5. AUXILIARY SYSTEMS

Details of most RD-14M auxiliary systems are given in this chapter, however the fast-fill, degas, and electrical systems are given in Appendices D-F, respectively.

5.100 SURGE SYSTEM

The surge system provides three main functions in the primary circuit system:

- it provides a means of controlling the operating pressure,
- it accommodates expansion and contraction of the primary circuit coolant due to temperature and/or phase change, and
- it purges the non-condensable gases from the primary circuit.

Not all CANDU reactors have surge tanks (also referred to as pressurizers). Some reactors use a feed-and-bleed system to perform the functions given above. In RD-14M, the surge tank, shown schematically in Figure 5.1, serves the functions described above only during steady-state operation. Ball valve MV3, located in the line connecting the surge tank to the loop, is normally closed to isolate the surge tank prior to any transient experiments. Thus the RD-14M surge tank is not scaled to its counterpart in the reactor.

The major components of the surge system are described below. The elevation diagram is shown in Figure 5.2.

5.110 Surge System Piping

All surge system piping is ASTM A106, Grade-B carbon-steel pipe. Pipe sizes vary from 0.5-inch (nominal), schedule-80 to 1.5-inch (nominal), schedule-80. All surge system piping is pressure rated to 16.5 MPa (g) at 343°C. Socket-welded joints are used for nominal piping up to 2 inches.

5.120 Surge Tank

Surge tank TK1, shown schematically in Figure 5.1, is a vertical, carbon-steel vessel suspended from the roof of the building. The vessel has a carbon-steel shell (ASME SA106 Gr-C) with a ring-joint flanged closure on the bottom, in which an electric heater is located.

The surge tank has a design pressure of 16.5 MPa (g) at 343°C. The working pressure for the vessel is 13.9 MPa (g) at 337°C.

The empty vessel mass is 2273 kg, and the capacity is 0.549 m^3.

5. AUXILLARY SYSTEMS

To enable degassing of the primary system fluid, the surge tank is provided with a degas line to atmosphere regulated by solenoid valve MV1 (see Figure 5.1). The liquid level in the surge tank is determined by measuring the pressure difference between two taps provided near the top and bottom of the vessel, as shown in Figure 5.1. The level is measured with devices associated with device code 5H. Fluid temperature (thermocouple 356T-D1) and flow (turbine flowmeter 15F), to and from the surge tank, are measured in connecting piping. Differential pressure between the inlet header HDR5 and TK1, is measured by differential pressure cell 64Q-D1. The instrumentation is listed in Chapter 6.

Motor-operated valves MV3 and MV19, are both used to isolate the surge system from the primary system.

A bursting disc and a relief valve are used to protect the surge tank from over-pressure. The bursting disc, used in series with the relief valve, protects the relief valve seat from corrosion and simmering by preventing the fluid from contacting the seat of the relief valve. The bursting disc and relief valve are both set at 16.5 MPa (g).

The turbine flowmeter, 15F, is only installed for necessary experiments, otherwise it is removed from the system to prevent damage.

5.130 Surge Tank Heater

A 100-kw immersion heater, HR1, is installed in the bottom of the surge tank via a ring-joint flanged connection. There are 15 U-shaped elements with a total heated length per element ranging from 793 mm to 1095 mm. The maximum height from the flange face to the top of the U-shaped element is 520 mm.

The heater was manufactured by Chromalox, model TMSS-8-1510015MMR Y/8.

The surge tank heater is used to pressurize the surge tank, which in turn pressurizes the primary circuit. Before the surge tank heater is started, the tank water level must be greater than 20%. This ensures there is enough fluid in the surge tank to cover the heater elements. A level recorder, 5H-R1, indicates the surge tank level. Also, valves MV3 and MV19 must be open.

Temperature devices monitor, control, and limit the temperature of the heater and the liquid in the surge tank. Thermocouple 46T protects the heater sheath from over temperature. RTD 45T is used to limit the surge tank liquid temperature. Thermocouple 47T monitors the surge tank liquid temperature.

5.140 Primary-Circuit Pressure Control

The primary pressure is measured at header HDR5 by pressure transducer 12P-D1, and is controlled by the surge tank heater, HR1. The heater is used only to raise or maintain pressure.

The heater is controlled by power controller HR1-PS1, which gets its demand signal from the primary circuit pressure controller 12P-C1, which in turn receives its input signal from 12P-D1. The set-point range is 0 to 15 MPa (g). The surge tank heater is protected from overheating by interlock 46T-K1.

