NUREG/CR-1708-ADD. I
EPRI NP-1524-ADD. I
GEAP-24865-ADD. I
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BWR Refill-Reflood Program Task 4.3 — Single Heated Bundle Experimental Task Plan

Addendum I
Stage 3 — Separate Effects Bundle

Manuscript Completed: July 1980
Date Published: March 1981

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Previous Reports in BWR Refill-Reflood Program Series

BWR Refill-Reflood Program Task 4.2 - Core Spray Distribution Experimental Task Plan, T. Eckert, General Electric Company, NUREG/CR-1558, August 1980.

BWR Refill-Reflood Program Task 4.2 - Core Spray Distribution Final Report, T. Eckert, General Electric Company, NUREG/CR-1707, September 1980.

BWR Refill-Reflood Program Task 4.3 - Single Heated Bundle Experimental Task Plan, D. D. Jones, L. L. Myers, J. A. Findlay, General Electric Company, NUREG/CR-1708, January 1980.

ABSTRACT

An experimental task plan for the separate effects bundle tests of the Single Heated Bundle Task in the BWR Refill-Reflood Test Program is presented. The tests will provide core spray and reflood heat transfer data and will investigate BWR refill-reflood controlling phenomena to support model development tasks in the BWR Refill-Reflood Program. Individual test conditions, the measurement plan and data utilization are discussed.

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ILLUSTRATIONS

TABLES

Section 1

OBJECTIVES

The objectives of the separate effects bundle (SEB) tests of the Single Heated Bundle (SHB) Task are to (a) extend the refill-reflood data base, and (b) provide a data base of separate parameters in support of model development and model qualification tasks.

Section 2

TASK ROLE IN PROGRAM

Separate effects bundle tests under Task 4.3 will be performed for model development and qualification. Tasks 4.7 and 4.8 of the BWR Refill-Reflood Program[1] will utilize the data from these tests to develop and qualify loss-of-coolant accident (LOCA) models. The specific models to be addressed are:

1. Core Spray Heat Transfer
2. Reflood Heat Transfer
3. Core to Bypass Heat Transfer
4. Entrainment
5. Core Liquid Carryover
6. Upper Tie Plate Counter-Current Flow Limiting (CCFL)
7. Upper Tie Plate CCFL Breakdown
8. Side Entry Orifice (SEO) CCFL
9. Top of Bypass (TOB) CCFL
10. Core Vaporization
11. Core Void Distribution
12. Condensation Effects of Lower Tie Plate Leakage
13. Refill-Reflood Flow Distribution

This experimental task plan describes the program to obtain these data.

Section 3

FACILITY DESCRIPTION

The SEB will be installed in the Emergency Core Cooling System (ECCS) Test Loop. The ECCS Test Loop is a 1/624-scale mock-up of the BWR/6-218 reactor. The major features of the facility are shown in Figure 3-1. These features include a full-scale simulated fuel bundle and a system mock-up which includes the lower plenum (LP), guide tube (GT), core, bypass, upper plenum (UP), separator, steam dome, annulus, and jet pump.

To conduct separate effects tests, the jet pump, bypass, and GT may be isolated. The ECC systems are simulated with (a) liquid injection 26 inches above the upper tie plate for high pressure core spray (HPCS) and low pressure core spray (LPCS) flows, and (b) liquid injection into the bypass region on all four sides of the fuel channel at 18.7 inches below the upper tie plate for low pressure coolant injection (LPCI) flows. The spray and the LPCI share a common controlled temperature water supply, and thus are injected at the same temperature. The spray and LPCI flows may be individually varied from 0.5 to 30 gpm and 1 to 10 gpm, respectively, at temperatures from ambient to near saturation. Liquid may also be injected directly into the lower plenum (LP). The generation of steam by flashing is simulated by the injection of steam into the GT and LP. Steam may also be injected directly into the core. Each of these flows may be set separately at up to 1000 lbm/hr.

The SEB is a new simulated BWR/6 fuel bundle made up of an 8x8 array of electrically heated simulated fuel rods including two water rods. Each of the heater rods will have a center peaked chopped cosine axial power profile and 10 clad-surface thermocouples (TC), as shown in Figure 3-2. An individual heater rod, of which there are 62 in the SEB test section, is shown in Figure 3-3. All other test section components for these Stage 3 tests are the same as those for the Stage 1 tests.[2]

