NRC Research and/or Technical Assistance Rept PDR

EGG-SEMI-5913

June 1982

THEF EXPERIMENT OPERATING SPECIFICATION FOR FLOW REGIME AND CRITICAL FLOW STUDIES EXPERIMENT 1

R. S. Semken

U.S. Department of Energy

Idaho Operations Office • Idaho National Engineering Laboratory

This is an informal report intended for use as a preliminary or working document

Prepared for the U.S. Nuclear Regulatory Commission under DOE Contract No. DE-AC07-76ID01570

FIN No. A6038

EG&G Idaho

EG&G Idaho, Inc.

FORM EG&G-398
(Rev. 11-79)

INTERIM REPORT

Accession No. ______

Report No. EGG-SEMI-5913

Contract Program or Project Title:

Thermal Hydraulic Experiment Facility

Subject of this Document:

THEF EXPERIMENT OPERATING SPECIFICATION FOR FLOW REGIME AND CRITICAL FLOW STUDIES EXPERIMENT 1

Type of Document:

Experiment Operating Specification

Author(s):

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Date of Document:

June 1982

Responsible NRC Individual and NRC Office or Division:

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Prepared for the
U.S. Nuclear Regulatory Commission
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LTSF EXPERIMENT OPERATING SPECIFICATION FOR
FLOW REGIME AND CRITICAL FLOW STUDIES
EXPERIMENT 1

Approved: GW Johnsen for

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ABSTRACT

This document is a transmittal of experiment operational requirements for the first experiment of the Flow Regime and Critical Flow Studies as defined by the Experimental Specification and Analysis Branch of the EG&G Idaho Inc., Water Reactor Research Test Facilities (WRRTF) Division. It is intended primarily for the WRRTF Facilities and Test Operations Branch as input to the detailed test operating procedures, but is also useful as an experiment description for general reference. Within this document are found the experiment description; hardware, measurement, and procedural requirements; data acquisition and processing requirements; and data analysis and reporting requirements.

ACKNOWLEDGEMENTS

Special thanks are due to J. S. Martinell for his considerable expertise and aid in the planning of this experiment.

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THEF EXPERIMENT OPERATING SPECIFICATION FOR

FLOW REGIME AND CRITICAL FLOW STUDIES

EXPERIMENT 1

1. INTRODUCTION

This document provides the programmatic information required by the WRRTFD Facilities and Test Operations Branch to develop the detailed experiment procedures for the Flow Regime and Critical Flow Tests to be performed in the Two Phase Flow Loop at the Thermal Hydraulic Experiments Facility (THEF).[1] Also, this EOS will assist the Measurement Engineering and Data Systems and Technical Support Branches in their preparation for the tests.

The flow regime studies segment of the experiment is intended to determine two phase regime transition boundaries in the 14" Sch. 160 horizontal test section of the Two Phase Flow Loop. The critical flow tests segment will follow the flow regime studies and is intended to quantify the relationship between two phase flow regimes and the rate and quality of the discharge flow through a break orifice in a depressurizing system. Specifically, the objectives for the flow regime studies are to (a) provide data to map the flow regimes in the two-phase flow loop test section over the loop's current range of two-phase flow capabilities, (b) provide data to aid in developing models to predict two-phase flow regime transition boundaries in large horizontal pipes, and (c) evaluate void fraction, superficial velocity, and momentum flux measurement techniques. The critical flow tests objectives are to (a) establish the two-phase flow loop's capabilities and control system limitations under break flow operating conditions, (b) provide data to assess flow regime affects on critical flow from a horizontal branch line, and (c) provide data for code assessment and development of break flow modeling.

The planning and design of this experiment was based largely on previous work done in two phase flow regime study and identification reported by N. Zuber[2] of the U.S. Nuclear Regulatory Commission, and

M. S. Vince and R. T. Lahey, Jr.[3] of Rensselaer Polytechnic Institute. This experiment is the first of the Flow Regime and Critical Flow Studies. Additional experimentation is planned and will be detailed based on the results of this first experiment.

Section 2 of this document presents the experiment description for each of the two testing segments. In Section 3, the procedural requirements are provided including hardware, water chemistry, and measurement requirements; followed by the recommended testing procedure. Data acquisition and processing requirements are given in Section 4, and finally, in Section 5, the data analysis and reporting requirements are discussed.

2. EXPERIMENT DESCRIPTION

The Flow Regime and Critical Flow Studies, Experiment 1, is comprised of two separate testing segments, each with an independent set of test objectives. The following paragraphs briefly describe these segments. More detailed requirements are given in Section 3.

2.1 Flow Regime Boundary Tests

The initial segment of the experiment will be the flow regime boundary tests. In general, these tests will entail determining the two phase flow regime in the test spoolpiece of the Two Phase Flow Loop for approximately one hundred pairs of phasic velocities covering the full operating ranges of the loop (to 11 m/s steam and 8.8 m/s liquid). The loop will be operated in its original design configuration at 7 MPa and saturation temperature.