To lower the pressure on the primary side, the set-point on the primary pressure controller, 12P-C1, is lowered, and the vent valve on the surge tank (MV1) is opened remotely by the loop operator. Lowering the pressure is not under automatic control whereas raising (or maintaining) pressure is, as discussed above.

The primary circuit is protected on high pressure by interlock switch 12P-K1. When this set-point is exceeded, the surge-tank heater is shut off; both primary pumps, P1 and P2, are shut down; the primary-circuit make-up water pump P4 is shut down; the "PRI pressure high" annunciator is activated; and all four power supplies are shut down. When the primary-circuit pressure falls below the set-point of interlock switch 12P-K2, the "PRI pressure low" alarm is activated and the primary pumps are shut down.

5.150 Surge Tank Level Control

The surge tank is filled by make-up water pump P4 (see Section 5.621 and Figure 5.10), a high-pressure, positive-displacement pump. The control signal for the make-up water pump comes from controller 5H-C1. The controller receives its input signal from the surge tank level, 5H (the level is compensated for density variations), and sends an output signal (to 5H-C1) to adjust the surge tank level. The normal operating tank level is in the 40 to 50% range with no quality in the primary circuit.

A dual alarm unit, 5H-K1/K2, provides high and low level alarms when the set-points for the surge tank are surpassed. When the surge tank level exceeds the set-point on interlock switch 5H-K1, the "surge TK level high" annunciator is activated, the make-up water pump is shut off, and the primary degassing pump P10 is shut off. When the surge-tank level falls below the set-point on the 5H-K2 interlock switch, the "surge TK level low" annunciator is activated, all test section power supplies are shut down, both primary pumps are shut down, and the surge tank heater is shut off.

5.200 DRAIN SYSTEM FOR NATURAL CIRCULATION TESTS

In partial inventory natural circulation tests, two-phase conditions are established by controlled intermittent draining of fluid from a drain connection to inventory tank TK3. The drain system schematic is shown in Figure 5.3. The drain rate, monitored by turbine flowmeter 237F-D1, is controlled manually by adjusting control valve 7H-CV7. For most of these experiments, the drain connection on outlet header HDR7 is used (see Figure 2.24).

Other connections are available. These are as follows:

1. Draining from the outlet lines of test sections TS9 (Station 12, Figure 2.9) or TS14 (Station 12, Figure 2.10) (these lines are normally capped).
2. Bypassing the inventory tank and venting or draining directly to the vent stack. This can only be done manually.
3. Draining from the end cap of inlet header HDR8, to TK3 (see Figure 5.3). A series of steam generator condensation tests (B9801-03) used this drain. No flow control was used for these tests (similar to a blowdown, but with the ability to measure the flow rate and inventory discharged).

The drained fluid is cooled in heat exchanger HX3 before it is collected in the inventory tank. The mass of water collected in this manner is inferred from measurements of the liquid level in the tank.

5.300 BLOWDOWN SYSTEM

Experimental requirements exist to study guillotine breaks in the piping of the primary heat transport system of a reactor. The blowdown system is used to produce the transient conditions that will occur in either an inlet or an outlet header break. The loop coolant is ejected from the loop through a blowdown valve and into the blowdown stack (which transports the steam/water safely to the roof of the RD-14M structure, where it is discharged to the atmosphere). The blowdown line is a 20-inch (nominal) schedule-20 carbon-steel pipe, and was chosen to minimize flow resistance. The blowdown pipe is joined within the loop cabinet to allow for inlet header (HDR8) or outlet header (HDR7) breaks.

Two blowdown valves are available - a fast-acting 6-inch ball valve (approximately 0.25 s opening time) and a fast-acting 2-inch ball valve (approximately 0.10 s opening time) (see Figure 5.4). The valves can be connected to either inlet header HDR8 or outlet header HDR7. A restriction orifice plate in a Grayloc fitting is installed immediately upstream of the ball valve (see Figures 5.4 and 5.5). Various orifice plates are available to simulate a range of break sizes.

A 2-inch drain line, shown in Figure 5.4, is provided to allow condensate (or rain) in the blowdown pipe to flow to the building drainage system.

The blowdown system elevation changes are given in Figure 5.6 (shown with the 6-inch blowdown valve, MV8).