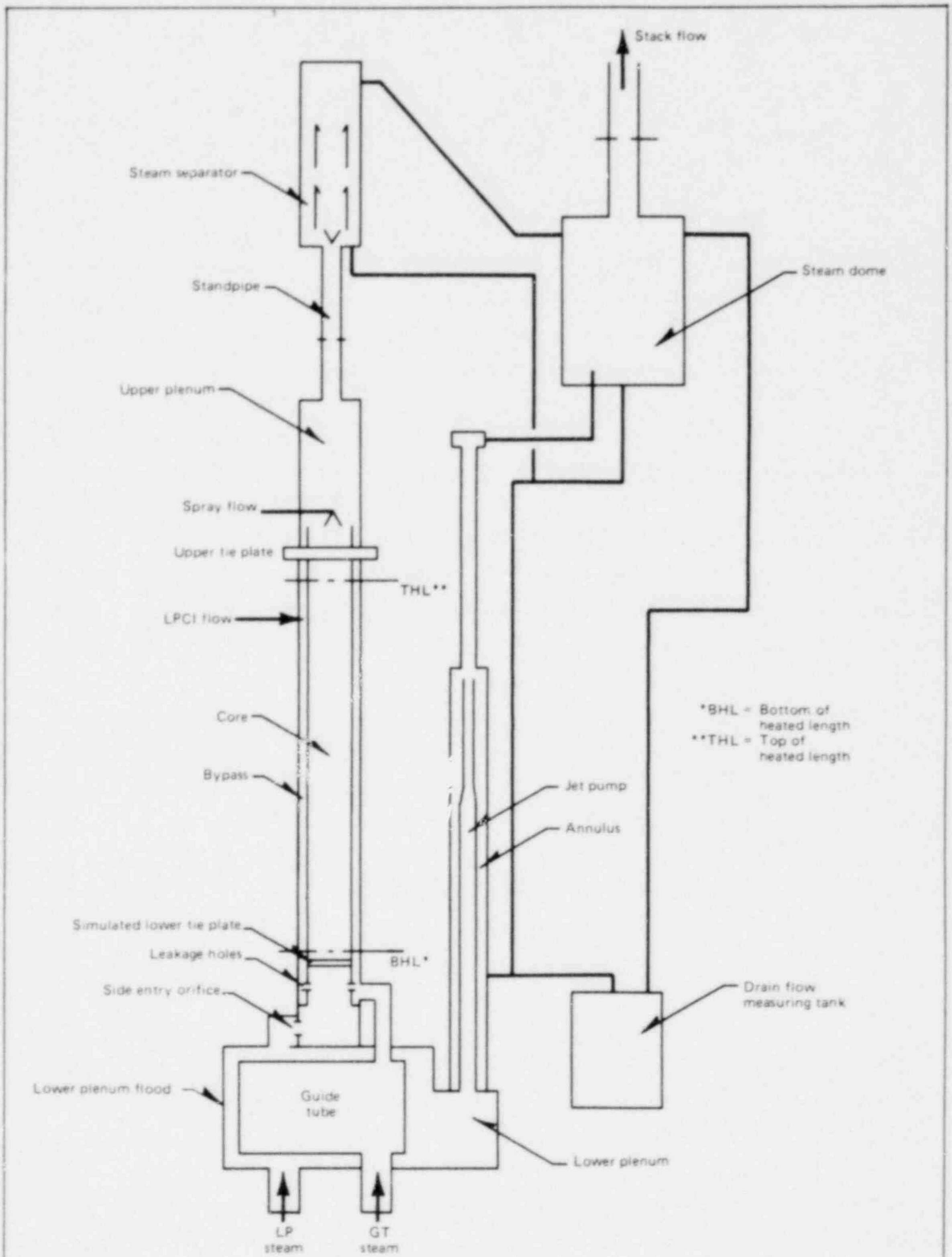

Figure 3-1. ECCS Test Loop

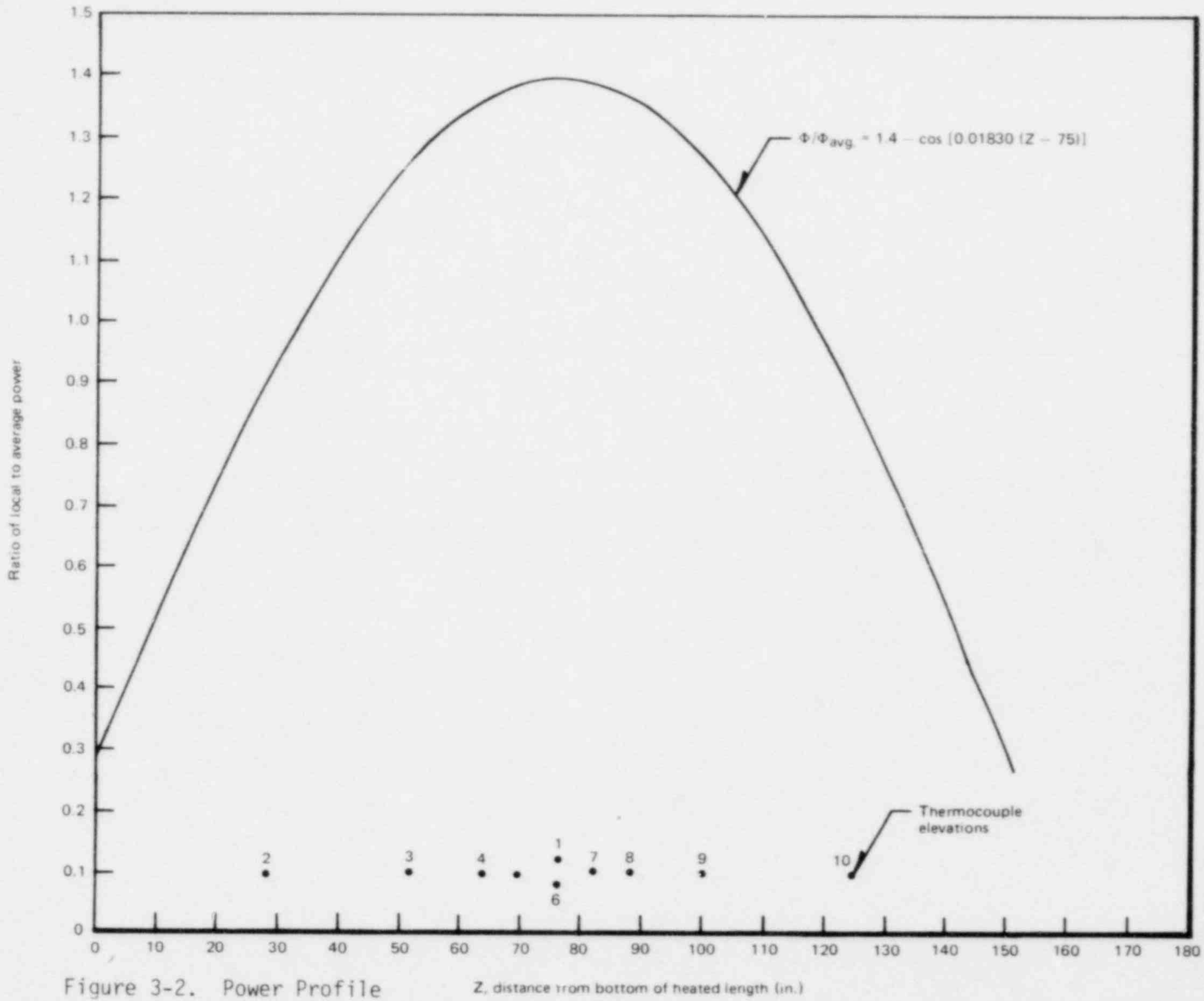

Figure 3-2. Power Profile

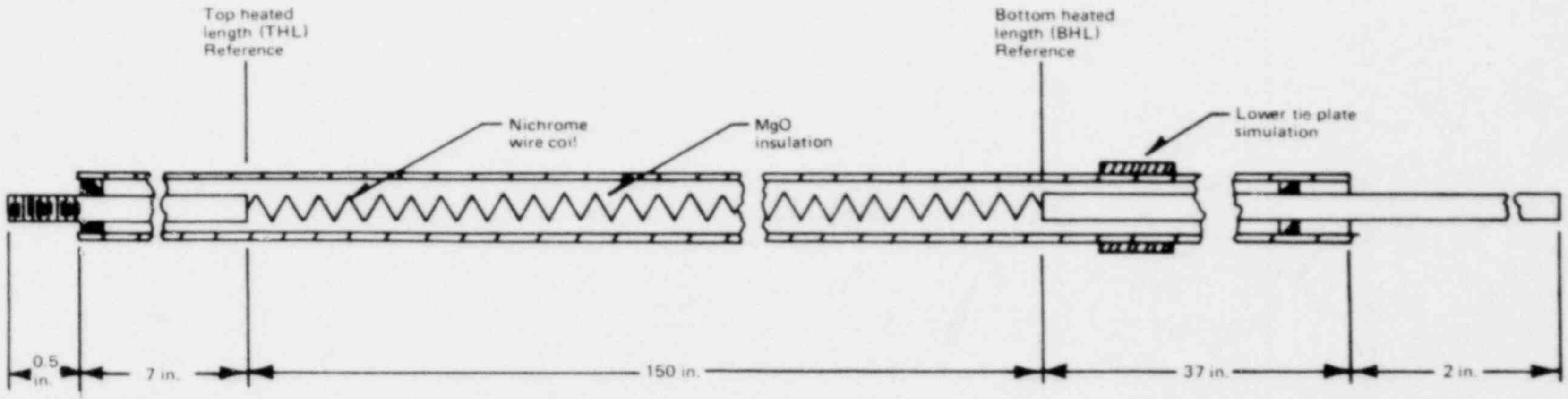

Figure 3-3. Heater Rod Configuration for Separate Effects Bundle Test Series

For the SEB tests, the test section may be configured several ways. These configurations are shown schematically in Figures 3-4 through 3-7 and are described below (system components are identified in Figure 3-1):

1. System Configuration: · All flow paths are open, including bypass leakage and jet pump (Figure 3-4).

2. Blocked Jet Pump: A blank flange is installed to isolate the jet pump (Figure 3-5).

3. Blocked jet pump; blocked bypass leakage lower tie plate leakage holes are plugged (Figure 3-6).

4. Blocked jet pump; blocked bypass leakage; isolated GT; top of bypass blocked; continuous bypass leakage - the bypass to GT connecting hoses are removed; the GT opening plugged; and the bypass water (which enters the test section via LPCI) is then drained into a measuring tank (Figure 3-7).