2.1.1 Test Section Geometry for Flow Regime Boundary Tests

The 14-in. Wyle test section will be used as originally designed except for modifications to add test specific instrumentation and an optical probe. A homogenizing screen will be added to the outlet of the mixing tee to ensure that phase separation is not artifically induced there.

2.1.2 Test Matrix for Flow Regime Boundary Tests

The test matrix for the flow regime tests is detailed in Table 1. There are 100 data points requested in the table, but more may be required as testing progresses. The requested data points are identified in Table 1 by a descriptive set of alpha-numeric characters. All identification designations begin with the letters "FR1-" for Flow Regime Studies, Experiment 1, followed by two numbers which correspond to the requested superficial steam and water velocities (m/s), respectively. The sequence of tests will be determined as testing progresses. Only 25 data points are defined in Table 1. These points were chosen to cover the full range of

TABLE 1. TEST MATRIX FOR FLOW REGIME BOUNDARY TESTS[a]

	Test Identification[b]	m_g (kg/s)	m_f (kg/s)	J_g[c] (m/s)	J_f[c] (m/s)
1.	FR1-0.5-0.06	1.14	2.8	0.5	0.06
2.	FR1-0.5-0.25	1.14	11.7	0.5	0.25
3.	FR1-0.5-0.80	1.14	37.6	0.5	0.80
4.	FR1-0.5-2.50	1.14	117.6	0.5	2.50
5.	FR1-0.5-8.80	1.14	414.0	0.5	8.80
6.	FR1-1.0-0.06	2.28	2.8	1.0	0.06
7.	FR1-1.0-0.25	2.28	11.7	1.0	0.25
8.	FR1-1.0-0.80	2.28	37.6	1.0	0.80
9.	FR1-1.0-2.50	2.28	117.6	1.0	2.50
10.	FR1-1.0-8.80	2.28	414.0	1.0	8.80
11.	FR1-2.5-0.06	5.70	2.8	2.5	0.06
12.	FR1-2.5-0.25	5.70	11.7	2.5	0.25
13.	FR1-2.5-0.80	5.70	37.6	2.5	0.80
14.	FR1-2.5-2.50	5.70	117.6	2.5	2.50
15.	FR1-2.5-8.80	5.70	414.0	2.5	8.80
16.	FR1-5.5-0.06	12.53	2.8	5.5	0.06
17.	FR1-5.5-0.25	12.53	11.7	5.5	0.25
18.	FR1-5.5-0.80	12.53	37.6	5.5	0.80
19.	FR1-5.5-2.50	12.53	117.6	5.5	2.50
20.	FR1-5.5-8.80	12.53	414.0	5.5	8.80
21.	FR1-11.0-0.06	25.06	2.8	11.0	0.06
22.	FR1-11.0-0.25	25.06	11.7	11.0	0.25
23.	FR1-11.0-0.80	25.06	37.6	11.0	0.80
24.	FR1-11.0-2.50	25.06	117.6	11.0	2.50
25.	FR1-11.0-8.80	25.06	414.0	11.0	8.80
26.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
27.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
28.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
29.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
30.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
31.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
32.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
33.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
34.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
35.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
36.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
37.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
38.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
39.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
40.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
41.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
42.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
43.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]

TABLE 1. (continued)

	Test Identification[b]	m_g (kg/s)	m_f (kg/s)	J_g[c] (m/s)	J_f[c] (m/s)
44.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
45.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
46.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
47.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
48.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
49.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
50.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
51.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
52.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
53.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
54.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
55.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
56.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
57.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
58.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
59.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
60.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
61.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
62.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
63.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
64.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
65.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
66.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
67.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
68.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
69.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
70.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
71.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
72.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
73.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
74.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
75.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
76.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
77.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
78.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
79.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
80.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
81.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
82.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
83.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
84.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
85.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
86.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]

TABLE 1. (continued)

	Test Identification[b]	m_g (kg/s)	m_f (kg/s)	J_g[c] (m/s)	J_f[c] (m/s)
87.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
88.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
89.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
90.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
91.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
92.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
93.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
94.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
95.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
96.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
97.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
98.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
99.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]
100.	FR1-TBD[d]-TBD[d]	TBD[d]	TBD[d]	TBD[d]	TBD[d]

a. Acceptable test condition tolerances are:

$m_g = m_g \pm 0.05\ m_g$
$m_f = m_f \mp 0.05\ m_f$
$T = 558 \pm 3$ K
$P = 6.90 \pm 0.07$ MPa.

b. Test identification is as follows: Flow Regime Tests 1 - J_g - J_f.

c. These are approximate values. Test is controlled on m_g and m_f.

d. To be determined.

operating conditions in an even distribution to locate, roughly, the flow regime boundaries. As these rough boundaries are defined, the remaining 75 data points will be specified to better identify the boundary regions.

2.2 Critical Flow Tests

The second experiment segment is the critical flow testing. These tests will be loop depressurizations to a catch tank through newly fabricated break piping in the Two Phase Flow Loop. Twelve blowdowns are planned, each initiated with a different flow regime in the test spoolpiece, covering the stratified, dispersed bubbly, and slug flow regimes.[a] The loop will be operated initially to establish the proper flow conditions in its original design configuration at a pressure of 7 MPa and saturation temperature. Blowdown will be initiated by actuating the blowdown valve in the new break piping.

