test

In the system leak test, the system is brought from 0 to 2250 psig and back to 0 psig in intervals of 500 psig. 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.

2.2 System and Accumulator CI-T-3 Warmup

In the system warmup, the system is brought from ambient conditions to the operating temperature of 544°F (Tests S-28-1 through S-28-4). All data should be recorded and displayed on the DDAPS at intervals specified in Table IX for the flow and no-flow cases. The pump must have the capability of starting at high pressure and temperature. It is required that the system be maintained at 544°F for approximately 10 minutes prior to approach to power to insure that system piping and fluid temperatures are stabilized.

Accumulator CI-T-3 will be used in the simulation of steam generator tube ruptures. A heat up period will be required to allow the specified conditions to be achieved (Tables I and IX).

2.3 Rod Thermal Behavior Repeatability Test

The Mod-1 heater rod thermal characteristics will possibly change with blowdown (and reflood) cycling. It is necessary to have information on the possible changes in the rods thermal behavior 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 for evaluation of the rod thermal behavior.

(1) The temperature level for switching the core power off will be set at 1250°F to insure no core damage will result from this test.

(2) The system will be heated at 100% flow rate (17.40 lb_m/sec) until the core inlet temperature reaches 400 $\pm$10°F. There will be no flow in the steam generator secondary side.

(3) The core power will be maintained constant (for greater than 5 minutes) until the core inlet temperature stabilizes within 2°F.

(4) When the core inlet temperature stabilizes, the core voltage will be step increased to 117 volts for 10 seconds and then returned to its original level.

TABLE IX

SEQUENCE OF EVENTS, MOD-1 STEAM GENERATOR TUBE RUPTURE TEST SERIES

Event		Time of Application
1.	Fill and vent primary system and establish water chemistry including that in the accumulator CI-T-3.	Several hours before blowdown
2.	Establish the proper water volume and heat the accumulator CI-T-3 until the temperature reaches the specific value listed in Table I. The temperature should be maintained until the initiation of blowdown.	8 hours before blowdown
3.	Zero adjust DP cells	
4.	Perform system hydro	
5.	Instrumentation systems warmup and checkout	
6.	System warmup to 544°F isothermal	Flow and no-flow DDAPS data at RBU-2 = amb, 100, 200, 300, 400 and 500°F
7.	Establish core power level	Approximately 10-15 minutes before blowdown
8.	Take primary system water sample	When RBU-2 indicates 544°F
9.	Verify that the specified system initial conditions exist	At specified core power before blowdown
10.	Vent accumulator CI-T-3 injection line until the fluid temperature stabilizes at approximately 525°F	
11.	Valve out broken loop conditioning circuits and re-establish core flow and core ΔT by pump speed	
12.	Re-verify that the specified system initial conditions exist prior to blowdown	Up to 20 seconds before break initiation
13.	Makeup pump off and pressurizer heaters off	One (1) second before break initiation

TABLE IX (contd.)

SEQUENCE OF EVENTS, MOD-1 STEAM GENERATOR TUBE RUPTURE TEST SERIES

Event	Time of Application
14. Initiate blowdown (burst rupture discs)	Reference time = 0
14.1 Switch to the specified transient core power control	
14.2 Trip pump power	
15. Trip steam generator discharge valve closed	Reference time t = 1 sec.
16. Reestablish pump power to maintain speed of .61 x the initial speed	When pump speed coasts down to 61% of the initial speed
17. Initiate ECC injection (manual)	As specified in Table I.
18. Initiate accumulator CI-T-3 injection and subsequent valve closure (automatic) Initiate steam generator secondary side bleed.	As specified in Table I.
19. Record hand data	When PV+10 = P-PSS
20. Trip main core power breaker	
21. Trip intact loop pump power	
22. Drain system from low points	

(5) The DDAP and analog data systems will measure all data specified in Tables IV through VIII for the test to be conducted and a magnetic tape will be generated.

2.4 Approach to Power

(1) With all safety trip functions activated and the experimental measurements specified for each test continuously recorded on the digital system, increase core power in a smooth ramp to 1.08 MW (75%). Take warmup data when system is stabilized.

(2) Ramp the core power up in successive, discrete steps, permitting sufficient time between steps for the steam generator secondary steam temperature to stabilize. For tests numbered S-28-1 through S-28-4 the maximum core power to be applied is 1.44 MW.

0.5 MW - record data

1.2 MW - record data

full power - record data

2.5 Transient Core Power Control Following Blowdown Initiation

As noted in Table IX, the core power is switched to transient control simultaneous with break initiation. The required core power as a function of time after break initiation is shown in Figure 11. In addition, if the core power is tripped by a high heater rod temperature indication prior to the end of system blowdown, the core power will be