5.400 LOOP INSULATION

The RD-14M loop is lagged using light-weight (200 kg/m^3), low thermal-conductivity (0.91 W/m·K) hydrous calcium silicate pipe insulation, covered with canvas lagging cloth and/or aluminum sheet. This insulation is 65-mm thick for nominal pipe sizes from 2 to 3.5 inches, and 76-mm thick for 1-, 1.25-, and 4-inch pipe. Non-pipe items such as the headers, steam generators shell and plena, and pump volutes, are also well insulated. The heated sections are insulated with granular vermiculite fill as described in Section 2.240.

5.500 TRACE HEATING

Heat losses from feeders can be significant, in particular for low-flow, low-power tests (e.g., natural circulation tests). Heat losses in RD-14M have been characterized (see Section 8.700).

To counteract the feeder heat losses, the feeders and end-fittings are trace-heated with fiberglass "HOTFOIL" trace heating tapes (see Figure5.7).

To guard against adding heat into the system, four variable transformers are installed and adjusted for the heat losses expected. Each transformer controls the power to each bank of inlet and outlet piping, one control for each set of five feeders. Four meters are installed to indicate the power the tracer heaters use. Figure 5.7 also shows temperatures at the inlet and outlet of the test section and near the headers. These are the thermostat set-points. If the temperature of the thermostat is below the set-point, the trace heating is on, if below the set-point it switches off (automatically). There is also a remote shutoff switch to shut the system down. Nominal full-power trace heating powers (as per design specifications) for each feeder are given in Table5.1. The total trace heating power is approximately 10 kW/pass to the inlet feeders and 12 kW/pass to the outlet feeders. The electrical schematic for the trace heating system is given in Appendix F.

In 1999 January, the trace heating on TS11 outlet feeder was replaced with three "ACCUTRON" mineral insulated trace-heating cables, installed at 120° intervals around the pipe circumference (see Figure 5.8). These cables were attached and cemented to the pipe (as per manufacturer's requirements). The power to these heating cables has the capability of being adjusted from 0-10 kW.

5.600 MAKE-UP WATER ADDITION

There are two systems available to add make-up water to the loop. They are referred to here as the metered and non-metered systems.

5.610 Metered Make-Up Water Addition System

Some experiments require the primary system to be injected with known quantities of water. This installation was completed in 1994 and consists of an inventory tank, TK4, and a level transmitter, 12H. The injected water quantities are inferred from 12H. The degassing pumps P10/P11 are used to inject the primary system through the ECI lines to the headers with water from tank TK4. The tank is open to atmosphere, made from stainless steel, and has a capacity of approximately 0.7 m^3. The metered make-up water addition system schematic is given in Figure 5.9.

5.620 Non-Metered Make-Up Water Addition System

The other make-up water system could be used to replace any losses in the primary or secondary system due to leaks during normal operations (this system is isolated during partial inventory tests and is not typically used for other tests either). The amount of inventory injected into the primary and/or secondary systems is not measured.

The water is supplied to the loop, via a 3-inch line, from a distilled water system. This line also services the fast-fill system (see Appendix D) when the loop is shutdown and depressurized. Positive displacement pumps are used to fill the loop because the distilled water supply is at a lower pressure than RD-14M. Check valves, in the loop piping, protects the building's distilled water system from over-pressure and reverse flow. Relief valves are installed on the discharge piping of the pumps to protect the piping system from over-pressure. The non-metered make-up water addition system schematic is shown in Figure 5.10.

5.621 Primary System

Make-up water is injected into the primary system upstream of pump P2. A Milton Roy positive displacement pump, P4, is used for this purpose. The surge tank level controller, associated with the 5H level measurement (compensated for temperature), is used to determine the primary system water level. The pump is shut off when the desired operating level is reached.

5.622 Secondary System

Make-up water is injected into the secondary system piping downstream of heat exchanger HX2. A Milton Roy positive displacement pump, P5, is used for this purpose. The jet condenser level controller, associated with the 4H level measurement (compensated for temperature), is used to determine the secondary system water level. The pump is shut off when the desired operating level is reached.

5.700 EVENT SEQUENCER

A Durant Systems model 6450 programmable timer is used for precise event sequencing during an experiment. This versatile controller can time and energize or de-energize up to 16 channels in any selected sequence, according to a set of instructions given by the loop operator. These channels are used for such things as activating/deactivating valves (open/close), starting pump rundowns, and starting the ECI pumps.