2.2.1 Test Section Geometry for Critical Flow Tests

A new break piping configuration will be fabricated and fixed between the test spoolpiece and the catch tank. The break piping configuration will be nominally the same as that used in the LOFT small break experiments (L3-5 and L3-6). A 0.6374 in. I.D. orifice plate will represent a scaled 4" break, which will be actuated by a quick opening blowdown valve.

2.2.2 Test Matrix for Critical Flow Tests

The test matrix for the critical flow tests is not yet defined completely. Twelve blowdowns are planned, four from each of three flow regimes including the stratified, dispersed bubbly, and slug.

---

a. Designation of anticipated flow regimes is based on Weisman[4] flow regime map. Actual regimes will be determined in the first test segment.

TABLE 2. EXAMPLE TEST MATRIX FOR CRITICAL FLOW TESTS[a]

	Test[b] Identification	Flow Regime	m_f (kg/s)	m_f (kg/s)	J_g (m/s)	J_f (m/s)
1.	CF1-S-TBD_g-TBD_f	stratified	TBD[c]	TBD	TBD	TBD
2.	CF1-S-TBD_g-TBD_f	stratified	TBD[c]	TBD	TBD	TBD
3.	CF1-S-TBD_g-TBD_f	stratified	TBD[c]	TBD	TBD	TBD
4.	CF1-S-TBD_g-TBD_f	stratified	TBD[c]	TBD	TBD	TBD
5.	CF1-DB-TBD_g-TBD_f	dispersed bubbly	TBD[c]	TBD	TBD	TBD
6.	CF1-DB-TBD_g-TBD_f	dispersed bubbly	TBD[c]	TBD	TBD	TBD
7.	CF1-DB-TBD_g-TBD_f	dispersed bubbly	TBD[c]	TBD	TBD	TBD
8.	CF1-DB-TBD_g-TBD_f	dispersed bubbly	TBD[c]	TBD	TBD	TBD
9.	CF1-SF-TBD_g-TBD_f	slug flow	TBD[c]	TBD	TBD	TBD
10.	CF1-SF-TBD_g-TBD_f	slug flow	TBD[c]	TBD	TBD	TBD
11.	CF1-SF-TBD_g-TBD_f	slug flow	TBD[c]	TBD	TBD	TBD
12.	CF1-SF-TBD_g-TBD_f	slug flow	TBD[c]	TBD	TBD	TBD

a. Acceptable test conduction tolerances are:

$m_g = m_g \pm .05\ m_g$
$m_f = m_f \pm .05\ m_f$
$T = 558 \pm 3$ K
$P = 6.90 \pm 0.07$ MPa

b. Test identification is as follows: Critical Flow Tests 1 - Flow Regime - J_g - J_f.

c. To be determined.

The requested data points will be defined following the Flow Regime segment of the experiment. Each data point will be identified by a set of alpha-numeric characters as were the data points of the Flow Regime Studies segment of the experiment. The first set of characters "CF1," represents "Critical Flow Studies, Experiment 1." The second set will be either "S," "DB," or "SF" to designate the respective flow regime in the test spoolpiece upon blowdown actuation. And finally, the last two numbers will represent the steam and water superficial velocities (m/s) in the test spoolpiece. Table 2 provides an example of the test matrix for the critical flow tests. The sequence of these blowdowns will be determined following the flow regime test segment.

3. EXPERIMENT REQUIREMENTS

This section presents the hardware, chemistry, measurement, and procedural requirements for the Flow Regime and Critical Flow Studies, Experiment 1. The hardware description includes a configuration sketch and the instrumentation section provides an instrument list and figures illustrating measurement locations.

3.1 Experiment Hardware Requirements

The Two Phase Flow Regime and Critical Flow Studies, Experiment 1, will be performed in the Two Phase Flow Loop (TPFL) at THEF. The standard loop piping will be used for the two phase flow regime studies segment, including the 16-in. liquid metering section, the 6-in. liquid metering section, the 12-in. steam metering section, the mixing tee, and the 14-in. test section. A homogenizing screen will be installed at the outlet of the mixing tee section. The critical flow tests segment will make use of a newly fabricated small break piping section which branches off of the 3 inch flange of the test spoolpiece and runs eventually into the catch tank. The pressure and temperature rating of the new piping section will be 17.25 MPa at 620 K (2500 psi at 650°F) from the 14-in. spoolpiece to and including the blowdown valve and approximately 3.5 MPa at saturation temperature from the blowdown valve and approximately 3.5 MPa at saturation temperature from the blowdown valve to the catch tank. Modifications will be made to the existing catch tank system to decouple, as much as possible, the break piping from the catch tank so no loads are transmitted to the catch tank load cells. The Two Phase Flow Loop is illustrated in Figure 1, and the general configuration of the critical flow tests break piping section is illustrated in Figure 2.