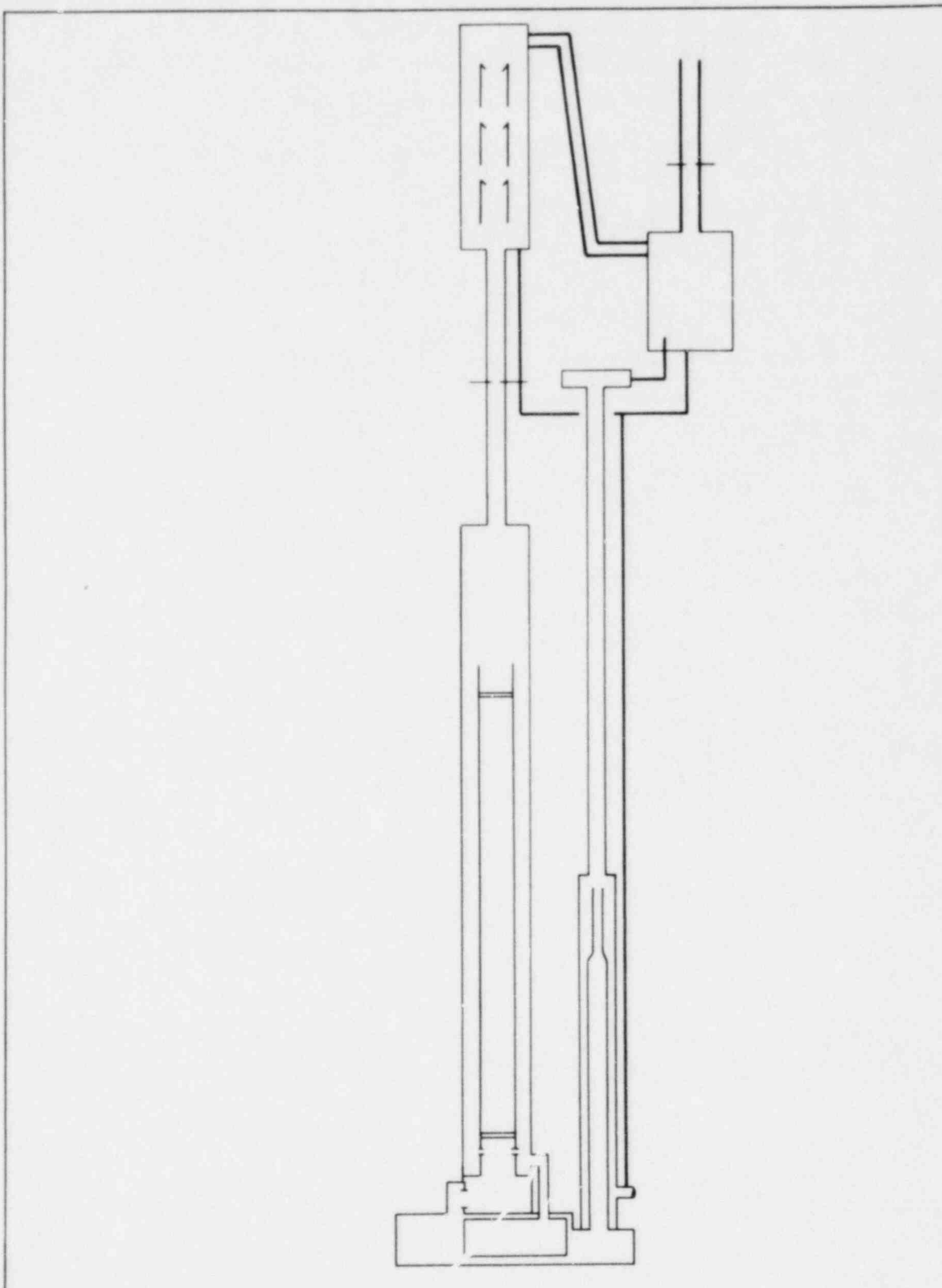

Figure 3-4. System Configuration

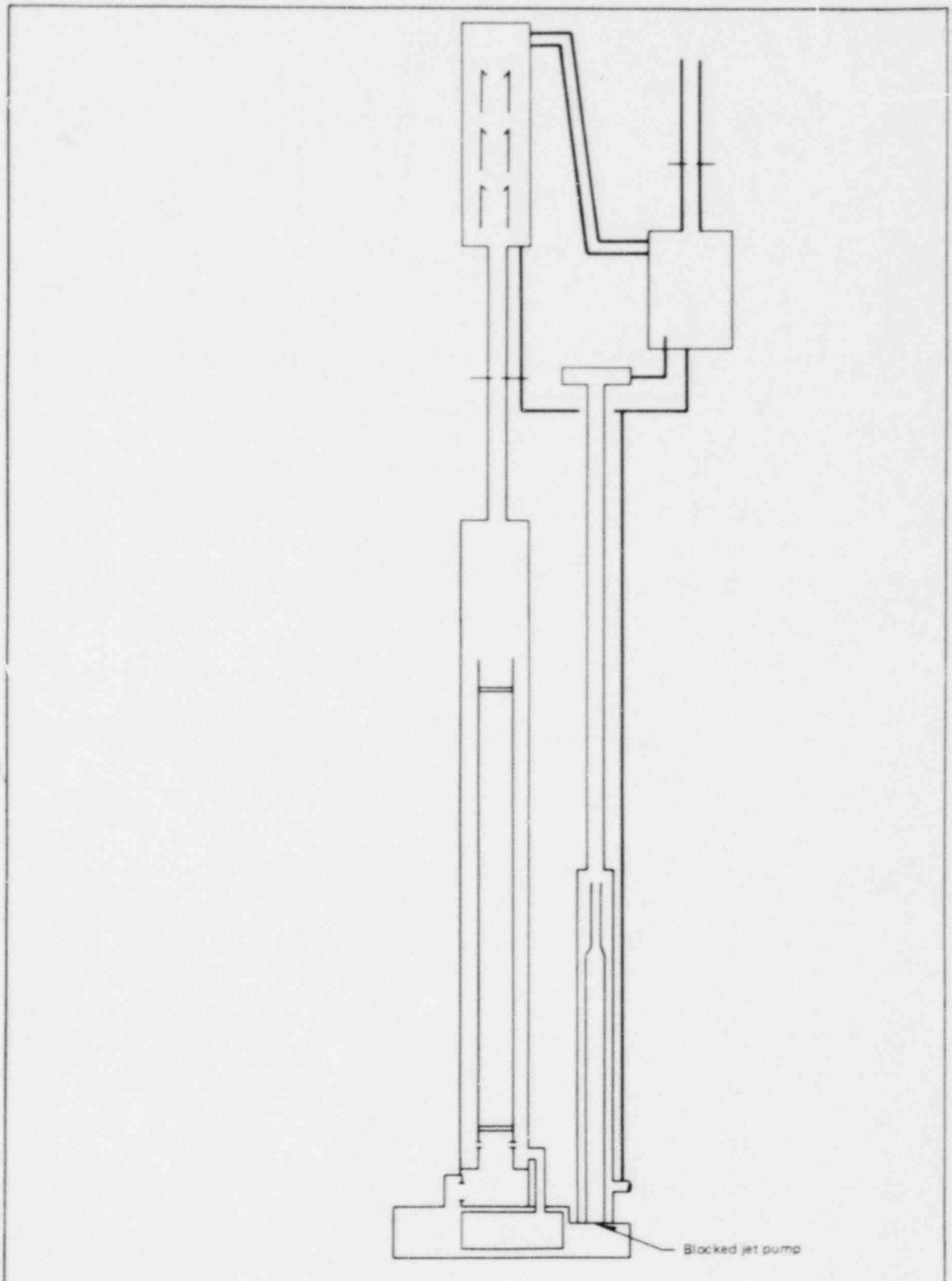

Figure 3-5. Blocked Jet Pump

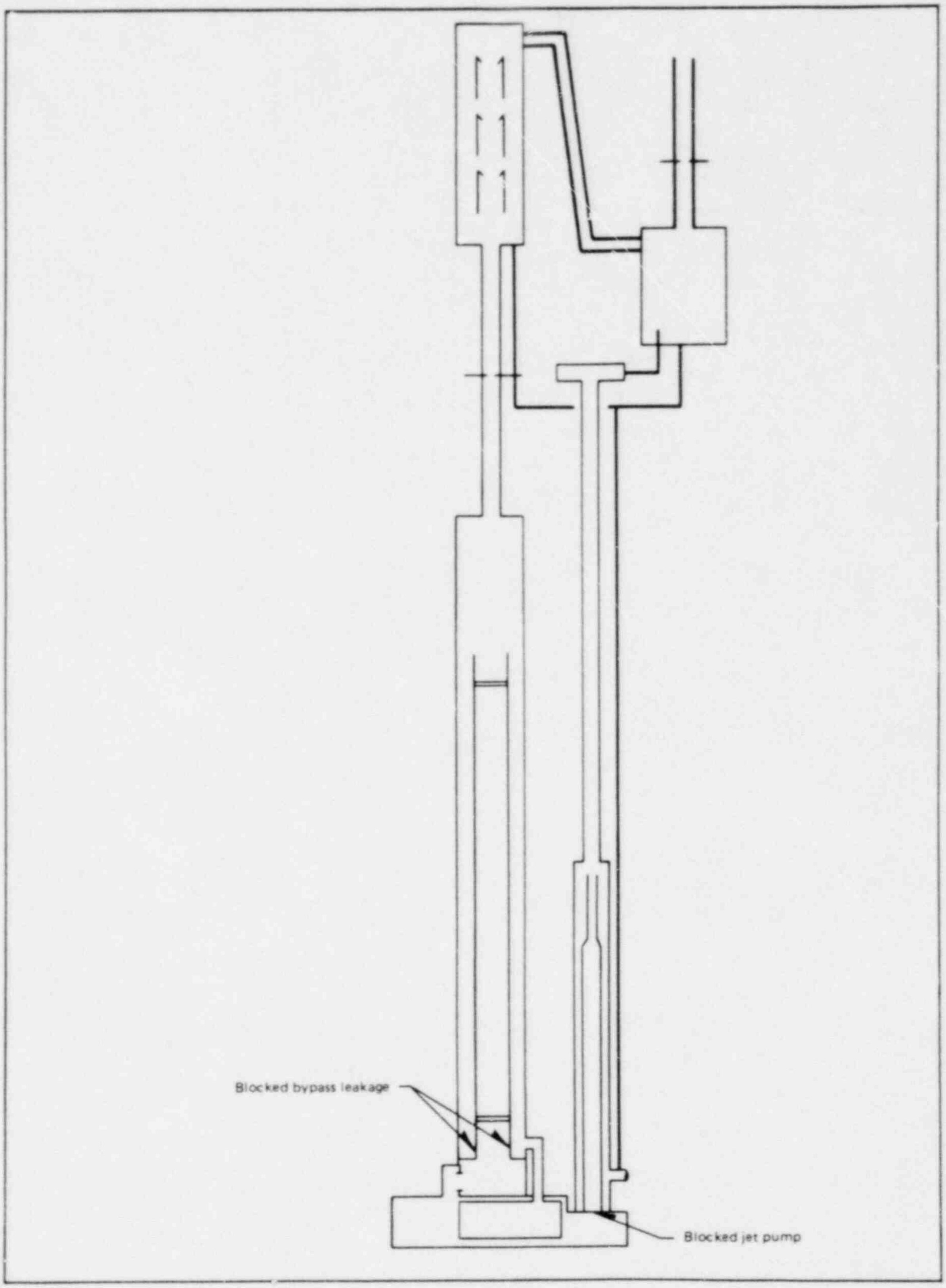

Figure 3-6. Blocked Jet Pump and Blocked Bypass Leakage

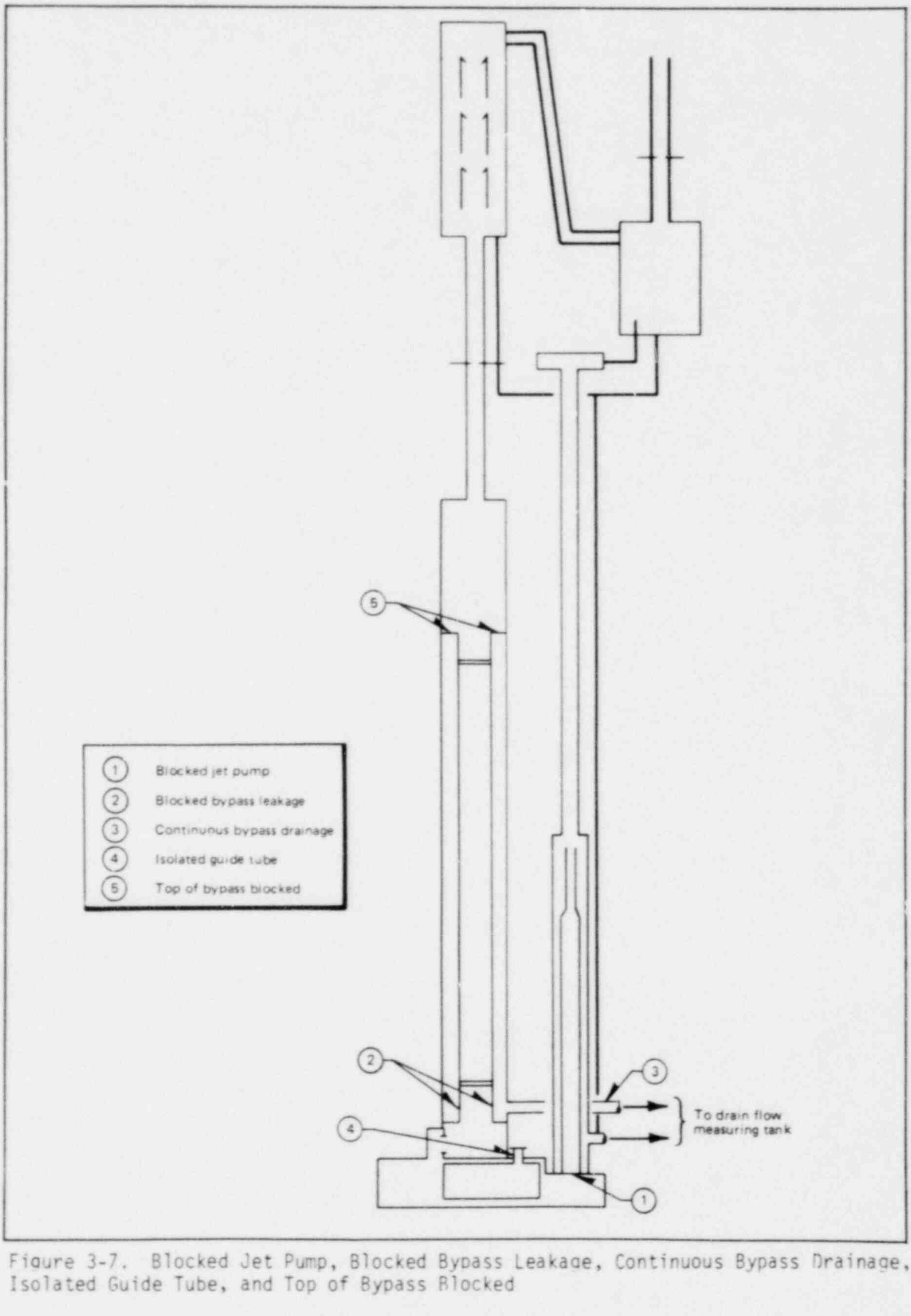

Figure 3-7. Blocked Jet Pump, Blocked Bypass Leakage, Continuous Bypass Drainage, Isolated Guide Tube, and Top of Bypass Blocked

Section 4

DATA REQUIREMENTS AND MEASUREMENT PLAN

The LOCA model requirements are to develop and qualify the following separate effects models:

1. Core Spray Heat Transfer
2. Reflood Heat Transfer
3. Core to Bypass Heat Transfer
4. Entrainment
5. Core Liquid Carryover
6. Upper Tie Plate CCFL
7. Upper Tie Plate CCFL Breakdown
8. Side Entry Orifice CCFL
9. Top of Bypass CCFL
10. Core Vaporization
11. Core Void Distribution
12. Condensation Effects of Lower Tie Plate Leakage
13. Refill-Reflood Flow Distribution

To provide the data to fulfill these requirements, the measurement objectives for the Stage 3 tests are:

1. To assure that the initial conditions specified for each test have been established. Initial conditions will include ECC flows and temperatures, inlet steam flows, liquid level in the LP and GT, and bundle power and temperatures.
2. To provide sufficient auxiliary measurements to ensure efficient operation of the test loop, continuous strings of pressure differentials, and provide checks on the measurement system and verification of the data.
3. To provide sufficient primary measurements to fulfill the data requirements of the various separate effects models. Required measurements will be discussed in the following paragraphs.

4.1 MEASUREMENT PLAN

The SEB measurement plan is designed to provide measurements of (a) controllable test parameters (independent variables), and (b) dependent variables sufficient to meet the measurement plan objectives. The measured independent variables are summarized in Table 4-1 and are shown schematically in Figure 4-1.

Measurements to meet the model development data requirements are made with absolute and differential pressure transducers and thermocouples (TCs). The specific data requirements and measurements designed to meet those requirements are tabulated in Table 4-2. The various absolute and differential pressure measurements may be grouped into three major categories:

1. Measurements of flows which cross the test section system control volume (external flows).
2. Measurements of flows which are within the test section control volume (internal flows).
3. Measurements of the regional mass inventories and two-phase levels.

Measurements of the internal flows aid in determination of the core liquid vaporization rate and the steam flow split between the core and the jet pump. The measurement groupings used to determine the external and internal flows are shown in Figure 4-2. The differential pressures shown in Figures 4-3 and 4-4 provide for tracking of the collapsed level within the test section. Secondary measurements are also provided to verify the sum of differential pressure strings. The temperature measurements shown in Figures 4-5 and 4-6 monitor the degree of subcooling in the various regions and provide a means of detecting subcooled CCFL breakdown at each flow restriction, e.g., the side SEO, upper tie plate, and TOB. The relative locations of the bottom of the heated length (BHL) and the ECC injection points are shown for reference on the temperature measurement figures. The locations of temperature measurements for the Stage 3 SEB test are shown on Tables 4-3, 4-4, and 4-5 for the heater rods (10 axial locations), inner channel (28 TCs) and outer channel (20 TCs), respectively. Power measurements are made for each of the 62 heater rods individually and for each of the nine groups. Total bundle power is the calculated sum of the nine groups.