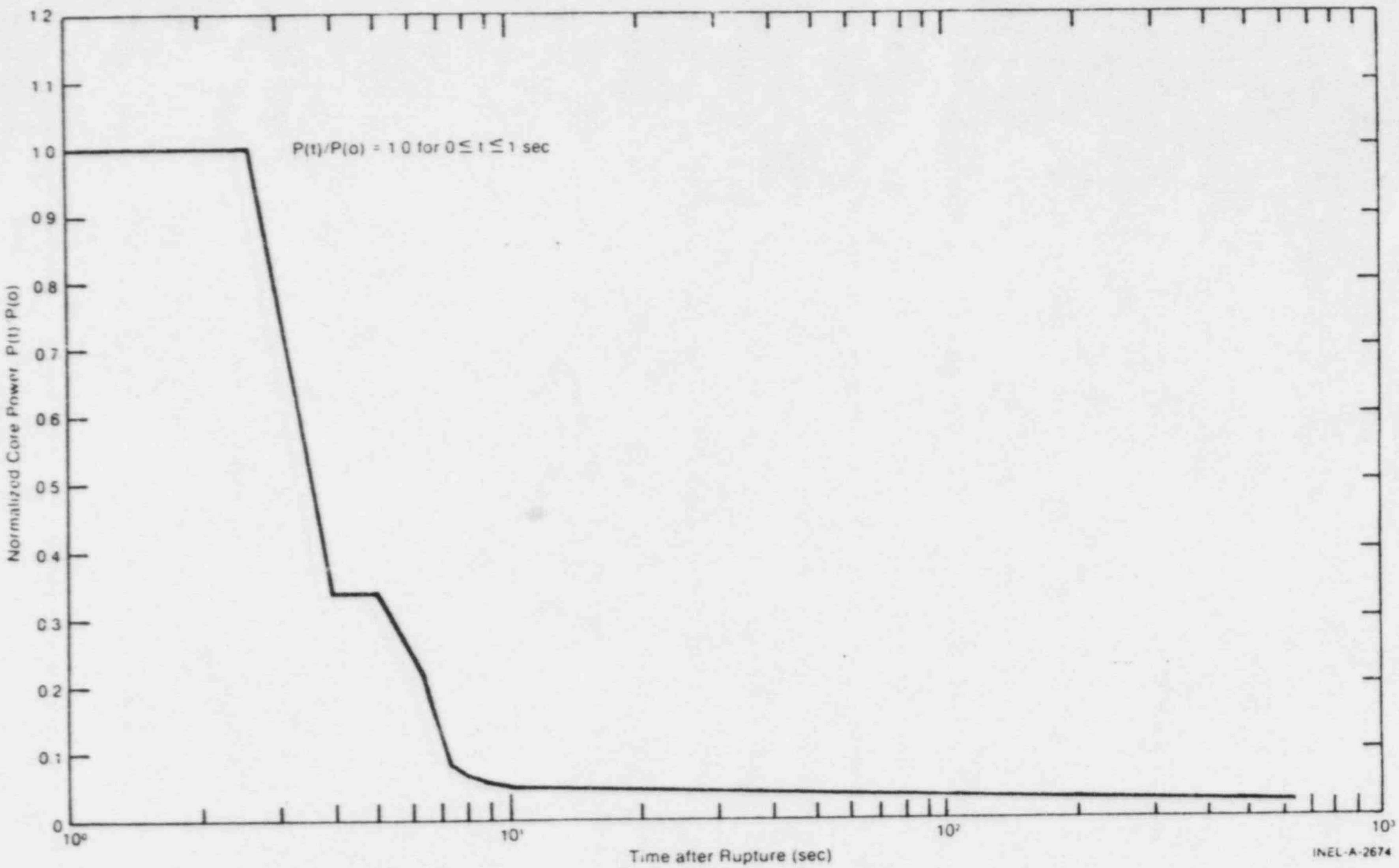


Figure 11. Core Power Contorl Curve After Break Initiation

tripped to 0.10 MW as long as the hottest heater rod temperature is less than 1800°F. At an indicated temperature of 1800°F, core power is tripped to zero. The heater trip point temperature is a linear function of core power level defined by the following, based on a maximum core total power of 1.6 MW:

Core Power (%)	Core Trip Temperature (°F)
100	1250
6	1800

2.6 Coolant Pump Speed

(1) During system heating to isothermal conditions and approach to power, the pump speed is to be set at the value that produces a core flow rate indicated by FTVCOR-150 of 165 gpm.

(2) When the final value of steady state core power has been applied, the pump speed may require adjustment to produce the required value of vessel temperature differential. The temperature differential is increased by reducing pump speed and the temperature differential is reduced by increasing pump speed. Before adjusting pump speed, verify that the core flow is within 5 gpm of the intact loop flow rate: FTVCOR-150 = FTU-15 (within 5 gpm).

(3) With the above conditions verified, adjust the pump speed slowly to produce the required fluid temperature differential (hot leg to cold leg ΔT = RBU-2 minus RBU-14) of 66°F $\pm$1°F.

(4) When the broken loop pre-conditioning lines are valved out prior to the blowdown experiment, the resulting flow redistribution will require readjustment of the pump speed to maintain the previously established value of core flow rate defined by the required vessel fluid temperature differential.

(5) The transient pump speed during a blowdown experiment is required to approximate the reference plant coastdown resulting from a pump power trip simultaneous with break initiation. For Tests S-28-1 through S-28-4, the pump power shall be tripped at the break time, but when the pump speed drops to 61% of the initial value, pump power must be reapplied to maintain the speed at that level (approximately 1465 rpm).

2.7 Steam Generator Valve Control

During steady state operation preceding the blowdown experiments, the steam generator discharge and feedwater valves are positioned by automatic controllers which control primary system cold leg fluid temperature and steam generator secondary water level, respectively. For all Series 28 tests the steam discharge valve is to be tripped closed 1 second after break initiation. The valve closure time is estimated to be in the order of 0.6 to 1 second. The secondary feedwater valve will be closed simultaneously with the steam valve. The steam generator secondary fluid discharge valve will be opened simultaneously with the vessel accumulator injection line valve and remain open for the duration of the test.

2.8 Accumulator CI-T-3 Valve Control

Immediately before rupture, excess fluid in accumulator CI-T-3 will be vented through a bleed valve positioned so that heated water will be close to the injection point in Spool Piece 6. The venting will be terminated before rupture. The air-operated valve in the injection line will be actuated to the fully open position by a timer 40 seconds after rupture. The valve will be closed automatically at the time specified in Table I.

2.9 Broken Loop Fluid Conditioning Circuit Control During System Heatup and Approach to Power

The fluid in the broken loop cold and hot legs is circulated in parallel with the unbroken loop cold leg and hot leg respectively to provide the correct fluid temperatures in the broken loop prior to blowdown. These circuits are to be valved out a sufficient amount of time in advance of blowdown to permit adjustment of pump speed to preserve the steady state core flow rate.

3. INITIAL CONDITIONS

The values of the Semiscale Mod-1 system variables that must be established and maintained preceding the steam generator tube rupture tests are shown in Table X. It is required that the variables be stable and within the tolerances shown in Table X at the time the experiments are initiated. The suggested instrumentation that can be used to monitor the stated initial variable conditions is also designated in the table.

TABLE X

INITIAL CONDITIONS PRECEEDING STEAM GENERATOR TUBE RUPTURE TESTS

(1) Core power (PWRCOR-T1) = 1.42 - 1.44 MW

(2) Cold leg fluid temperature (RBU-14A) = 544 ± 2°F

(3) Hot to cold leg temperature differential (RBU-2)-(RBU-14A) = 66.0 ± 1°F

(4) Pressurizer pressure (PU-PRIZE) = 2250 ± 5 psig

(5) Pressurizer liquid mass = 20.0 lbm

(6) Maximum primary system leakage (FTU-HPIS+FTB-HPIS) < 1.5 gpm

(7) Steam generator feedwater temperature (TFU-SGFW) = 435 $^{+10°F}_{-30°F}$

(8) Steam generator secondary liquid level (DPU-SG-SEC) = 116 ± 2 in.

(9) Broken loop heatup bypass lines closed

(10) Fluid temperature in broken loop (TFB-30) = 600 - 610°F

(11) Metal temperature, vessel filler (TMVFO-156A) = RBU-14 $^{+0}_{-5}$ °F

(12) Metal temperature, core barrel (TMV-CI-35A) = RBU-2 $^{+0}_{-5}$ °F

(13) Metal temperature, unbroken loop hot leg (TMU-1B16) = RBU-2 $^{+0}_{-5}$ °F

(14) Metal temperature, broken loop hot leg (TMB-30B16) = RBU-2 $^{+0}_{-5}$ °F

(15) PSS tank water volume (DP-PSS-TB) = level corresponding to 30 ft^3

(16) PSS tank water temperature (TF-PSS-33) = ambient

(17) PSS tank water pressure (P-PSS) = 22.5 ± 1 psig

(18) Accumulator CI-T-3 and ECC accumulator conditions per Table I.

V. SYSTEM CONFIGURATION, INSTRUMENTATION AND OPERATIONAL REQUIREMENTS TO BE EMPHASIZED

To accomplish the objectives of the series of tests specified in this Appendix to the EOS, a restatement of those test elements which differ from prior tests or are considered critical to the successful conduction of the tests is advisable. It is thus the intent of this section of the Appendix to emphasize these elements and their importance. This information, together with the test specification check lists generated as required for each test, should minimize problems in preparing for and in conducting each test and maximize the value of the test data in the analysis of test results.