The Two Phase Flow Regime Studies segment will be accomplished by establishing positive flow in the loop and mixing in steam from the steam supply system. The loop pressure for each experiment will be 7 MPa and the fluid temperature will be near saturation. Data points will be obtained at varying steam and water velocity over the full range of possible loop flow

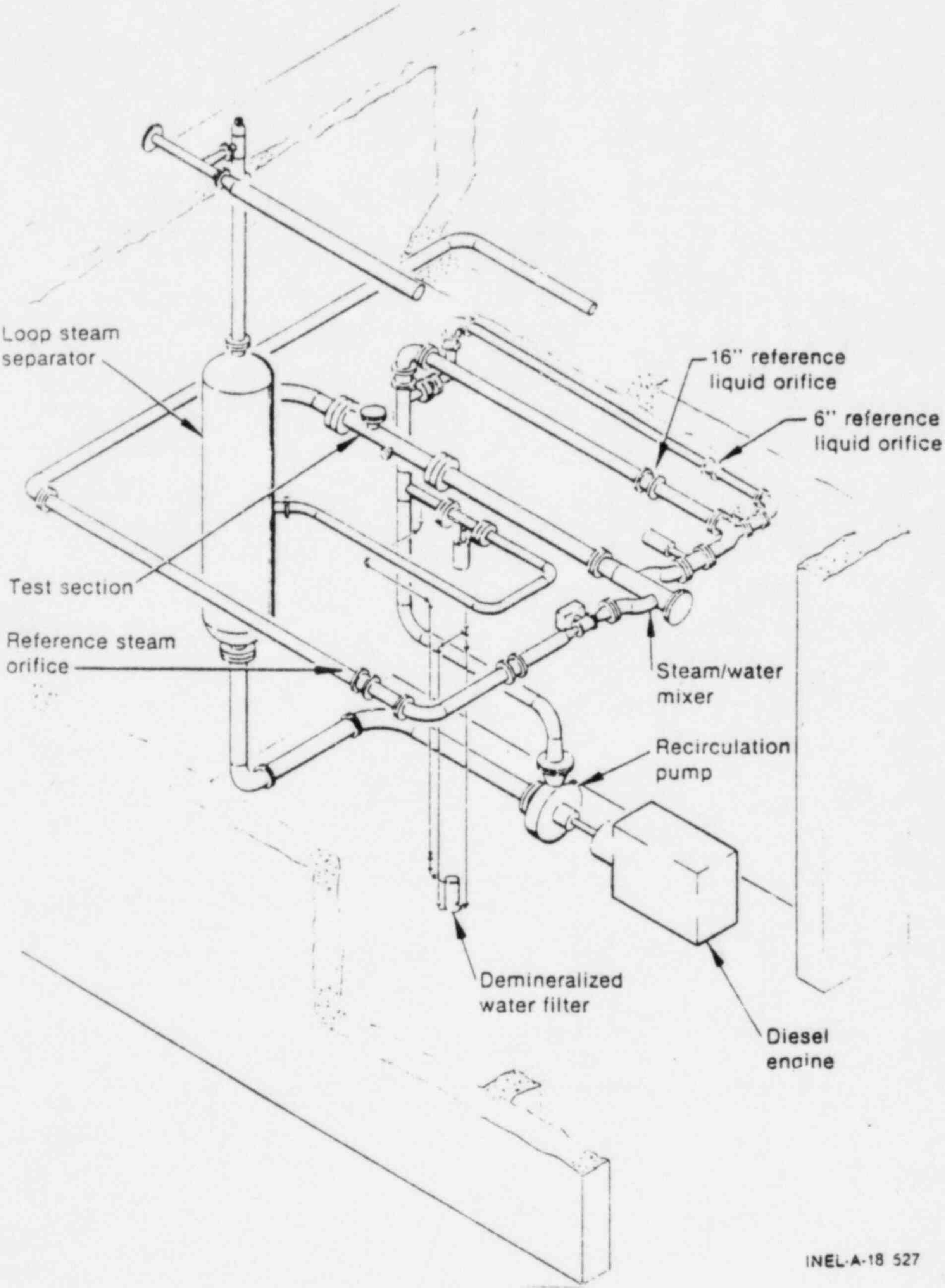

Figure 1. Two Phase Flow Loop (new break piping not shown).