The simulated fuel assembly consists of 62 heater rods and 2 water rods. As with the heater rods, each water rod is instrumented with 10 TCs, as described in Table 4-6. Of these 10, 8 TCs are welded to the inside surface of the hollow

Table 4-1

INDEPENDENT VARIABLES

Independent Variables Controlled:

m_{OL}	Initial mass of water in LP
m_{OG}	Initial mass of water in GT
W_{gL}	Steam injection rate into LP
W_{gG}	Steam injection rate into GT
W_{gD}	Steam injection rate into steam dome
W_{gC}	Steam injection rate into core
$\dot{Q}_C$	Bundle power rate of change
T_{OC}	Initial bundle temperature
Q_{OC}	Initial bundle power
W_{spray}	Spray injection rate
W_{LPCI}	LPCI injection rate
T_{ECC}	Spray and LPCI temperature
W_{LP}	LP flood rate

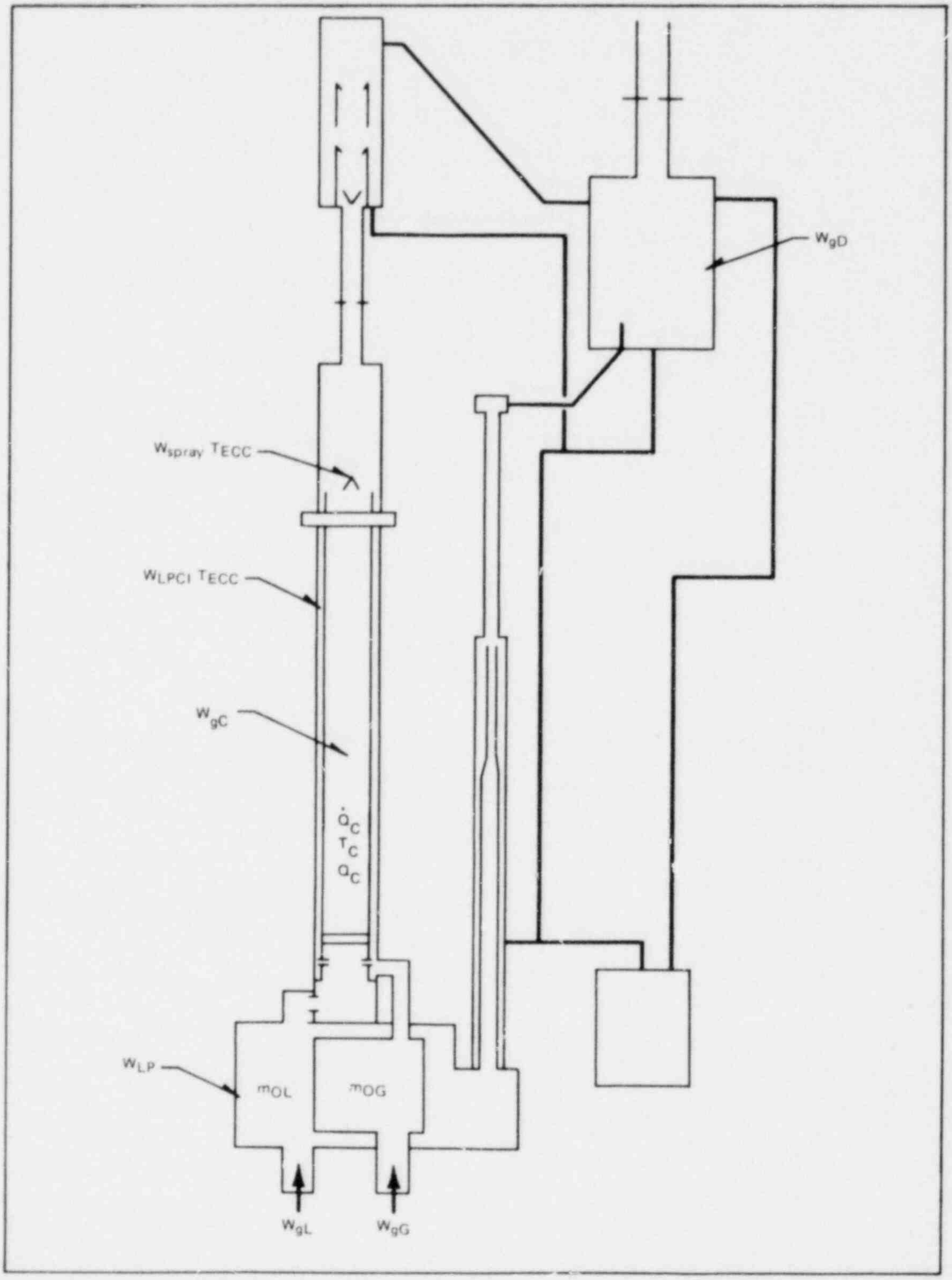

Figure 4-1. Measured Independent Parameters

Table 4-2

SEPARATE EFFECTS BUNDLE MEASUREMENT PLAN

Separate Effects Model	Primary Data Requirements	Primary Measurements
1. Core Spray Heat Transfer	• ECC flow rate and temperature	TM1, TM2, T18, T20
2. Reflood Heat Transfer	• Rod surface temperature	640 Rod TCs
3. Core to Bypass Heat Transfer	• Channel surface temperature	48 Inner/Outer Channel TC
	• Core power	Heater Power, Silicon Controlled Rectifier (SCR) Power
	• Core two-phase level	DP23 through DP29
	• Core single-phase level	DP5
	• Bypass temperature	T8, T9, T10, T11
	• Injected steam flow rate	DP37, P14, T33
	• Core steam superheat	4 TCs on Water Rods
	• LP flooding rate and temperature	TM2, T34
4. Entrainment	• Core ΔP	DP5
	• Bypass ΔP, Guide Tube ΔP	DP13, DP11
5. Core Liquid Carryover	• Core steaming rate	DP35, T28, P13
	• ECC flow rate and temperature	TM1, TM2, T18, T20
	• Injected steam flow rate	DP37, P14, T33
	• Steam separator liquid flow rate	Drain Tank, DP34, Measurement of Separated Liquid Flow

Table 4-2

SEPARATE EFFECTS BUNDLE MEASUREMENT PLAN (Continued)

Separate Effects Model	Primary Data Requirements	Primary Measurements
6. Upper Tie Plate CCFL	• Upper tie plate steam flow	DP35, T28, P13, DP32, P11, T31
7. Upper Tie Plate CCFL Breakdown	• Upper tie plate liquid down flow	TM1
	• ECC flow and temperature	TM1, T18
	• Upper tie plate pressure	P2
	• Fluid temperature below UTP	T12
	• Fluid temperature above upper tie plate	T13
	• UP mass	DP7
8. SEO CCFL	• SEO steam flow	DP32, P11, T31
	• SEO liquid flow	TM2
	• ECC flow and temperature	TM2, T20
	• SEO pressure	P3, DP1, DP2
9. TOB CCFL	• TOB steam flow	DP33, P12, T30
	• TOB liquid flow	TM1
	• ECC flow and temperature	TM1, T18
	• TOB pressure	P5, P2
10. Core Vaporization	• Steam flow exiting from the core	DP35, T28, P13
	• Core rod temperatures	640 Rod Thermocouples
	• Core two-phase level	DP23-DP29
	• ECC flow and temperature	TM1, TM2, T18, T20
	• Core power	Heater Power, SCR Power

Table 4-2

SEPARATE EFFECTS BUNDLE MEASUREMENT PLAN (Continued)

Separate Effects Model	Primary Data Requirements	Primary Measurements
11. Core Void Distribution	• Core pressure drop	DP23-DP29, DP5
12. Condensation Effects of Lower Tie Plate Leakage	• Lower tie plate leakage flow rate	DP13, DP38
	• Lower tie plate leakage flow temperature	T8, T9, T10, T11
	• Core rod temperatures	640 Rod TCs
	• Channel temperatures	48 Inner/ Outer Channel TCs
	• Steam flow exiting the core	DP35, T28, P13
13. Refill-Reflood Flow Distribution	• Core mass	DP5
	• LP mass	DP1, DP2
	• Bypass mass	DP13

water rod, and 2 TCs protrude through the rod surface into the region between adjacent fuel rods. These four TCs (two TCs per each of the two water rods) protrude 0.100 inch and are intended to provide an indication of steam superheat in the core.

In addition to the series of TCs and pressure transducers, one conductivity probe will be installed at the jet pump entrance into the LP to provide an indication of the void fraction of the two-phase mixture flowing through the jet pump.

The orientation of the rods within the inner and outer channel, and also the orientation of the bundle in reference to north, south, east, and west directions are shown in Figure 4-7.