1. SYSTEM CONFIGURATION

As presented in Section II of this Appendix, the basic system configuration will duplicate that used in Test S-04-6 with a 200% cold leg break. Intact loop ECC injection (accumulator, LPIS, and HPIS) will be into the cold leg (spool piece 14); broken loop ECC injection (accumulator, LPIS, and HPIS) will also be into the cold leg (spool piece 42). Unpowered rods in the bundle will be C-3, D-5, F-3, and F-6; powered rods D-4, E-4, and E-5 will operate at a 5% higher power level than the remaining 33 powered rods. The power decay curve for the powered rod bundle is given in Figure 11.

The principal difference between this series of tests and preceding groups is the use of accumulator CI-T-3 to simulate steam generator tube leakage by injection of hot water just upstream of the steam generator

inlet (spool piece 6). Flow tests are required to establish the hydraulic resistance (R') for the injection line. No system hardware changes are planned between tests. Detailed test parameters are given in Table I.

2. SYSTEM INSTRUMENTATION

The primary objective of the Series 28 tests is to evaluate the effect of a range of steam generator tube ruptures assumed to occur in the period when secondary pressure exceeds primary system pressure following a LOCA. Certain instrumentation requirements are of special significance in assessing the effects of tube rupture. These instrumentation functions are listed in Table XI by instrument identification nomenclature; details on each instrument requirement may be found in Tables IV through VII as appropriate.

TABLE XI

INSTRUMENTATION OF SPECIAL SIGNIFICANCE

PU-SG-S3-T

DPU-SGS-5

DPU-SGS3TB

TFU-SGS

TFU-SGS3-B

FTU-SGS-L (or FTU-SGS-H)

3. INITIAL CONDITIONS AND OPERATIONAL REQUIREMENTS

Detailed descriptions for each individual test are presented in Subsection 3 of Section I. The following points should be emphasized:

(1) Time for taking test data is from -20 to 640 seconds (referenced to time of rupture).

(2) Accumulator CI-T-3 flow is to be initiated 40 seconds after the cold leg break.

(3) Injection of accumulator CI-T-3 water should be terminated in time to prevent nitrogen injection into the primary system.

REFERENCES

1. P. M. Lang letter to P. E. Litteneker, PML-32-74, Transmittal of Mod-1 Operating Specifications, January 31, 1974.

2. J. O. Zane letter to R. E. Swanson, Zan-74-76, Transmittal of Semiscale EOS Appendix 4, March 29, 1976.

3. J. O. Zane letter to P. E. Litteneker, Zan-250-76, Transmittal of Quick Look Report for Semiscale Mod-1 Integral Blowdown Reflood Tests S-04-5 and S-04-6, October 15, 1976.

4. J. O. Zane letter to P. E. Litteneker, Zan-248-76, Transmittal of Semiscale EOS Appendix 5, October 13, 1976.

5. P. M. Lang letter to R. E. Swanson, PML-317-74, Revision 1 to Semiscale EOS Appendix 1, March 17, 1974.

6. J. O. Zane letter to R. E. Swanson, Zan-31-75, Transmittal of Semiscale EOS Appendix 2, March 17, 1975.

7. J. O. Zane letter to R. E. Swanson, Zan-27-75, Transmittal of Semiscale Program Description Document, March 10, 1975.

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

9. SDD-1, Semiscale Mod-1 System Design Description.

Addendum 28-A

to

Appendix 28 of the Semiscale Mod-1
Experiment Operating Specifications

The Analysis of the Effects of Steam Generator Tube
Ruptures on Peak Rod Cladding Temperature During a
200% Cold Leg Break LOCA

This addendum is a summary of the analysis performed to investigate the effects of a rupture of tubes in the steam generator on the peak rod cladding temperature reached during a 200% double-ended cold leg break. The effect of the magnitude of the secondary to primary mass flow rate and the time during the loss-of-coolant accident (LOCA) at which the tubes ruptured was included in this study. For the purpose of this study the assumption was made that the tube ruptures occurred at the inlet plenum of the intact loop steam generator.

To provide a basis for comparing the relative magnitudes of the secondary to primary mass flow rates between the Semiscale Mod-1 system and a PWR system, the mass flow rates are presented in terms of numbers of single ended tube ruptures in a PWR steam generator. Thus, in discussing the response of the Semiscale Mod-1 system to a given secondary to primary mass flow rate, the number (or range) of single ended tube ruptures that would provide an equivalent secondary to primary mass flow rate in a PWR steam generator is specified.

The analysis for this study was performed in two parts depending on the number of ruptured tubes. This division was a result of different hydraulic phenomena that would occur for a small number of ruptured tubes (0 to 12) than would occur for a larger number of ruptured tubes (50 to 120). The RELAP4 and FLOOD4 computer codes were used for the analysis of the smaller number (0 to 12) of ruptured tubes. The RELAP4

code was used to investigate the effect of steam generator tube ruptures on the temperature until the initiation of reflood and the FLOOD4 code was used to calculate the sensitivity of the peak rod temperatures to the number of ruptured tubes during reflood. The analysis for the larger number (50 to 120) of ruptured tubes made use of the RELAP4 code, data from the baseline test (Test S-04-6), and the FLOOD4 code. The RELAP4 calculations and Test S-04-6 data were used to establish the rod cladding temperatures that were used as input to the FLOOD4 code. The FLOOD4 code was then used to calculate the sensitivity of the peak rod cladding temperature during reflood to the number of ruptured tubes.

1. ANALYSIS OF SEMISCALE MOD-1 SYSTEM FOR TUBE RUPTURES EQUIVALENT TO THE RUPTURE OF BETWEEN 0 AND ABOUT 12 PWR STEAM GENERATOR TUBES

An analysis was conducted to determine the effect of the rupture of a very small number of steam generator tubes (equivalent to between 0 and 12 tubes in a PWR steam generator) during reflood on the peak cladding temperature in the Semiscale Mod-1 core. The range of tube ruptures considered for this analysis was such that positive core flow persisted during reflood despite the increased steam binding problem resulting from the secondary-to-primary flow associated with the steam generator tube ruptures. For this analysis the steam generator tube ruptures were assumed to occur at the initiation of reflood.

To establish the proper system conditions at the initiation of reflood, it was first necessary to evaluate the effect of a small number of steam generator tube ruptures on the core response during blowdown.

For this purpose, a RELAP4 calculation for a PWR system was performed. The following subsections discuss the models and results of the analysis for both the blowdown and reflood phase of the LOCA with a small number of rupture steam generator tubes.

1.1 Model and Results when Rupture of a Small Number of Steam Generator Tubes Occurs During Blowdown

To investigate the effect on the core and system response of a rupture of a small number (10) of steam generator tubes, a RELAP4 calculation for a PWR was performed. For this calculation the tube ruptures were assumed to occur during the blowdown at the instant at which the primary pressure was less than the secondary pressure. The RELAP4 calculation was stopped 30 seconds after the LOCA due to the expense of running the code; however, it was expected that the results for the initial 30 seconds after the LOCA would be typical of results until the completion of refill.

A comparison of the RELAP4 calculations for the case with steam generator tube ruptures to the RELAP4 calculation for the case without steam generator tube ruptures indicates that the system and core response were not significantly affected. For the RELAP4 calculations that included rupture of 10 steam generator tubes, the intact loop pressure increased by about 20 psia and the core hot spot temperature decreased by about 20°F. Overall, it was concluded that a rupture of a small number of steam generator tubes in a PWR system would not significantly effect the core and system response during blowdown.