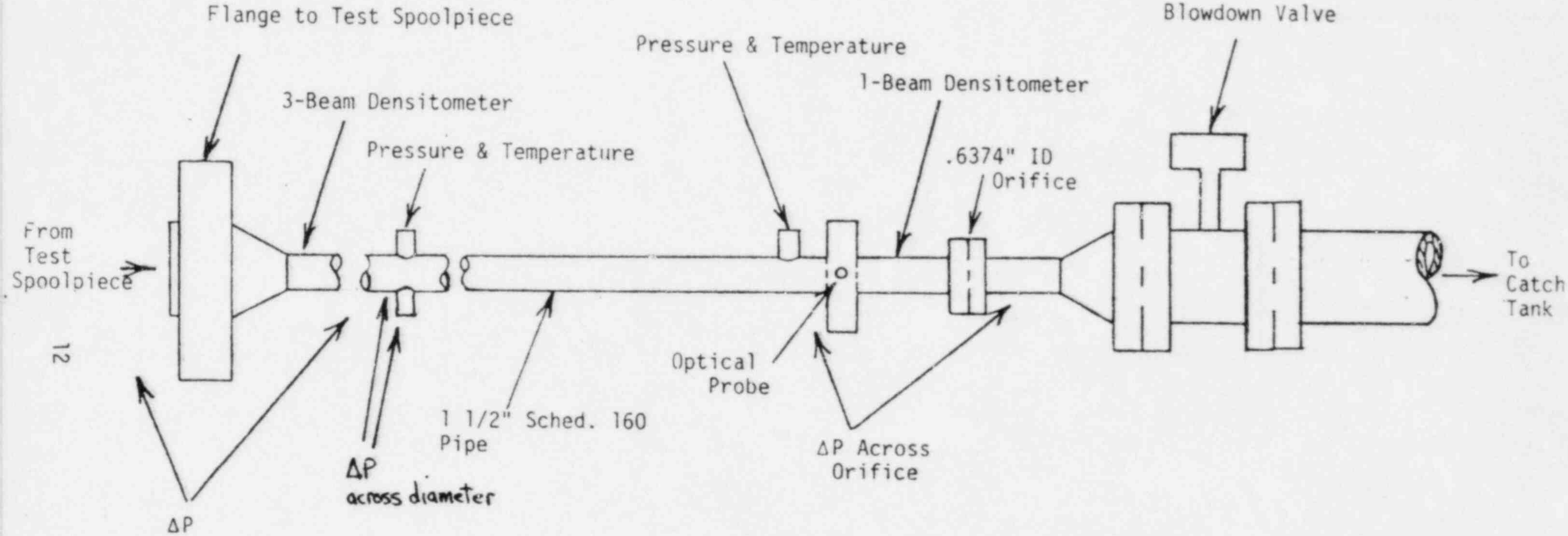

Figure 2. Schematic of new break piping section showing measurement locations for Two Phase Flow Regime and Critical Flow Studies Experiment.

conditions. The critical flow tests will entail establishing flow in the two phase loop at specified steam and water fractions, and opening the blowdown valve in the new small break piping section.

To cover the full range of operating conditions, provision should be made for changing out individual-phase metering section orifice plates during the testing procedure. Four steam orifice plates (2.88 through 7.63 inch inner diameters), three 16 inch liquid line orifice plates (3.58, 5.73, and 8.88 inch I.D.), and two 6 inch liquid line orifice plates (1.73 and 3.57 inch I.D.) will be used.

3.2 Chemistry Requirements

The chemistry requirements for the two phase loop are as follows:

pH at 298 K	9.0 to 10.5
Electrical Conductivity	2 Micromhos/cm max
Oxygen	0.10 ppm max
Chlorides	0.15 ppm max
Fluorides	No specified
Suspended solids	1.5 ppm max

A water sample will be taken at a minimum of 308 K and tested each testing day, with results provided to the test engineer.

3.3 Measurement Requirements

The required measurements for the Two Phase Flow Regime and Critical Flow Studies, Experiment 1 are listed in Table 3. Measurements of temperature, pressure, differential pressure, density, and mass flow rate are included in this table. In addition, the tests will require optical probes in two locations to provide a visual record of fluid conditions during testing. Figures 2 and 3 illustrate the general locations for each required measurement.

TABLE 3. MEASUREMENT REQUIREMENTS FOR THE TWO-PHASE FLOW REGIME AND CRITICAL FLOW STUDIES, EXPERIMENT 1

Description	Range
Loop Reference Measurements	
Fluid temperature upstream of reference steam orifice, top.	300 - 560 K
Fluid temperature upstream of reference steam orifice, bottom.	300 - 560 K
Fluid temperature at steam inlet to mixing tee.	300 - 560 K
Fluid temperature upstream of reference liquid orifice, 16-inch metering section.	300 - 560 K
Fluid temperature upstream of reference liquid orifice, 6-inch metering section.	300 - 560 K
Fluid temperature liquid inlet to mixing tee.	300 - 560 K
Pressure upstream of reference steam orifice.	0 - 10.5 MPa
Pressure at steam inlet to mixing tee.	0 - 10.5 MPa
Pressure upstream of 16-inch reference liquid orifice.	0 - 7 MPa
Pressure upstream of 6-inch reference liquid orifice.	0 - 7 MPa
Pressure liquid inlet to mixing tee.	0 - 7 MPa
Differential pressure across reference steam orifice, low range.	0 - 60 kPa
Differential pressure across reference steam orifice, high range.	60 - 260 kPa
Differential pressure across reference liquid orifice, low range, 16-inch.	0 - 60 kPa
Differential pressure across reference liquid orifice, high range, 16-inch.	60 - 260 kPa
Differential pressure across reference liquid orifice, low range, 6-inch.	0 - 60 kPa

TABLE 3. (continued)