5. AUXILLARY SYSTEMS

TABLE 5.1

NOMINAL FULL-POWER TRACE HEATING VALUES

Feeder	Power (W)
HS5 Inlet	983
HS6 Inlet	1351
HS7 Inlet	2402
HS8 Inlet	2402
HS9 Inlet	2502
HS5 Outlet	1451
HS6 Outlet	1677
HS7 Outlet	2954
HS8 Outlet	2502
HS9 Outlet	2954
HS10 Inlet	983
HS11 Inlet	1351
HS12 Inlet	2402
HS13 Inlet	2402
HS14 Inlet	2502
HS10 Outlet	1451
HS11 Outlet	1677
HS12 Outlet	2954
HS13 Outlet	2502
HS14 Outlet	2954

5. AUXILLARY SYSTEMS

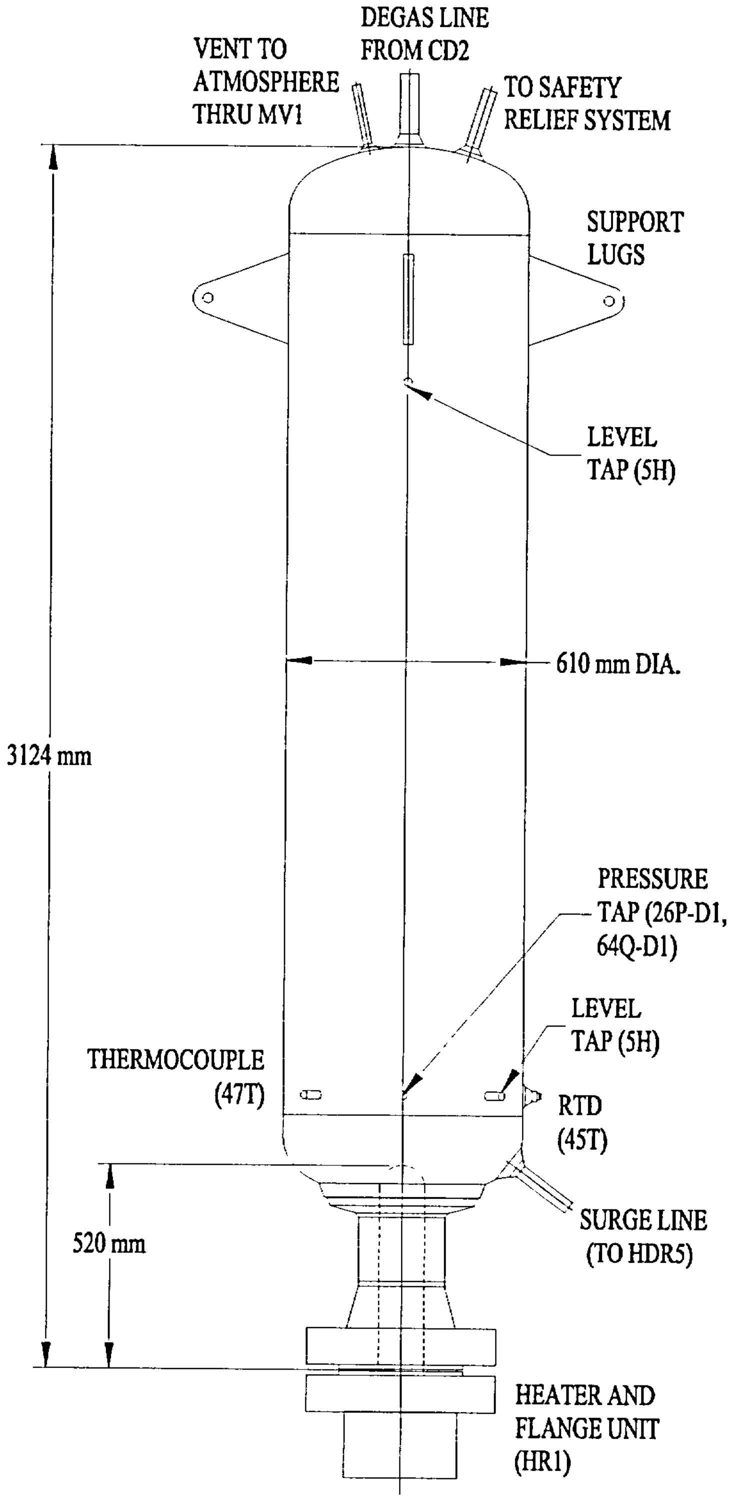

FIGURE 5.1: Surge Tank (TK1) Schematic

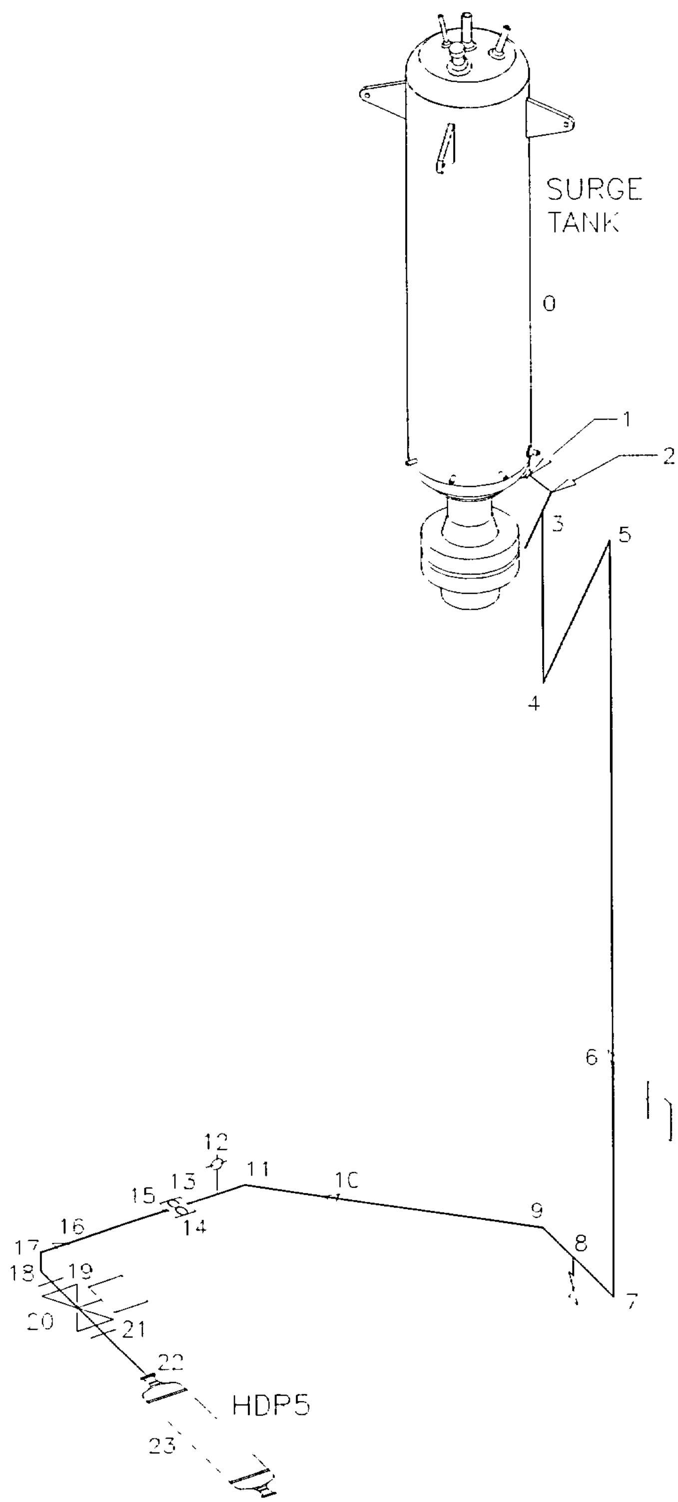

FIGURE 5.2: Surge Piping System Schematic/Elevation Diagram

5. AUXILLARY SYSTEMS

FIGURE 5.2 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Surge Tank TK1				
1	Surge Tank Inlet	23.66			
			0.14	38.10	37
2	Elbow (90°)	23.58			
			0.18	38.10	0
3	Tee	23.58			
			2.22	38.10	90
4	Elbow (90°)	21.36			
			1.29	38.10	0
5	Elbow (90°)	20.07			
			5.74	38.10	90
6	Valve (MV19)	14.33			
			3.50	38.10	90
7	Elbow (90°)	10.83			
			0.40	38.10	0
8	Tee (Drain)	10.83			
			0.30	38.10	0
9	Elbow (45°)	10.83			
			0.68	38.10	0
10	Reducer	10.83			
			0.40	20.60	0
11	Elbow (45°)	10.83			
			0.16	20.60	0
12	Thermocouple (356T-D1)	10.83			
			0.15	20.60	0
13	Grayloc	10.83			
14	Turbine Flowmeter (15F)		0.15	20.60	0
15	Grayloc	10.83			
			0.62	20.60	0
16	Reducer	10.83			
			0.09	38.1	0
17	Elbow (90°)	10.83			
			0.12	38.1	90