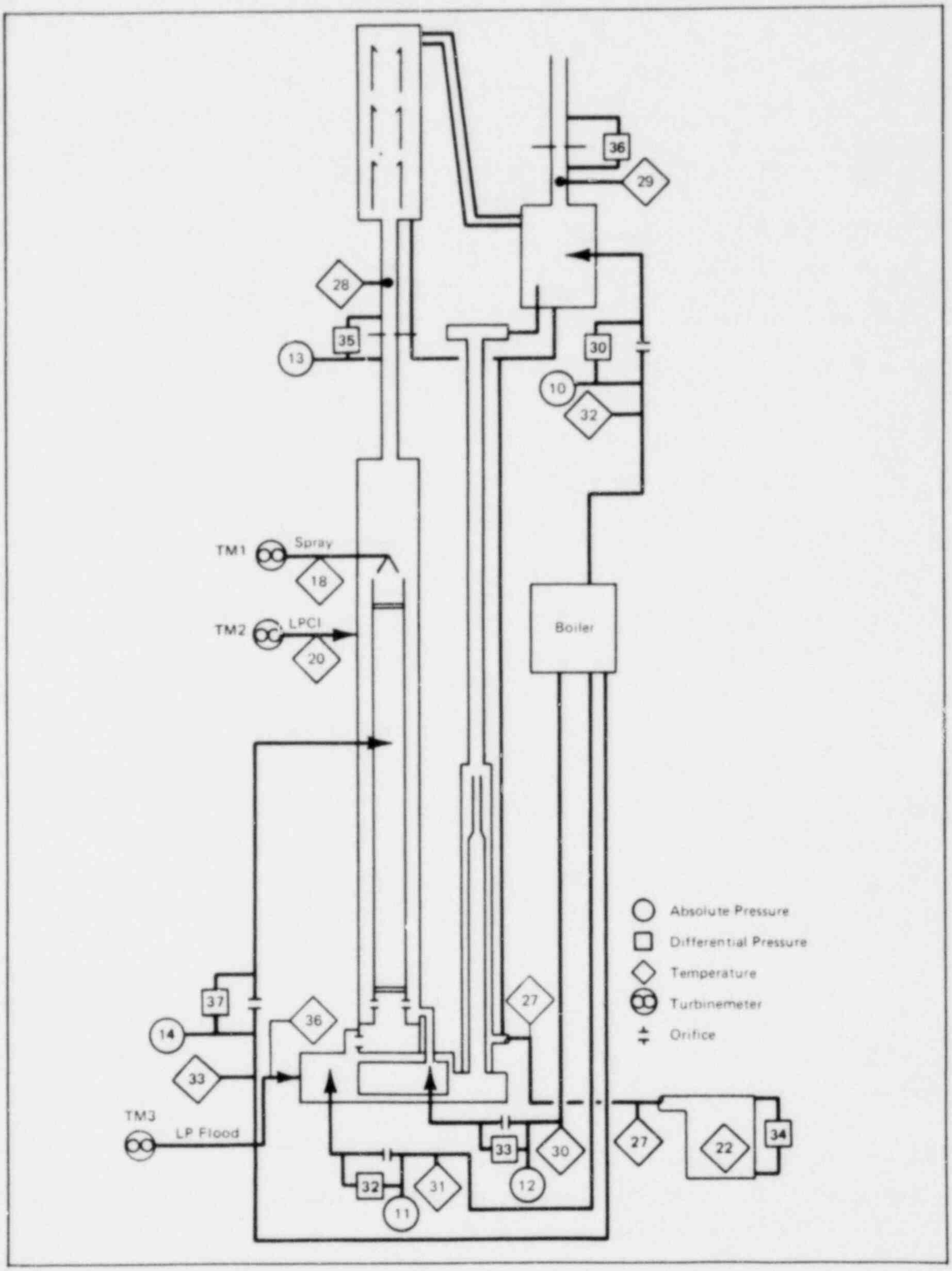

Figure 4-2. Internal and External Flow Measurements

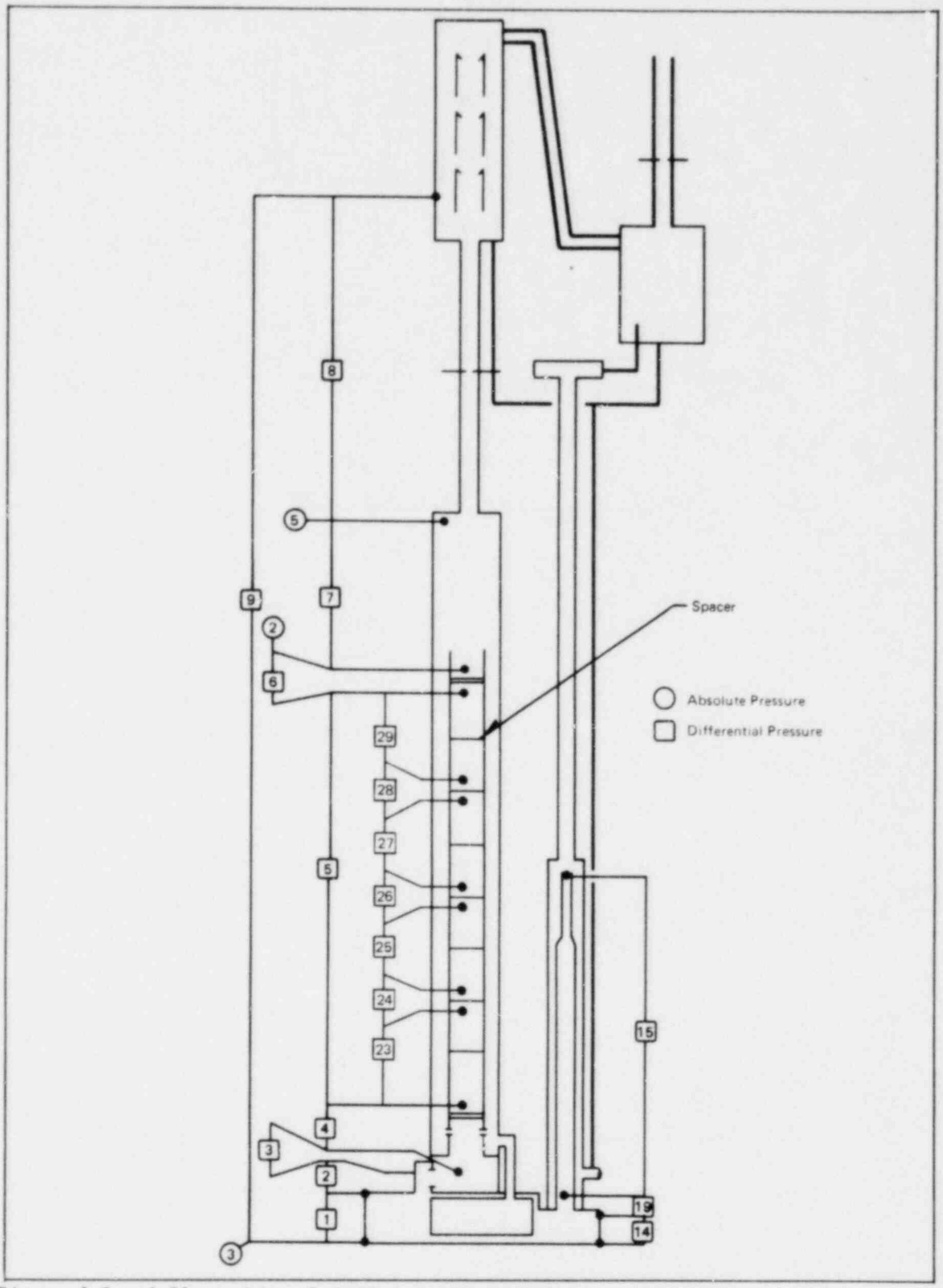

Figure 4-3. Collapsed Level Differential Pressure Measurements (Lower Plenum and Jet Pump Strings)

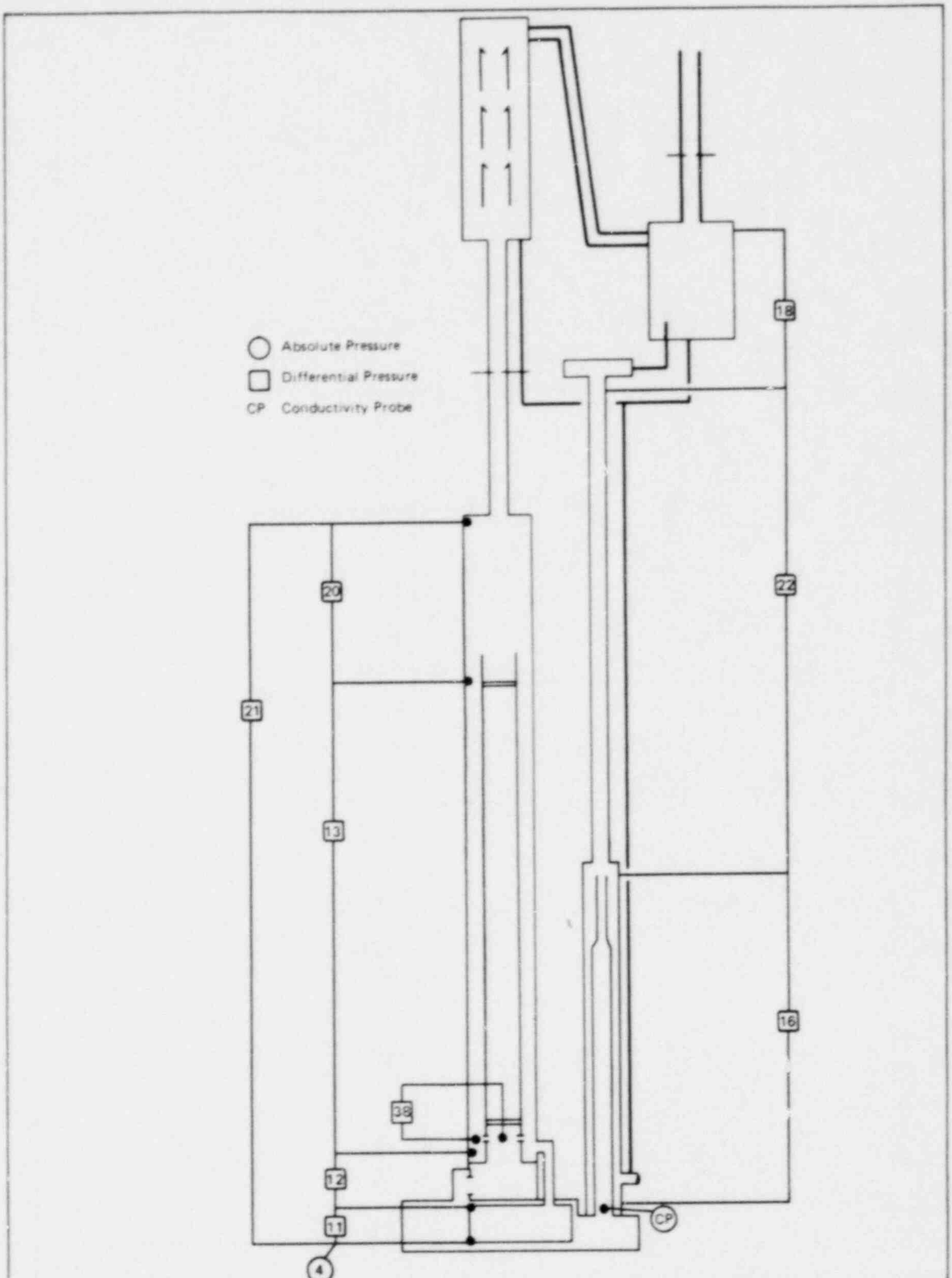

Figure 4-4. Collapsed Level Differential Pressure Measurements (Guide Tube and Annulus Strings)