Description	Range
Loop Reference Measurements (continued)	
Differential pressure across reference liquid orifice, high range, 6-inch.	60 - 260 kPa
Differential pressure across steam side of mixing tee.	0 - 345 kPa
Differential pressure across liquid side of mixing tee.	0 - 345 kPa
Liquid level in steam separator.	0 - 500 cm
Test Section Measurements	
Fluid temperature at outlet of mixing tee.	300 - 560 K
Fluid temperature at entrance to break piping.	300 - 560 K
Pressure at outlet of mixing tee.	0 - 7 MPa
Pressure at middle of 18' section to spoolpiece.	0 - 7 MPa
Pressure at outlet of 18' section to spoolpiece.	0 - 7 MPa
Pressure at entrance to break piping.	0 - 7 MPa
Pressure at outlet of test spoolpiece.	0 - 7 MPa
Differential pressure across 18' section upstream of spoolpiece.	0 - 60 kPa
Differential pressure from spoolpiece entrance to entrance to new break piping.	0 - 60 kPa
Differential pressure across spoolpiece diameter from top to bottom.	0 - 10 kPa
3-beam densitometer at outlet of mixing tee.	0 - 1000 kg/m^3
13-beam densitometer upstream of spoolpiece.	0 - 1000 kg/m^3
6-beam densitometer at inlet to test spoolpiece.	0 - 1000 kg/m^3
Optical probe at 6-beam densitometer location.	---
Break Piping Section Measurements	
Fluid temperature at inlet of break piping section.	300 - 560 K
Fluid temperature upstream of break orifice.	300 - 560 K

TABLE 3. (continued)

Description	Range
<u>Break Piping Section Measurements</u> (continued)	
Pressure at inlet of break piping section.	0 - 7 MPa
Pressure upstream of break orifice.	0 - 7 MPa
Differential pressure across inlet to break piping section.	0 - 60 kPa
Differential pressure across break piping diameter from top to bottom.	0 - 5 kPa
Differential pressure across break orifice.	0 - 7 MPa
2-beam densitometer at inlet to break piping section.	0 - 1000 kg/m^3
1-beam densitometer just upstream of break orifice.	0 - 1000 kg/m^3
Optical probe horizontally oriented near break orifice.	---
Liquid weight in catch tank.	0 - 4500 kg
Liquid weight in catch tank.	0 - 4500 kg
Fluid temperature in catch tank.	300 - 400 K
Fluid temperature in catch tank.	300 - 400 K
Pressure in catch tank.	0 - 1 MPa

NOTE: All thermocouples should have an uncertainty less than ±2.5 K, all pressure transducers should have an uncertainty less than ±1.0% of range, and all differential pressure transducers should have an uncertainty less than ±3.0% of range.