Based on these results for a PWR, it was concluded that the rupture of an equivalent small number of steam generator tubes in the Semiscale Mod-1 system also would not effect the core and system response. Therefore, the conditions that were measured at the initiation of reflood for the baseline test (Test S-04-6), would exist for other tests with nominally identical initial conditions.

1.2 Model and Results When Rupture of a Small Number of Steam Generator Tubes Occurs at the Initiation of Reflood

To investigate the effect on the peak rod cladding temperature of the rupture during reflood of small numbers of steam generator tubes, a series of FLOOD4 calculations was performed for the Semiscale Mod-1 system. The sensitivity of the calculated peak rod cladding temperature to the number of ruptured tubes was evaluated by changing the mass flow injected into the upper plenum (which is the same as the hot leg in the FLOOD4 model).

The input for the FLOOD4 model for this study was based on Test S-04-6 data. As discussed in Section 1.1, the RELAP4 results indicated that the rod cladding temperatures during blowdown would not be significantly affected by the rupture of a small number of steam generator tubes. Therefore, for this study, a peak rod cladding temperature of 1450°F (obtained from thermocouple TH-D8-26) was used as the peak temperature at the initiation of reflood.

The fraction of the mass flow from the steam generator that flashes to steam in the primary system is required as input for the FLOOD4 model. Based on an isenthalpic calculation for typical conditions, it was calculated that about 30% of the mass from the steam generator would be flashed to steam. This percentage was used in the FLOOD4 calculations.

A series of FLOOD4 calculations for the Mod-1 system with steam generator tube ruptures equivalent to ruptures in a PWR ranging from 0 to about 12 tubes was performed. This range of ruptured tubes corresponds to mass flows from the steam generator of from 0 to about 0.24 lb/sec. in the Semiscale Mod-1 system. The results of the FLOOD4 calculations indicated for the range of from 0 to about 12 tubes ruptured, the peak rod cladding temperature increased when the number of ruptured tubes increased, as shown in Figure 28-A-1. At a mass flow rate of about 0.23 lb/sec from the steam generator (which corresponds to about 12 ruptured PWR tubes), the peak temperature was calculated to be about 1650°F. The calculation for a mass flow rate of 0.24 lb/sec from the steam generator resulted in a peak rod cladding temperature of about 1800°F and still increasing when the calculation was stopped at about 300 seconds after reflood initiation (note that 1800°F is the trip set point for the Semiscale Mod-1 core). The increase in the peak cladding temperatures for ruptures of 11 to 12 tubes is a result of a decrease in the core flow almost to the point of stagnation.

The results of the study using the FLOOD4 code and the rod cladding temperatures at the initiation of reflood from Test S-04-6, indicate that steam generator tube ruptures in the Semiscale Mod-1 system which result in mass flows greater than 0.23 lb/sec into the primary system

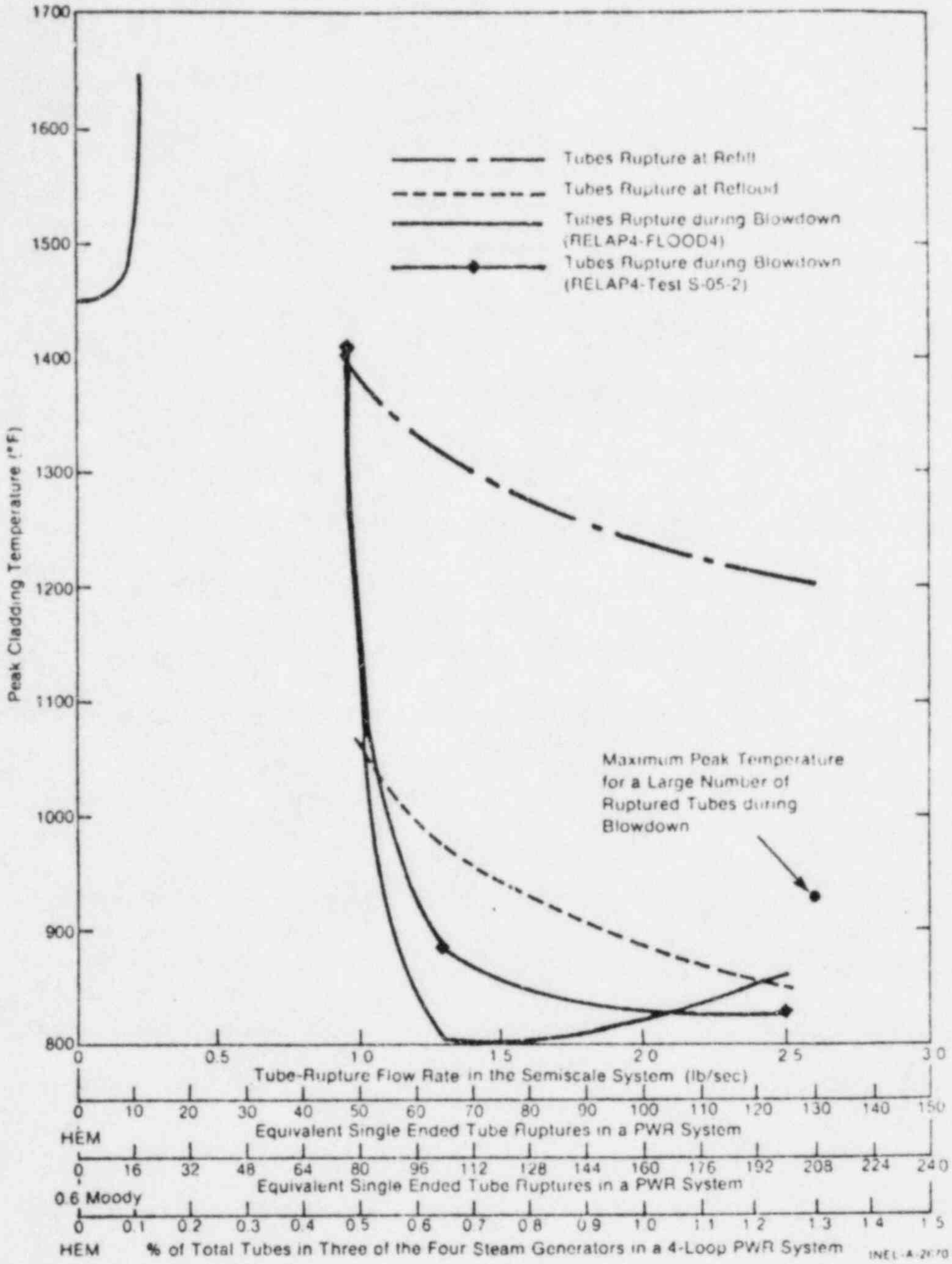


Figure 28-A-1. The Influence of the Tube Rupture Flowrate or the Number of Ruptured Tubes on the Peak Cladding Temperature

could result in high peak core temperatures. However, the FLOOD4 computer code tends to predict lower rod cladding temperatures than were measured during FLECHT-SET tests conducted at low flooding rates. Since low flooding rates were calculated by FLOOD4 in this portion of the study, it is possible that elevated peak cladding temperature could occur with steam generator rupture flows that are somewhat lower than the 0.23 lb/sec mentioned above.