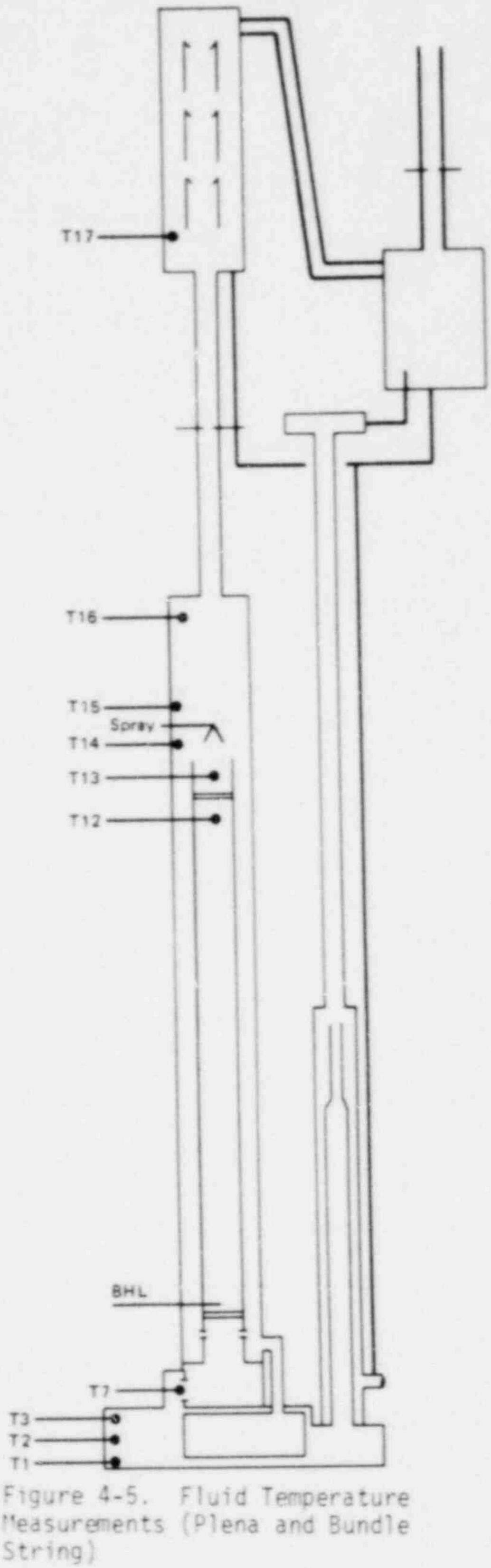

Figure 4-5. Fluid Temperature Measurements (Plena and Bundle String)

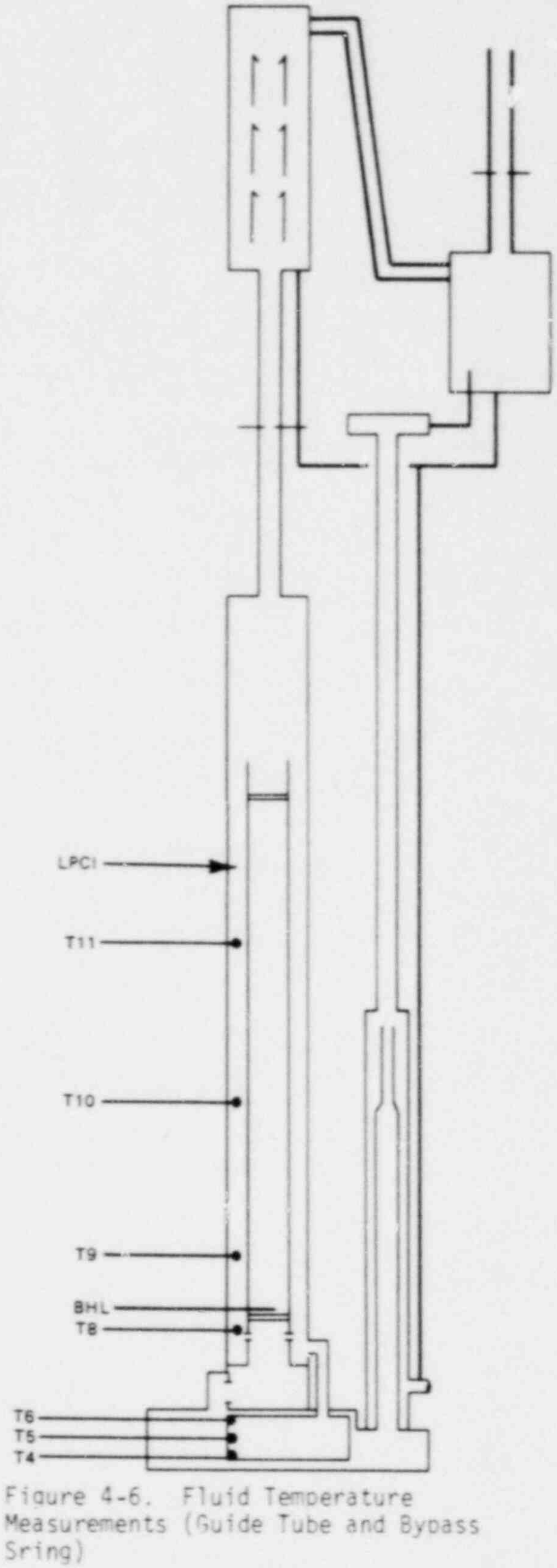

Figure 4-6. Fluid Temperature Measurements (Guide Tube and Bypass Sring)

Table 4-3

HEATER ROD

THERMOCOUPLE LOCATIONS

(10 Thermocouples Per Heater)

Thermocouple	TC Location, Distance Above BHL (in.)
1	75
2	27
3	51
4	63
5	69
6	75
7	81
8	87
9	99
10	123

Table 4-4

INNER CHANNEL THERMOCOUPLE

LOCATIONS

(28 Thermocouples)

Side of Channel	TC Location, Distance Above BHL (in.)
South	27, 48, 60, 69, 75, 81, 90, 102, 123
North	27, 51, 69, 75, 81, 99, 123
East	27, 51, 69, 75, 81, 99
West	27, 51, 69, 75, 81, 99

Table 4-5

OUTER CHANNEL

THERMOCOUPLE LOCATIONS

(20 Thermocouples)

Side of Channel	TC Location, Distance Above BHL (in.)
North	27, 51, 75, 99, 123
South	27, 51, 75, 99, 123
East	27, 51, 75, 99, 123
West	27, 51, 75, 99, 123

Table 4-6

WATER ROD

THERMOCOUPLE LOCATIONS

(10 Thermocouples per Water Rod)

Thermocouple	TC Location, Distance Above BHL (in.)*
1	24
2**	48
3	60
4	66
5**	72
6	72
7***	78
8	84
9	96
10***	120

*Water rod TCs are located 3 inches lower than heater rod TCs due to increased thermal expansion allowance after the TCs were installed.

**Steam superheat TC for first water rod (location 29).

***Steam superheat TC for second water rod (location 36).

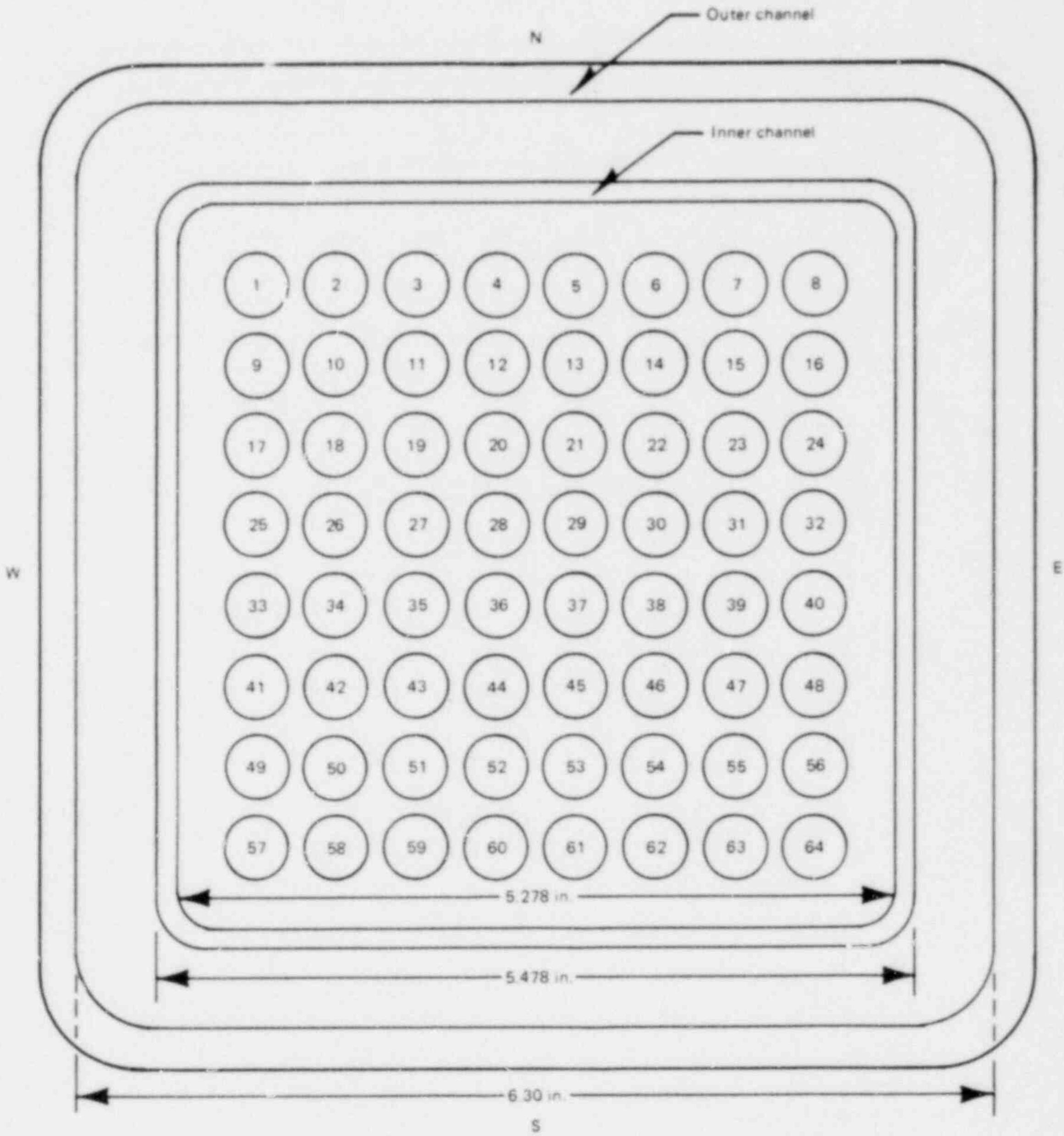

Figure 4-7. Bundle Cross Section Showing Rod Orientation

Section 5

TEST PLAN

The test plan for Stage 3 of Task 4.3 is divided into facility calibration and separate effects tests. Facility calibration tests include facility operational shakedown and calibration of various system components. Separate effects tests will include tests to investigate the following general phenomena:

1. Core Spray Heat Transfer
2. Reflood Heat Transfer
3. Bypass Heat Transfer
4. Refill-Reflood Performance

5.1 FACILITY CALIBRATION TEST PLAN

The objectives of the facility calibration tests are:

1. To debug facility operational problems.
2. To provide test section calibration data to aid in evaluation of the separate effects data.

The test series includes the following types of tests:

1. Single-phase fill
2. SCR Power System Checkout
3. Upper Tie Plate CCFL
4. TOB CCFL
5. SEO CCFL
6. Bypass Leakage Calibration

Each of these tests is described briefly in the following paragraphs.

5.1.1 Single Phase Fill

Configuration: System Configuration (Figure 3-4)

Objective: Checkout operation of facility and the test instrumentation

Procedure: Use saturated LPCI to fill test section

5.1.2 Silicon Controlled Rectifier Power System Checkout

Configuration: System Configuration (Figure 3-4)

Objective: Verify operation of heater rods and the power decay transient system.

Procedure: Initialize core power at 100 kW and then initiate transient. Compare power versus time data against expected transient.