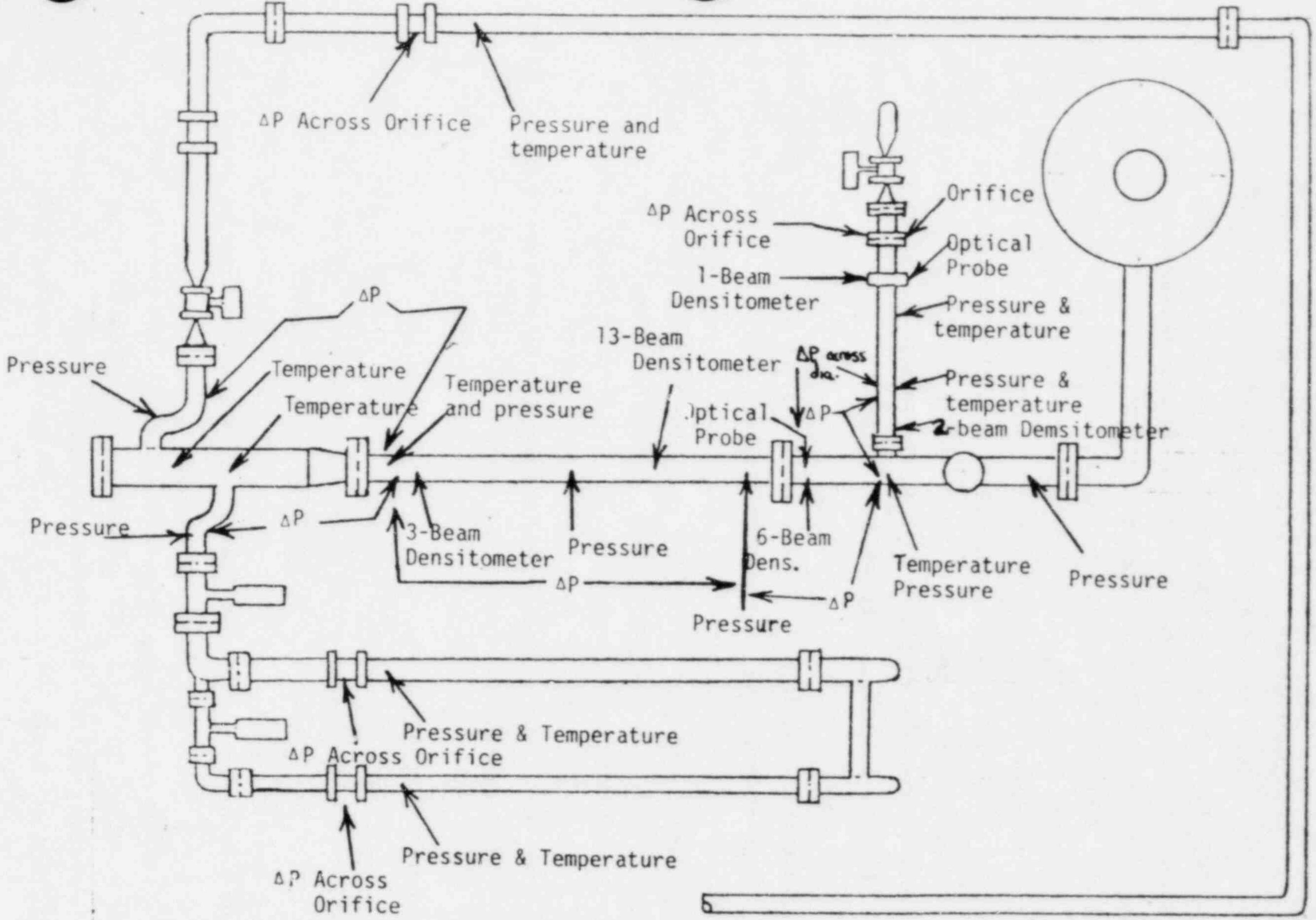

Figure 3. Plan view of Two Phase Flow Loop showing measurement locations for Two Phase Flow Regime and Critical Flow Studies Experiment.

For the purpose of clarity, the required measurements for this experiment will be discussed in three groups. First, the loop reference measurements will be discussed, including all loop measurements with programmatic importance except those located from the outlet of the steam/water mixing section to and including the catch tank. Second, the measurements required from the mixing section outlet to the entrance of the new small break piping section, called the test section measurements, will be discussed. Finally, those measurements required in the new break piping section and the catch tank will be discussed.

Analog recording will be required for the absolute and differential pressure measurements in the test and break piping sections. This is required to interpret the AC portion of the instrument outputs. Any analog bandwidth requirements will be provided at a later date. The frequency response of the analog recording will be less than 5 kHz.

All thermocouples should have an uncertainty less than $\pm$2.5 K, all pressure transducers should have an uncertainty less than $\pm$1.0% of range, and all differential pressure transducers should hae an uncertainty less than $\pm$3.0% of range. The densitometers should have an uncertainty less than $\pm$50 Kg/m^3. The uncertainty and accuracy of the load cell weighing system will be determined by a calibration test to preceed the test series if time and hardware availability permits, or following the test series. Modifications to the catch tank/load cell weighing system are being made to bring the weighing uncertainty during blowdown to within $\pm$0.05%.

3.3.1 Loop Reference Measurements

The loop reference measurements required are basically the same as those detailed in the TPFL L5-1 EOS. They consist of pressure, temperature, and differential pressure in each of the single phase supply lines, the mixing tee, and the steam separator. The single phase steam line will have two temperature measurements upstream of the reference steam flow orifice, one on top of the pipe, and one on the bottom to help indicate condensation in the steam line. An absolute pressure transducer will be located just upstream of the reference steam flow orifice. Two differential pressure measurements will be made across the steam orifice to determine mass flow rates for low range and high range measurements. A temperature and pressure measurement will be made at the steam line inlet to the mixing section.

The 16-in. and the 6-in. liquid metering sections both will be instrumented to determine reference liquid mass flow rate. The 16-in. line will have a temperature measurement and a pressure measurement upstream of the reference liquid orifice, and a differential pressure measurement across the orifice with high range and low range transducers. The 6-in. metering line will have temperature and pressure measurements upstream of the reference liquid orifice, and also a differential pressure measurement across the orifice with high and low range transducers. Pressure and temperature measurements will be made at the liquid inlet to the mixing section. Two differential pressure transducers will measure pressure drops from inlet to outlet of the mixing section, and a differential pressure measurement will be made to determine the liquid level in the steam separator.

3.3.2 Test Section Measurements

The test section measurement requirements are as follows. Temperature measurements will be made at the outlet of the mixing section and near the inlet to the new small break piping section. Absolute pressure measurements will be made at the outlet of the mixing section, near the middle of the 18' piping section upstream of the test spoolpiece, near the entrance to the test spoolpiece, near the inlet to the new small break piping section, and near the loop outlet to the test spoolpiece. Differential pressure measurements will be taken from the mixing section outlet to the test spoolpiece inlet and from the spoolpiece inlet to the entrance of the new small break piping section. A differential pressure measurement will also be made across the spool piece diameter from top to bottom at the inlet region. A 3-beam densitometer will be located at the mixing section outlet; a 13-beam densitometer will be located upstream of the test spoolpiece; and a 6-beam densitometer will be located just upstream of the entrance to the new break piping section. An optical probe will be provided as near as possible to the 6-beam densitometer and the entrance to the new break piping section.