2. ANALYSIS OF SEMISCALE MOD-1 SYSTEM FOR TUBE RUPTURE EQUIVALENT TO BETWEEN 50 AND 120 PWR STEAM GENERATOR TUBES

To investigate the effect of much larger numbers of ruptured tubes a different analysis model was required. For larger numbers of ruptured tubes a significant period of sustained negative core flow would result. The magnitude and duration of the negative core flow would depend on the number of ruptured tubes and when during the LOCA the tubes ruptured. Therefore, the analysis for a relatively large number of ruptured tubes included the investigation of the effect of the number of ruptured tubes as well as the effect of the time during the LOCA at which the tube ruptures occurred. For this analysis the steam generator tube ruptures were assumed to occur (1) during blowdown, (2) before the initiation of lower plenum refill, and (3) at the initiation of reflood. The following subsections discuss the models and results for this part of the study.

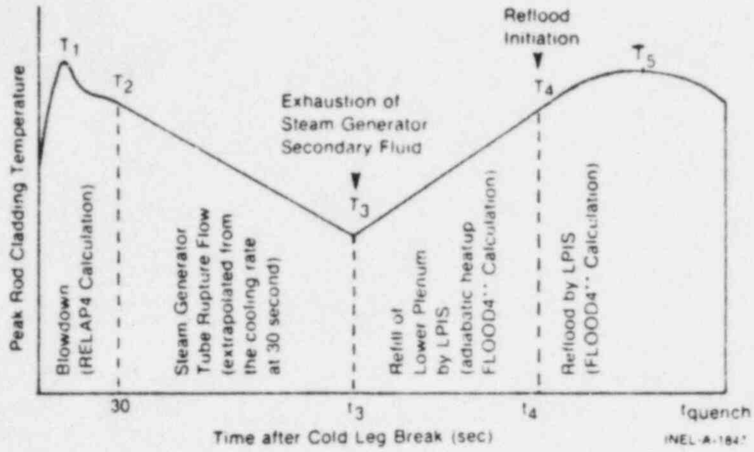
2.1 Model and Results When Steam Generator Tubes Rupture During Blowdown

The RELAP4 and FLOOD4 computer codes together with an extrapolation of RELAP4 predicted results were used to investigate the effect on the

peak rod cladding temperature of the rupture of a relatively large number of tubes during blowdown in the Semiscale Mod-1 system. The calculational technique is illustrated in Figure 28-A-2 which shows how the results of each part are coupled together to predict the final peak rod temperature during reflood.

The RELAP4 computer code was used to calculate the Semiscale Mod-1 system and core response for the initial 30 seconds after the occurrance of a 200% double-ended cold leg break LOCA. The steam generator tubes were assumed to rupture when the primary pressure became less than the secondary pressure, which occurred at about 10 seconds after the LOCA. The rod cladding temperature at the time that the steam generator was emptied was hand calculated from the RELAP4 results by assuming that the core cooling rate calculated by RELAP4 at about 30 seconds after LOCA initiation would continue until the steam generator secondary water was exhausted. The time period for the emptying of the steam generator depended on the number of ruptured tubes.

The temperature extrapolated from the RELAP4 calculations was assumed to be the peak core temperature at the initiation of the refill period. The time period for refill was estimated by assuming that the lower plenum (0.66 ft^3) must be refilled by the low pressure injection system (LPIS) flow alone. (The refill period was calculated to be about 74 seconds). The peak temperature at the initiation of refill was input into the FLOOD4 code and an adiabatic heat-up option (h = 0.0) was used for 74 seconds to calculate the temperature at the initiation of reflood. The reflood of the core using LPIS flow was then calculated with the FLOOD4 code. Several of the important temperatures and times used in this model are noted in Figure 28-A-2.



Total Rupture Mass flow (lb/sec)	Temperature (°F)					Time (sec)			Cooling Rate (°F/sec)‡
	T_1	T_2	T_3	T_4	T_5	t_3	t_4	t_5	
0.96	1305	1237	862	1205	1225	264	338	424	1.6
1.3	1305	1162	322	714	802	168	232	276	5.0
2.5	1305	1055	268	755	862	79	153	209	12.8

‡ Cooling rate calculated by RELAP4 at 30 seconds and applied during the extrapolation process.

* For Historical configuration control load module FLOOD4 103 was used for these calculations.

Figure 28-A-2. Calculation Technique When Postulated Steam Generator Tube Ruptures Occur During Blowdown

The peak rod cladding temperatures calculated for this section of the study are also shown in Figure 28-A-1. These results show that for the three cases investigated the peak temperature decreased slightly as the number of ruptured tubes decreased from about 125 to 65 and then significantly increased for about 50 ruptured tubes. The decrease in the peak temperature, as the number of ruptured tubes decreased from about 125 to 65, resulted from the fact that the heat generation is lower for the smaller number of ruptured tubes during the adiabatic heat-up. The heat generation was lower for 65 ruptured tubes because the heat-up occurred much later after the LOCA and the power calculated from the ANS power decay curve was lower. The peak rod cladding temperature does not continue to increase as the number of ruptured tubes increase. A limiting calculation was performed which assumed that the number of ruptured tubes was large enough to allow the steam generators to immediately empty at the initiation of the tube ruptures and quench the core. The heat-up for this limiting case therefore was initiated from the saturation temperature and at 30 seconds after the LOCA which results in a relatively high power calculated from the ANS power decay curve. A peak rod temperature during reflood of 930°F was calculated for this limiting case and is shown in Figure 28-A-1 for comparison purposes. Using this model, which includes a period of negative core flow, it was indicated that ruptures of less than about 50 steam generator tubes may result in elevated peak cladding temperatures. The peak cladding temperature increased for about 50 ruptured steam generator tubes mainly because of a decrease in the core flow and therefore a decrease in the core cooling during the period of steam generator emptying.

It is anticipated that several of the assumptions used in this analysis may result in higher calculated rod cladding temperatures than would actually occur. The use of an adiabatic heat-up ($h = 0.0$) may be somewhat conservative and therefore result in higher predicted peak rod cladding temperatures than would occur. The use of a heat transfer coefficient of 5 BTU/hr-ft^2-°F during the heat-up would decrease the peak rod cladding temperature by about 150°F. The potential accumulation of water in the lower plenum during the emptying of the steam generator was not included in estimating the volume of water that must be supplied by the LPIS to completely fill the lower plenum. If a smaller volume of LPIS liquid was needed to fill the lower plenum, the adiabatic heat-up would occur for a shorter period of time, which would also result in lower calculated rod cladding temperatures.