5.1.3 Upper Tie Plate Counter-Current Flow Limiting

Configuration: Blocked jet pump; blocked core to bypass leakage (Figure 3-6)

Objective: Confirm CCFL characteristics of upper tie plate as predicted by current best estimate CCFL correlation.

Procedure: Turn on saturated LPCI and fill the GT and bypass. Inject core steam. Inject saturated spray, as required to maintain a constant level in the UP. Record steam flow and spray flow. Repeat for several steam flows.

5.1.4 Top of Bypass Counter-Current Flow Limiting

Configuration: Blocked jet pump; blocked core to bypass leakage (Figure 3-6)

Objective: Determine CCFL characteristics of the reduced flow area at the TOB.

Procedure: Fill the LP and core, to the top of the inner channel, with saturated liquid. Inject GT steam. Turn on saturated spray and adjust spray rate to maintain a constant level in the UP. Record steam flow and spray rate.

5.1.5 Side Entry Orifice Counter-Current Flow Limiting

Configuration: Blocked jet pump; blocked bypass leakage (Figure 3-6)

Objective: Confirm CCFL characteristics of SEO.

Procedure: Inject LP steam. Inject saturated spray as required to maintain a constant level in the region above the SEO. Record steam flow and spray flow. Repeat for several steam flows.

5.1.6 Bypass Leak Calibration

Configuration: System Configuration (Figure 3-4)

Objectives: Determine bypass leakage as a function of bypass head.

Procedure: Inject saturated LPCI into bypass. Allow bypass level to reach steady state. Record LPCI flow and bypass level. Repeat for several LPCI flows.

5.1.7 Facility Calibration Test Matrix

A complete test matrix for the Stage 3 facility calibration tests is shown in Table 5-1.

Table 5-1

FACILITY CALIBRATION TEST MATRIX - STAGE 3

Run Number Series	Core Power (kW)	ECC Flow (gpm)	ECC Temp (°F)	Steam Injection LP (lb/hr)	Steam Injection GT (lb/hr)	SEO Diam (in.)	Test Section Configuration	Comments
100 (Single-Phase Fill)	0	10	212	0	0	2.43	System	LPCI Only
200 (SCR Checkout)	100	17	120	0	0	2.43	System	Spray Only
300 (Upper Tie Plate CCFL)	0	Vary	212	Vary	0	2.43	Blocked jet pump; blocked bypass leakage	Bypass Full Spray Only
400 (TOB CCFL)	0	Vary	212	0	Vary	2.43	Blocked jet pump; blocked bypass leakage	Core Full Spray Only
500 (SEO CCFL)	0	Vary	212	Vary	0	2.43	Blocked jet pump; blocked bypass leakage	Spray Only
600 (Bypass Leak)	0	Vary	212	0	0	2.43	System	LPCI Only

5.2 SEPARATE EFFECTS TEST PLAN

The separate effects strategy is designed to study LOCA phenomena to support the model development task of the BWR Refill-Reflood Program. The test plan is divided into four types of tests: (a) core spray heat transfer, (b) reflood heat transfer, (c) bypass heat transfer, and (d) refill-reflood performance. The test plan for each of these tests is outlined in the following subsections.

5.2.1 Core Spray Heat Transfer

Configuration: Blocked jet pump; blocked core to bypass leakage; SEO removed; isolated guide tube; top of bypass blocked (Figure 3-7).

Objective: Determine bundle core spray heat transfer characteristics at spray flows less than 2.5 gpm. Two types of tests will be performed. The first has a flooded bypass region throughout the test. The other type is to have a bypass flow which is 20% of the spray flow rate.

Procedure: Establish bypass conditions according to the test matrix. Inject steam into the LP. Set core power to desired value and allow core to heat up to desired temperature. Initiate core spray and power decay and continue until core has cooled (T bulk < 400°F). If the core bulk temperature exceeds 1800°F, terminate core power and allow core to cool. Continually drain the LP to prevent core reflooding.

Test Plan: The test parameters are based on best estimate values for the BWR. The test plan is to vary the core spray from 3 gpm down to 0. Once these tests are complete, the core steaming rate and the core spray rate are varied. It is necessary to limit the bundle temperature to preserve the test bundle for other separate effects tests. The test matrix is shown in Table 5-2.

5.2.2 Reflood Heat Transfer

The objective of the reflood heat transfer (RHT) tests is to examine the reflood heat transfer performance to provide entrainment, void fraction, spacer differential pressure, quench front propagation, and bundle temperature data. The RHT tests are divided into three categories:

1. RHT with controlled bottom flooding
2. RHT with core-bypass interaction and
3. RHT with core-bypass-jet pump interaction.

The test plan for each of these is outlined in the following pages.

Table 5-2

CORE SPRAY HEAT TRANSFER TEST MATRIX

Run	Spray Rate (gpm)	LP Steam Injection (lbm/hr)	Initial Temp (°F)	Initial Power (kW)	Comments*
1001	2.5	400	1100	250	
1002	2.0	400	1100	250	
1003	1.5	400	1100	250	
1004**	1.0	400	1100	250	
1005	0.5	400	1100	250	
1006**	0	400	1100	250	Dry Bypass
1007**	1.5	0	1100	250	
1008**	2.0	0	1100	250	
1009	2.5	0	1100	250	
1010**	3.0	0	1400	250	Tieback Test
1011**	1.0	1200	1100	250	Dry Bypass
1012**	1.5	0	1100	250	Flooded Bypass
1013**	1.0	0	1100	250	
1014**	1.0	600	1100	250	
1015	0.5	600	1100	250	
1016	0	600	1100	250	
1017	2.0	200	1100	250	
1018**	1.0	200	1100	250	
1019	2.0	200	800	250	
1020	1.0	200	800	250	
1021	0	200	800	250	
1022	0.5	200	1100	250	
1023	0	200	1100	250	
1024**	0.5	0	1100	250	
1025	1.0	400	800	250	Flooded Bypass
1026	0.5	400	800	250	Flooded Bypass
1027**	1.0	400	1100	250	
1028**	2.0	0	1100	250	Flooded Bypass
1029**	0.5	0	1100	250	Flooded Bypass
1030**	1.0	0	1100	250	Flooded Bypass
1031	0	0	N/A	30	Steady-State Radiation Test***

*All tests with bypass flow = 20% of spray rate except those labeled "Flooded Bypass" or "Dry Bypass."

**1st Priority Tests

***Other steady-state radiation tests to monitor bundle condition are included as part of another test.

All Tests:

Configuration:	Blocked jet pump; blocked bypass leakage; isolated GT; top of bypass blocked.
ECC Temperature	= 212°F
Steam Dome Steam Injection	= 100 lbm/hr
GT Steam Injection	= 0 lbm/hr
GT Full of Saturated Water	
Maximum Allowable Bundle Temperature	= 1800°F

5.2.2.1 Reflood Heat Transfer With Controlled Bottom Flood

Configuration: Blocked jet pump; blocked bypass leakage (Figure 3-6).

Objective: Determine reflood heat transfer characteristics with controlled bottom flood. Measure entrainment, core void fraction, spacer ΔP, and bundle temperatures.

Test Procedure: Fill the LP to the bottom of the lower tie plate with saturated water. Initiate steam flow as required. Initiate core power (if required) and allow core bulk temperature to reach desired value. Initiate power transient and LP flood. If core peak temperature exceeds 1800°F, terminate the core power and allow core to cool. Otherwise, allow test to continue until bulk core temperature is less than 400°F.

Test Plan: Conduct this series of tests with three LP flood rates (1, 2, and 3 LPCI) and three core steam flow rates with no core power. Vary the core power and initial bulk temperature to investigate the effect of stored and decay heat. Vary the core steam injection rate to determine its effect on RHT. The test matrix is shown in Table 5-3.

Table 5-3

REFLOOD HEAT TRANSFER WITH CONTROLLED BOTTOM FLOODING TEST MATRIX

Run	Lower Plenum Flood Water Flow (gpm)	Lower Plenum Flood Water Temp. (°F)	Core Power (kW)	Initial Core Temp. (°F)	LP Steam Injection (lbm/hr)
2301*	8	212	0	Saturation	200
2302*	8	212	0	Saturation	400
2303	8	212	0	Saturation	800
2304	16	212	0	Saturation	200
2305	16	212	0	Saturation	400
2306	16	212	0	Saturation	800
2307	24	212	0	Saturation	155
2308	24	212	0	Saturation	400
2309	24	212	0	Saturation	800
2310	8	212	250	1100	0
2311	16	212	250	1100	0
2312	24	212	250	1100	0
2313	8	212	250	800	155
2314*	8	212	250	1100	155
2315	8	212	250	1400	155
2316	8	212	150	800	155
2317	8	212	150	1100	155
2318	8	212	150	1400	155
2319*	8	212	100	1100	155
2320	8	212	100	1400	155

Table 5-3

REFLOOD HEAT TRANSFER WITH CONTROLLED BOTTOM FLOODING TEST MATRIX (Continued)

Run	Lower Plenum Flood Water Flow (gpm)	Lower Plenum Flood Water Temp. (°F)	Core Power (kW)	Initial Core Temp. (°F)	LP Steam Injection (lbm/hr)
2321	8	212	100	800	400
2322	8	212	300	1100	0
2323	8	212	100	1100	0
2324	8	212	250	800	0
2325	8	212	250	1400	0
2326	8	120	250	1100	0
2327	8	160	250	1100	0
2328*	8	212	0	Saturation	155
2329*	8	212	250	1100	0
2330*	8	212	100	1100	0
2331*	4	212	250	1100	155
2332	1	212	250	1100	155
2333	8	212	0	Saturation	800
2334	24	212	0	Saturation	400
2335	16	212	0	Saturation	155

*1st Priority Test.

All Tests:

Configuration: Blocked jet pump; blocked bypass leakage
GT Steam = 0 lbm/hr
Core Steam = 0 lbm/hr
Bypass Continually Drained
SEO Diameter = 2.43 in.
Maximum Allowable Peak Cladding Temperature (PCT) = 1800°F
Lower plenum full of saturated liquid to lower tie plate.

5.2.2.2 Reflood Heat Transfer with Core-Bypass Interaction

Configuration: Blocked Jet Pump (Figure 3-5).

Objective: Determine core heat transfer performance with core-bypass interaction; compare results to controlled bottom flood RHT results.

Procedure: Fill the LP to the level of the lower tie plate with saturated water. Initiate steam flow and core power and allow core bulk temperature to reach desired value. Initiate LPCI and power transient. Allow test to continue until the core temperature exceeds 1800°F, terminate core power and allow core to cool.

Test Plan: Perform this test with three bundle powers and three LPCI subcoolings. The test matrix is shown in Table 5-4.