3.3.3 Break Piping and Catch Tank Measurements

The measurements required in the remaining group, from the inlet of the new break piping section to the catch tank, are as follows. Temperature measurement will be made at two locations upstream of the break orifice as will absolute pressure measurements. Differential pressure will be measured across the entrance to the break piping, across the break orifice, and across the break piping diameter from top to bottom. A 2-beam densitometer will be located at the inlet, and a 1-beam densitometer will be located at the upstream side of the break orifice. As near as possible to the 1-beam densitometer, an optical probe will be located to view horizontally into the pipe. In the catch tank liquid weight will be measured continuously during blowdown testing. In addition, two temperature and one absolute pressure measurements will be made in the catch tank.

3.4 Test Procedural Requirements

The following section presents the general test procedural requirements for each testing segment of the Two Phase Flow Regime and Critical Flow Studies Experiment to be performed in the Two-Phase flow loop at the THEF. This section may be used as input to the detailed Test Operating Procedures (TOP). The actual testing sequence will be provided during testing by the test engineer.

3.4.1 Flow Regime Boundary Tests

The test matrix for the Flow Regime Boundary Tests was presented in Table 1. Each data point will be obtained at a loop presure of 6.9 $\pm$ 0.04 MPa and temperature of 558 $\pm$ 3 K in the test spoolpiece section. Depending on liquid mass flowrate, the 16-in. or 6-in. metering section will be used. The unused section will be blanked off.

For each data point, the loop will be heated to the saturation temperature (558 K) at 6.9 MPa using pump heat and/or steam whichever is most appropriate. This temperature will be held for 15 minutes. A flow data check will be made by printing a LOFT Data Average (LDA) during warmup, prior to reaching conditions for each data point. The liquid mass flowrate will be set and maintained as specified by the test engineer while the steam mass flowrate is set to its desired level. These combined test conditions will be maintained for 30 s prior to recording data. Sixty seconds of test data will then be recorded before steam mass flow is stopped. Liquid level in the steam separator will be maintained below the mixing section inlet throughout the tests.

3.4.2 Critical Flow Tests

Each data point for the Critical Flow Tests segment of the experiment will be obtained with the same procedure as those of the Flow Regime Boundary segment with one difference. After 30 seconds of test data is recorded (not 60 s), the blowdown valve in the new break piping assembly will be actuated and the subsequent blowdown will be recorded until the loop pressure in the test section reaches 2 MPa. The test will be terminated at that point.

Prior to obtaining each data point, the system will be refilled as indicated by standard operating practice and the initial conditions in the catch tank will be reestablished. The initial catch tank water level will be determined prior to testing.

4. DATA ACQUISITION AND PROCESSING REQUIREMENTS

The measurements listed in Table 3 will be recorded on the Mod Comp prior to and during testing and stored on magnetic tape for posttest processing.

The test engineer will determine the measurements to be displayed before testing. A voltage insertion calibration (VICAL) will be run at intervals per THEF standard practice to ensure no drift in the data system. The AC components of the pressure transducer outputs should be analog recorded. The frequency response required (<5 kHz) and any bandwidth requirements will be specified later. The densitometer, differential pressure, and pressure transducer data in the test spool piece and break piping sections will be sampled at a rate of 200 Hz. All other data will be sampled at a rate of 50 Hz.

Plots of the following test data will be necessary as soon as possible after each test so that a Flow Regime assessment may be made.

<u>Measurement</u>

Liquid mass flowrate

Steam mass flowrate

Temperature at test spoolpiece entrance

Temperature at break orifice entrance

Test spoolpiece pressures (with AC components)

Break piping pressures (Critical Flow segment only)

ΔP across test spoolpiece inlet

ΔP across break piping inlet (Critical Flow segment only)

ΔP across break orifice (Critical Flow Segment only)

All densitometers

5. DATA ANALYSIS AND REPORTING REQUIREMENTS

All of the test data will be qualified and recorded along with an uncertainty analysis for all measurements. Flow regime identifications will be made for all datum points, utilizing appropriate measurement data. Mod Comp plots and LDAs will be made available as soon as possible following test completion for these analyses and qualifications.

Flow regime identification for this experiment will make use of five groups of instrumentation including: (1) visual observation optical probes, (2) 3- and 6-beam gamma densitometers, (3) a reconstructive tomographic densitometer system, (4) frictional and hydrostatic differential pressure measurements, and (5) absolute pressure measurements. The tomographic system will be the primary reference instrument for flow regime identification using the data reduction software currently on the CYBER system (ART) for data analysis. The optical probes will add visual support for comparison to previous data available in the literature. The 3- and 6-beam densitometers will function to monitor flow regime development along the test section. The 3- and 6-beam densitometer data will be evaluated using a modified version of the LOFT densitometer data reduction program (DPROF3). In addition, statistical analysis (primarily PDF and variance) of the diametrical beams will be used as a cross-comparison identification technique. Fluctuations of the pressure transducer outputs will be statistically analyzed as another identification technique.

EP&A will prepare an Experimental Data Report (EDR) which will present experiment objectives, a facility description, measurements, operating procedures, and methods of data acquisition. All qualified data including LDAs and Mod Comp plots will be presented along with the uncertainty analyses. Finally, a discussion section will be prepared which will address flow regime identification and applicability of test results. Results from the flow regime identifications will be compared to previously constructed (from small diameter pipe data) flow regime maps.

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