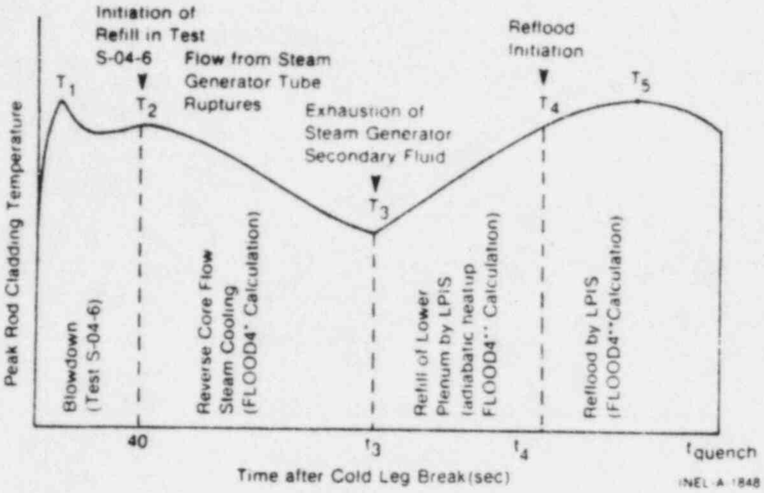
Another estimate of the peak rod cladding temperatures during reflood when the steam generator tubes ruptured during the blowdown was obtained using the results of a previous Semiscale test in which a core heat-up had occurred. It was observed that for Test S-05-2, after the injection of accumulator nitrogen, the core may have undergone an adiabatic heat-up while the LPIS flow was refilling the pump suction and lower plenum. The core then reflooded with LPIS flow. During the periods of refill and reflood the rod cladding temperatures increased by about 550°F for this test. Therefore, another estimate of the peak cladding temperature was obtained by adding 550°F to the temperatures estimated from the RELAP4 results at the initiation of refill. These points are also plotted on Figure 28-A-1 for the purpose of comparison. The results for the mass flow rates corresponding to about 125 and 65 ruptured tubes

are fairly close to the results from the previous calculations, whereas the result for the mass flow rates in the Semiscale Mod-1 system corresponding to about 50 ruptured tubes in a PWR is much higher than previously calculated. However, the general overall agreement in the resulting peak rod cladding temperatures calculated by the two methods is encouraging.

2.2 Model and Results When Steam Generator Tube Ruptures Occur Before Refill

To determine the effect on the calculated rod cladding temperatures of the time during the LOCA at which the tubes ruptured, a series of calculations was performed assuming the steam generator tubes ruptured just before the initiation of refill. Data from Test S-04-6 were used to establish the conditions when the tubes ruptured and the FLOOD4 code was used to calculate the effect of tube ruptures on the core and systems.

Figure 28-A-3 illustrates the calculational technique used in this part of the stuc, ^s indicated on this figure the blowdown and conditions at the initiation of re\.ll were estimated from Test S-04-6 data, since the tube ruptures would not effect the system response prior to this time. It was estimated from Test S-04-6 data that refill began at about 40 seconds after the LOCA and the peak cladding temperature at 40 seconds was 1450°F. At the occurrance of the steam generator tube ruptures at 40 seconds after the LOCA it was assumed (as indicated on Figure 28-A-3)



Total Rupture Mass Flow (lb/sec)	Temperature (°F)					Time (sec)			Heat Transfer# Coefficient (BTU/hr-ft^2°F)
	T_1	T_2	T_3	T_4	T_5	t_3	t_4	t_5	
1.0	1480	1450	1024	1345	1382	282	356	451	22.4
1.3	1480	1450	925	1270	1315	226	300	391	27.7
2.5	1480	1450	765	1162	1207	137	211	296	46.7

* For historical configuration control, load module FLOOD4 102 was used for this section of the study.

** Load module FLOOD4 103 was used for this section of the study.

\# Steam cooling heat transfer coefficient.

Figure 28-A-3. Calculation Technique When Postulated Steam Generator Tube Ruptures Occur Before Refill

that reverse flow existed in the core and the core was cooled by single phase heat transfer to steam. The time period and magnitude of the steam flow depended on the number of ruptured tubes. The heat transfer from the rods to the steam during the period of reverse core flow was calculated by the FLOOD4 program using a heat transfer coefficient calculated from the Dittus Boelter correlation. The heat transfer coefficients that were used for each rupture mass flow rate are also shown in Figure 28-A-3. Since the current version of FLOOD4 is not able to calculate sustained periods of negative core flow, the initial temperature profile was reversed and positive core flow was modeled in the FLOOD4 code to perform this calculation.

As indicated in Figure 28-A-3 following the calculation of the reverse core flow and steam cooling, an adiabatic heat-up (h = 0.0) and the core reflood was calculated by FLOOD4. The model for the calculation of the 74 second adiabatic heat-up during the lower plenum refill used in this study was identical to the model discussed for this calculation in Section 2.1. Following the adiabatic heat-up the FLOOD4 code was used to calculate the core and system response during the reflood.

The results of these calculations are indicated on Figure 28-A-1. The peak rod cladding temperatures increased from about 1200°F to 1400°F when the number of ruptured tubes decreased from about 125 to 50. The higher calculated peak rod temperatures during reflood for the smaller number of ruptured tubes in this study was primarily a result of a higher rod temperature at the end of the reverse core flow and the

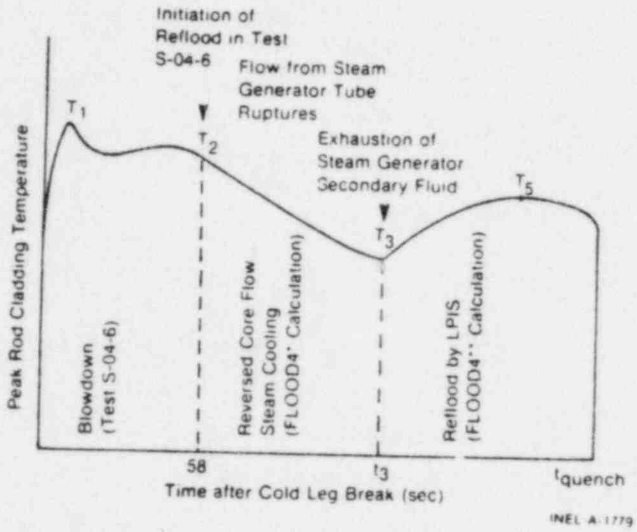
initiation of the adiabatic heat-up for the smaller number of ruptured tubes. The higher temperatures at the initiation of refill were a result of a smaller convection heat transfer to the steam during the reverse core flow due to a lower steam flow rate.

A comparison of the calculated peak rod cladding temperature for this study and the study discussed in Section 2.1 (see Figure 28-A-1), indicated that higher peak rod cladding temperatures result when the steam generator tubes rupture at the initiation of refill rather than during the blowdown.

2.3 Model and Results when Steam Generator Tube Ruptures Occur at the Initiation of Reflood

To further investigate the effect on the peak rod cladding temperature of the time during the LOCA when the steam generator tubes ruptured, an analysis was performed that assumed that the tubes ruptured at the initiation of reflood. Results from Test S-04-6 and the FLOOD4 computer code were used for this study.