Table 5-4

REFLOOD HEAT TRANSFER WITH CORE-BYPASS INTERACTION TEST MATRIX

Run	LPCI Temp (°F)	Core Power (kW)
2101*	212	250
2102	160	250
2103*	130	250
2104	212	150
2105	160	150
2106	130	150
2107	212	100
2108	160	100
2109	130	100

*1st Priority Test

All Tests:

Configuration:	Blocked Jet pump
Spray	= 0 gpm
LPCI	= 8 gpm
Initial Core Temperature	= 1100°F
Maximum PCT	= 1800°F
Steam Dome Steam Injection	= 100 lbm/hr
LP Steam	= 155 lbm/hr
GT Steam	= 0 lbm/hr

Lower plenum initially full of saturated liquid to lower tie plate.

5.2.2.3 RHT with Core-Bypass - Jet Pump Interaction

Configuration: System Configuration (Figure 3-4).

Objective: Determine the effect of the jet pump flow path on the RHT performance.

Procedure: Same as RHT with blocked jet pump. For tests with LP steam flow, start the steam flow prior to initializing the core power.

Test Plan: Repeat the high power RHT with core-bypass interaction tests, with and without LP steam injection. The test matrix is shown in Table 5-5.

Table 5-5

REFLOOD HEAT TRANSFER WITH CORE-BYPASS - JET PUMP INTERACTION TEST MATRIX

Run	LPCI Temp (°F)	LP Steam Injection (lbm/hr)
2201*	212	155
2202	160	155
2203	120	155
2204	212	0
2205	160	0
2206	130	0
2207	130	155
2208	130	155
2209	130	155

*1st Priority Test

All Tests:

Configuration:	System (open jet pump)
Core Power	= 250 kW
Spray	= 0 gpm
LPCI	= 8 gpm
Initial Core Temperature	= 1100°F
Maximum Allowable PCT	= 1800°F
Steam Dome Steam Injection	= 100 lb/hr
GT Steam	= 0 lbm/hr

Remove the SEO

Lower plenum initially full of saturated liquid to lower tie plate.

5.2.3 Bypass Heat Transfer

Configuration: Blocked jet pump; blocked bypass leakage; isolated GT; TOB blocked (Figure 3-7).

Objective: Determine the bypass heat transfer rate.

Test Procedure: Initiate lower plenum flow as required. Initiate core power as required and allow core to heat up to desired initial temperature. Initiate LPCI and core power transient. Continue test until core temperature has peaked and is below 400°F. Terminate core power if PCT exceeds 1800°F.

Test Plan: Perform adiabatic (no core power) tests. Vary LPCI flow rate and LPCI temperature to determine bypass heat transfer rate. Perform similar heated tests for three bundle powers with various initial core temperatures. The test matrix is shown in Table 5-6.

Table 5-6

BYPASS HEAT TRANSFER TEST MATRIX

Run	LPCI Temp (°F)	Core Power (kW)	Initial Core Temp (°F)	LP Steam Injection (lbm/hr)	LPCI Flow (gpm)
3001	212	0	Saturation	200	8
3002	212	0	Saturation	800	8
3003	212	0	Saturation	400	8
3004	160	0	Saturation	400	8
3005	160	0	Saturation	800	16
3006	160	0	Saturation	400	24
3007	120	0	Saturation	800	8
3008*	120	0	Saturation	800	16
3009	120	0	Saturation	800	24
3010*	120	250	800	400	16
3011	120	250	1100	400	16
3012*	120	250	1400	400	16
3013	120	250	800	400	16
3014	120	150	1100	400	16
3015	120	150	1400	400	16
3016	120	100	800	400	16
3017	120	100	1100	400	16
3018*	120	100	1400	400	16
3019	120	300	1400	400	16
3020*	120	0	Saturation	400	8
3021*	120	0	Saturation	400	16
3022*	120	0	Saturation	400	24
3023*	160	0	Saturation	400	16

*1st Priority Test

All Tests:

Core Steam	= 0 lbm/hr
GT Steam	= 0 lbm/hr
Steam Dome Steam	= 100 lbm/hr
LP Initial Mass	= 0 lb/hr
Maximum Allowable PCT	= 1800°F

5.2.4 Refill-Reflood Performance

Configuration: System Configuration (Figure 3-4).

Objective: Repeat Stage 1 refill-reflood experiments with the additional instrumentation available for Stage 1 data.

Test Procedure: Establish initial mass levels in the LP and GT. Establish initial steam flows. Initiate core power and bring core to initial bulk temperature. Initiate spray and LPCI and power transient. Terminate test if PCT exceeds 1800°F. Continue test until core level is stabilized at the level of the jet pump.

Test Plan: Repeat "BWR-Like" Stage 1 test for average and high power bundles (run numbers 1800 and 1901). Perform tests to simulate TLTA test 6423 Run 3 (High Power, Low ECC). The test matrix is shown in Table 5-7.

Table 5-7

REFILL-REFLOOD PERFORMANCE TEST MATRIX

Run	ECC			Initial Core		Steam Injection (lbm/hr)			Initial Mass (lbm)		Comments
	LPCI (gpm)	Spray (gpm)	Temp (°F)	Power (kW)	Temp (°F)	Core	Lower Plenum	Guide Tube	Lower Plenum	Guide Tube	
4001	6.3	17.1	130	45	250	0	155	86	56	110	Avg. Power, Avg. ECC
4002	6.3	17.1	130	59	400	0	155	86	56	110	Avg. Power, Avg. ECC
4003*	6.9	7.1	124	130	400	0	400	151	52	71	High Power, Low ECC (T[illegible]-Like)
4004*	6.9	7.1	118	69	400	0	187	151	52	71	High Power, Low ECC (BWR-Like)

*1st Priority Test

All Tests:

Configuration:	System
Steam Dome Steam	= 100 lbm/hr
SEO Diameter	= 2.43 in.
Maximum Allowable PCT	= 1800°F

Section 6

DATA UTILIZATION

Data from these Stage 3 tests will be used to develop and qualify the separate effects models described in Section 4. The utilization of these Stage 3 data in fulfilling the data requirements is shown diagrammatically in Table 6-1, which indicates the particular models for which the various tests series are designed to provide data.

Note that specific test series are not designated for upper tie plate CCFL breakdown. Test Series 300 establishes saturated conditions and was not designed to include CCFL breakdown. The breakdown phenomena is expected to occur in Test Series 4000, but use of the data for CCFL correlation is not included in the planning.

Table 6-1

SHB STAGE 3 DATA UTILIZATION

Data Requirements	Core Spray Heat Transfer	Reflood Heat Transfer	Core Bypass Heat Transfer	Entrainment	Liquid Carryover	CCFL Upper Tie Plate	Upper Tie Plate CCFL Breakdown	SEO CCFL	Top of Bypass CCFL	Core Vaporization	Void Distribution	Condensation Effects - LTP Leak	Flow Distribution
Core Spray Heat Transfer (Run 1000 Series)	X									X	X		
Reflood Heat Transfer Controlled Bottom Flood (Run 2300 Series)		X		X	X					X	X	X	
Reflood Heat Transfer With Core-Bypass Interaction (Run 2100 Series)		X		X	X					X	X	X	
Reflood Heat Transfer With Core-Bypass-Jet Pump Interaction (Run 2200 Series)		X		X	X					X	X	X	
Bypass Heat Transfer (Run 3000 Series)			X										
Upper Tieplate CCFL (Run 300 Series)						X							
TOB CCFL (Run 400 Series)									X				
SEO CCFL (Run 500 Series)								X					
Refill-Reflood (Run 4000 Series)										X	X		X

Section 7

TEST STRATEGY AND SCHEDULE

The Stage 3 SEB test series will be divided into four sub-series dependent on the test section configuration utilized. The various tests described earlier are presented in Table 7-1 as a summary showing which tests required a particular configuration. Those tests labelled with a first priority in Tables 5-2 through 5-7 will be performed first in each sub-series. The other tests will be performed as necessary to meet the model development data requirements. All testing in Stage 3 is scheduled for completion in mid-September 1980.

The high temperature heat transfer tests typical of this program can damage the heated bundle. To monitor the condition of the test bundle so that the bundle remains in satisfactory condition for all tests series, a program of x-ray inspections will be conducted. These inspections will be performed at the end of each block of testing, and more often as required by the responsible engineer. Thermocouple and heater rod characteristics will also be assessed on a continuing basis.

Table 7-1

TEST CONFIGURATION SUMMARY

Test Configuration	Test Series
System (Figure 3-4)	Series 100, Single-Phase Fill
	Series 200, SCR check
	Series 600, Bypass Leakage
	Series 2200, RHT
	Series 4000, Refill-Reflood
Blocked Jet Pump (Figure 3-5)	Series 2100, RHT
Blocked Jet Pump; Bypass Leakage Blocked (Figure 3-6)	Series 300, UTP CCFL
	Series 400, TOB CCFL
	Series 500, SEO CCFL
	Series 2300, RHT
Blocked Jet Pump; Blocked Bypass Leakage; Isolated GT; TOB Blocked; (Figure 3-7)	Series 3000, Bypass HT
	Series 1000, Core Spray HT

Section 8

REFERENCES

1. Contract NRC-04-79-184, BWR Refill-Reflood Program, NRC, EPRI, GE-NED; Appendix B - BWR Refill-Reflood Program Workscope, February 12, 1979.

2. D. D. Jones, L. L. Myers, J. A. Findlay, "BWR Refill-Reflood Program Task 4.3 - Single Heated Bundle Experimental Task Plan," General Electric Company, January 1980 (NUREG/CR-1708; EPRI NP-1524; GEAP-24865).

NRC FORM 335 (7-77) U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET**	1. REPORT NUMBER (Assigned by DDC) NUREG/CR-1708-ADD.I GEAP-24865 - ADD.I
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) BWR Refill-Reflood Program; Task 4.3-Single Heated Bundle; Experimental Task Plan; Addendum I - Stage 3 - Separate Effects Bundle	2. (Leave blank)
	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) D. D. Jones	5. DATE REPORT COMPLETED MONTH July YEAR 1980
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) General Electric Company 175 Curtner Ave. San Jose, CA 95125	DATE REPORT ISSUED MONTH March YEAR 1981
	6. (Leave blank)
	8. (Leave blank)
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) U. S. Nuclear Regulatory Commission Div.of Reactor Safety Research Office of Nuclear Regulatory Commission Washington, D.C.	10. PROJECT/TASK/WORK UNIT NO.
	11. CONTRACT NO. B5877
13. TYPE OF REPORT Experimental Task Plan	PERIOD COVERED (Inclusive dates)
15. SUPPLEMENTARY NOTES	14. (Leave blank)

16. ABSTRACT (200 words or less)

An experimental task plan for the separate effects bundle tests of the Single Heated Bundle Task in the BWR Refill-Reflood Test Program is presented. The tests will provide core spray and reflood heat transfer data and will investigate BWR refill-reflood controlling phenomena to support model development tasks in the BWR Refill-Reflood Program. Individual test conditions, the measurement plan and data utilization, are discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS	17a. DESCRIPTORS
17b. IDENTIFIERS/OPEN-ENDED TERMS	

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (This report)	21. NO. OF PAGES
Unlimited	Unclassified	
	20. SECURITY CLASS (This page) Unclassified	22. PRICE $

NRC FORM 335 (7-77)