As illustrated in Figure 28-A-4, data from Test S-04-6 were used to describe the blowdown and determine the rod cladding temperature at the initiation of reflood when the steam generator tubes ruptured. The tube ruptures would not effect the blowdown or refill and therefore the conditions from Test S-04-6 at the initiation of reflood will be typical of other tests. From Test S-04-6 data it was estimated that reflood was



Total Rupture Mass Flow (lb/sec)	Temperature (°F)				Time (sec)	
	T_1	T_2	T_3	T_5	t_3	t_5
1.0	1480	1450	1024	1060	300	374
1.3	1480	1450	925	975	244	311
2.5	1480	1450	765	849	155	207

* Load module FLOOD4 103 was used for these calculations

Figure 28-A-4. Calculation Technique When Postulated Steam Generator Tube Ruptures Occur at the Initiation of Reflood

initiated at 58 seconds. To provide conservatism in the calculation the peak cladding temperature obtained for Test S-04-6 (about 1450°F) was used. As illustrated on Figure 28-A-4, a period of negative core flow was assumed to occur while the steam generators were emptying. The FLOOD4 calculational technique for this period of reverse core flow was identical to the techniques used for this period discussed in Section 2.2. When the steam generators were emptied and the reverse core flow was terminated, the core reflood using LPIS flow was calculated using the FLOOD4 code as illustrated in Figure 28-A-4. The difference between the calculations of this section and the calculations discussed in Section 2.2 was the elimination of the 74 second adiabatic heat-up during which the lower plenum was refilling.

The calculated peak rod cladding temperature during reflood increased from about 860°F to 1080°F for a decrease from about 125 to 50 ruptured tubes. The increase in the peak rod temperature when the number of ruptured tubes decreased from about 125 to 50 was primarily caused by lower steam velocities and therefore lower convection heat transfer for 50 ruptured tubes during the period when the steam generators were emptying.

The peak cladding temperatures for this part of the analysis are also shown on Figure 28-A-1. A comparison of the calculated peak temperatures during reflood shown on Figure 28-A-1 shows that when the steam generator tubes rupture at the initiation of reflood, about 350°F lower peak temperatures occur than when the tubes ruptured at the initiation

of refill. The peak rod temperature for 50 ruptured tubes for this study was also lower than the peak rod temperature when 50 tubes ruptured during the blowdown, as shown on Figure 28-A-1.

In interpreting the results of the analysis of each section it must be noted that the models and computer codes used have not been tested against data for the conditions of the rupturing of steam generator tubes and therefore, whereas they should indicate the trend of the results, they may not calculate the magnitude of the results. The results of Sections 2.2 and 2.3 may be conservative (predicting higher peak rod cladding temperatures than will occur) because the heat transfer to the liquid portion of the mass from the steam generator flowing into the core was neglected in the analysis during the period of reverse core flow.

Addendum 28-B

to

Appendix 28 of the Semiscale Mod-1
Experiment Operating Specification

Additional Hardware Required to Simulate
Steam Generator Tube Ruptures

ADDENDUM 28-B

This addendum is a summary of the additional equipment and the sequencing of events that will be required to meet the objectives of Test Series 28.

Accumulator CI-T-3 will be used to supply the fluid to simulate the rupture flow between the primary and secondary sides of the steam generator. Accumulator CI-T-3 will be connected to the intact loop hot leg at Spool Piece 6. To attain the required thermal conditions in accumulator CI-T-3 the following additional equipment is required:

(a) Three 4.5 kW immersion heaters are to be installed in the accumulator in addition to the existing vessel immersion heaters.

(b) The power to the immersion heating elements (new and existing) should be controlled by fluid thermocouple TFU-SGS3-B, utilizing a single on-off proportional controller. The setpoint temperature for this control will be identical to the vessel accumulator saturation temperature specified in Table 28-B-I.

(c) The accumulator is to be adequately insulated to minimize heat losses.

Accumulator CI-T-3 is to be connected to the intact loop at spool piece 6 upstream of the steam generator orifice, i.e., on the vessel side. The connections between accumulator CI-T-3 and spool piece 6 should be one inch piping and should contain an instrumented spool piece

(SGS), a drain valve, an air-actuated valve, a check valve, and a needle valve, as illustrated in Figure 28-B-1. The instrumented spool piece should contain a turbine meter, fluid thermocouple, and differential pressure tap. Turbine meters of sufficient range and accuracy to cover the flow rates specified in Table 28-B-1 should be available. The needle valves must be of sufficient size and range to provide the flow rates from the vessel accumulator specified in Table 28-B-I. The capability to open and close the air-actuated valve automatically at various times after rupture of the LOCA should be provided. (The time of opening of the air-actuated valve in the injection line will be from about 7 to 60 seconds after rupture; the valve will remain open for about 175 seconds for the large flow rates and for the duration of the test at low flow rates).

The fluid from the secondary side of the Semiscale Mod-1 steam generator will be exhausted to the atmosphere through a timer-controlled air-actuated valve and a needle valve in series. The timing for opening of the air valve in the vent line will be identical to that for opening of the accumulator CI-T-3 air valve. Once the vent air valve is actuated, it will remain open for the duration of the test. The needle valve (or valves) must be of sufficient size and range to provide the flow rates from the steam generator specified in Table 28-B-I.

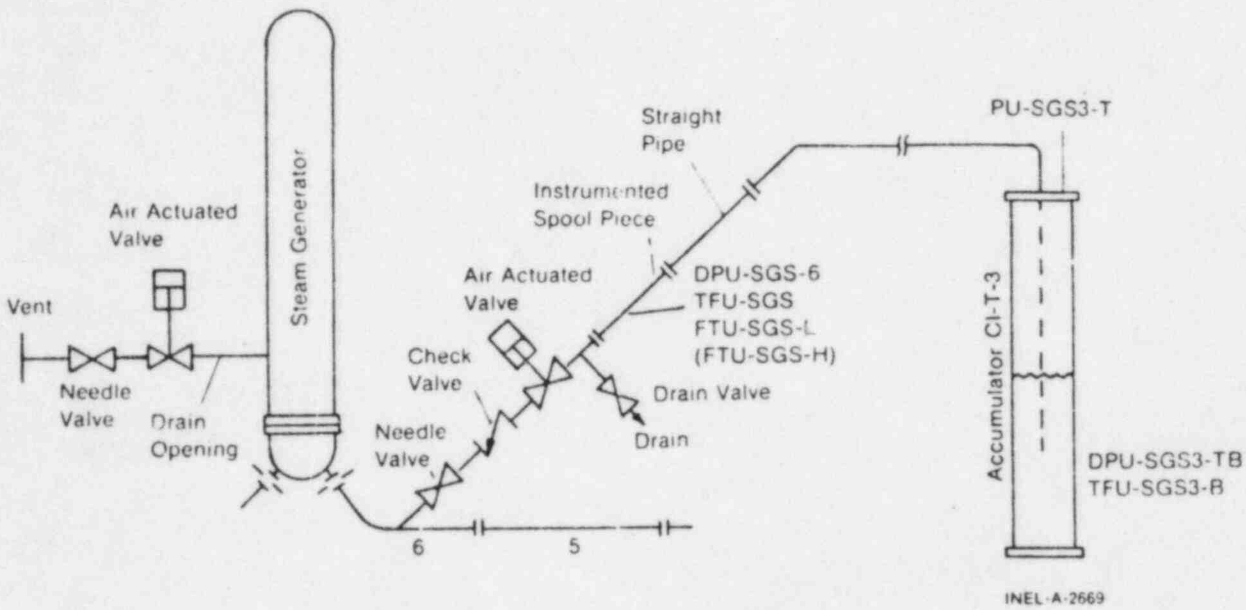


Figure 28-B-1. Schematic of Equipment Needed to Simulate Steam Generator Tube Ruptures

Addendum 28-C

to

Appendix 28 of the
Semiscale Mod-1 Experimental
Operating Specification

Steam Generator
Volume and Rupture Flow Rate
Scaling

Steam Generator Volume and Flow Rate Scaling

This addendum documents the scaling method used to scale the volume of fluid and the mass flow rate used in this test series to simulate the rupture of steam generator tubes in a PWR.

The total volume of fluid to be used to simulate the volume at rated load of 3 PWR steam generators was obtained by core area scaling as follows:

$$V_{\substack{ss \\ s/g}} = 3 \, V_{\substack{PWR \\ s/g}} \frac{A_{ss}}{A_{PWR}}$$

$$V_{ss} = 3\,(1687)\,\frac{(0.0530)}{52.4} = 5.1 \text{ ft}^3.$$

The rupture mass flow rate used to simulate the mass flow rate from the secondary to the primary side of the steam generator was obtained by core scaling as follows:

$$\dot{M}_{ss} = \dot{M}_{PWR} \frac{A_{ss}}{A_{PWR}}$$

$$\dot{M}_{ss} = \dot{M}_{PWR} \frac{0.0530}{52.4} = \frac{\dot{M}_{PWR}}{988}$$

Core area scaling was used for both the total volume and the mass flow rate used to simulate the rupture of steam generator tubes in a PWR because it is a more appropriate scaling criteria for the Semiscale Mod-1 system during reflood than is volume scaling.

TABLE 28-B-I

ECC AND STEAM GENERATOR SECONDARY INJECTION AND DISCHARGE PARAMETERS

ECC System	Test Number S-28-1	S-28-2	S-28-3	S-28-4
Accumulator CI-T-1				
Injection location	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)	Intact Loop Cold Leg (Spool Piece 14)
Pressure (psig)	600	600	600	600
Liquid volume (ft^3)	2.83	2.83	2.83	2.83
Gas volume (ft^3)	1.86	1.86	1.86	1.86
Injection rate (gpm)	23.0	23.0	23.0	23.0
Line resistance $\frac{sec^2}{in.^2-ft^3}$	1229	1229	1229	1229
N_2 flow duration (sec)	24	24	24	24
Accumulator CI-T-2				
Location	Broken Loop Cold Leg (Spool Piece 42)	Broken Loop Cold Leg (Spool Piece 42)	Broken Loop Cold Leg (Spool Piece 42	Broken Loop Cold Leg (Spool Piece 42)
Pressure (psig)	600	600	600	600
Liquid volume (ft^3)	0.58	0.58	0.58	0.58
Gas volume (ft^3)	0.326	0.326	0.326	0.326
Injection rate (gpm)	7.67	7.67	7.67	7.67

TABLE 28-B-I (contd)

ECC System	Test Number			
	S-28-1	S-28-2	S-28-3	S-28-4
Line resistance $\frac{\text{sec}^2}{\text{in.}^2\text{-ft}^3}$	11061	11061	11061	11061
N_2 flow duration (sec)	To Exhaustion	To Exaustion	To Exhaustion	To Exhaustion
Accumulator CI-T-3				
Injection location	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6)	Intact Loop Hot Leg (Spool Piece 6)
Temperature (°F)	525	525	525	525
Pressure (psig)	1100	1100	1100	1100
Liquid volume (ft^3)	5.1	5.1	5.1	5.1
Gas volume (ft^3)	1.7	1.7	1.7	1.7
Injection rate (gpm)	11.33 ± 1.00	TBD[a]	TBD[a]	$1.89^{+0}_{-0.19}$
N_2 flow duration (sec)	No N_2 flow allowed	No N_2 flow allowed	No N_2 flow allowed	No N_2 flow allowed
Air acutated valve				
Open (seconds after the Cold Leg Break)	40	40	40	40
Close (seconds after the Cold Leg Break)	242	TBD	TBD	Remains open.

TABLE 28-B-I (contd)

ECC System	S-28-1	S-28-2	S-28-3	S-28-4
	Test Number			
Steam generator secondary fluid discharge				
Initial liquid level (in.)	116	116	116	116
Flow rate (gpm)	15.33	TBD	TBD	1.89
Air actuated valve opening time (sec)[b]	40	40	40	40
Intact loop LPIS				
Location	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)
Actuation Pressure (psig)	150	150	150	150
Injection rate (gpm)	4.0	4.0	4.0	4.0
Broken loop LPIS				
Location	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)
Actuation pressure (psig)	150	150	150	150
Injection rate (gpm)	0.96	0.96	0.96	0.96
Intact loop HPIS				
Location	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)	Cold Leg (Spool Piece 14)
Actuation pressure (psig)	1800	1800	1800	1800
Injection rate (gpm)	0.31	0.31	0.31	0.31

[b] The valve remains open throughout the test.

TABLE 28-B-I (contd)

ECC System	S-28-1	S-28-2	S-28-3	S-28-4
	Test Number			
Broken loop HPIS				
Location	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)	Cold Leg (Spool Piece 42)
Actuation pressure (psig)	1800	1800	1800	1800
Injection rate (gpm)	0.103	0.103	0.103	0.103

EG&G Idaho, Inc.

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June 6, 1977

Mr. P. E. Litteneker, Chief
Reactor Safety Behavior Branch
Reactor Division
Idaho Operations Office - ERDA
Idaho Falls, Idaho 83401

TEST PREDICTION OF SEMISCALE MOD-1 INTEGRAL TEST S-28-1 - DJO-126-77

Reference: D. J. Olson Ltr to P. E. Litteneker, DJO-125-77
Transmittal of Semiscale EOS Appendix 28,
June 3, 1977

Dear Mr. Litteneker:

Enclosed is the test prediction document for Test S-28-1 of the steam generator tube rupture test series. Details of the system description and initial test conditions were transmitted in the referenced letter.

The objectives of Test S-28-1 are to set an upper limit on the range of steam generator tube ruptures over which high peak cladding temperatures can occur and to provide a data base for comparison between test data and the analysis results used to specify the tests in Series 28. Test S-28-1 will be a 200% double-ended cold leg break simulation. The rupture of 100 steam generator tubes will be simulated by a flow rate of 0.91 kg/s from accumulator injection into the intact loop hot leg between the pressurizer and the steam generator inlet plenum. The injection will begin at 40 seconds after the initiation of the cold leg break to simulate the steam generator tube ruptures. The change in heat transfer potential of the steam generator will be simulated by discharging the steam generator secondary fluid over the simulated tube rupture period. The system initial conditions and emergency core coolant injection parameters are the same as Test S-04-6, the baseline test for Series 28.

The blowdown response should be the same as Test S-04-6 until 40 seconds after rupture. The predictions for the remainder of the transient were performed with the FLOOD4 code. Results of Test S-04-6 indicate the peak rod temperature should occur at 8 seconds after rupture when a

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maximum of 1075 K was achieved. Initiation of the simulated tube ruptures at 40 seconds after rupture should delay the beginning of refill until about 161 seconds after the initiation of the cold leg break and the beginning of reflood until 235 seconds. Both refill and reflood must be accomplished by the high pressure injection system and the low pressure injection system alone. The core hot spot is predicted to quench at 327 seconds after rupture and the whole core is expected to quench by 341 seconds.

Very truly yours,

D. J. Olson, Manager
Semiscale Program

CPF:emw

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Very truly yours,

D. J. Olson, Manager
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