5. AUXILLARY SYSTEMS

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Elbow (90°)	10.71			
			0.10	38.1	0
19	Grayloc/Reducer	10.71			
20	Valve (MV3)		0.51	42.90	0
21	Grayloc Reducer	10.71			
			0.43	38.10	0
22	Grayloc	10.71			
			0.11	38.10	0
23	Header HDR5 Inlet	10.71			

5. AUXILLARY SYSTEMS

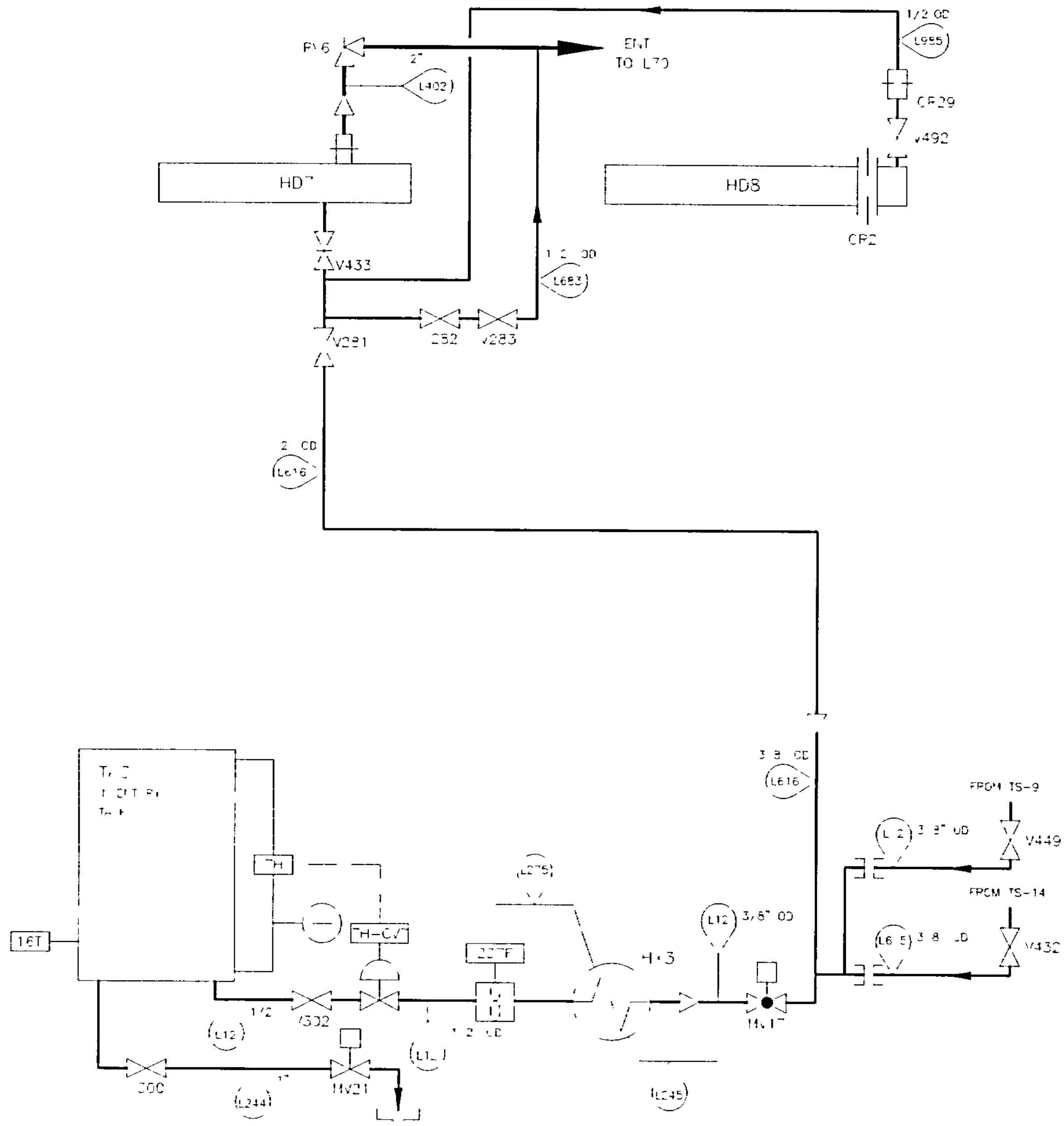

FIGURE 5.3: Drain System Schematic

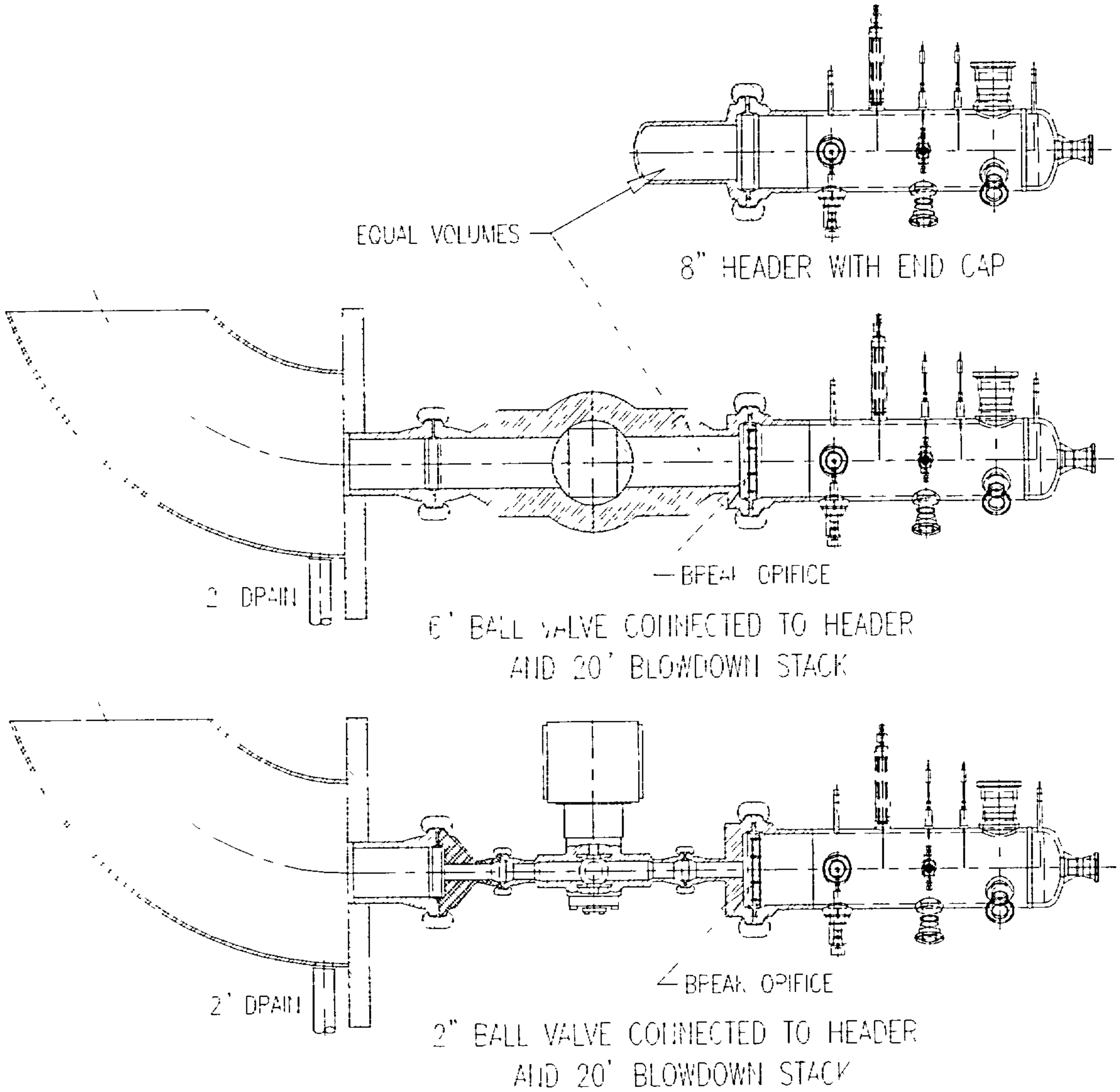

FIGURE 5.4: Blowdown Valves

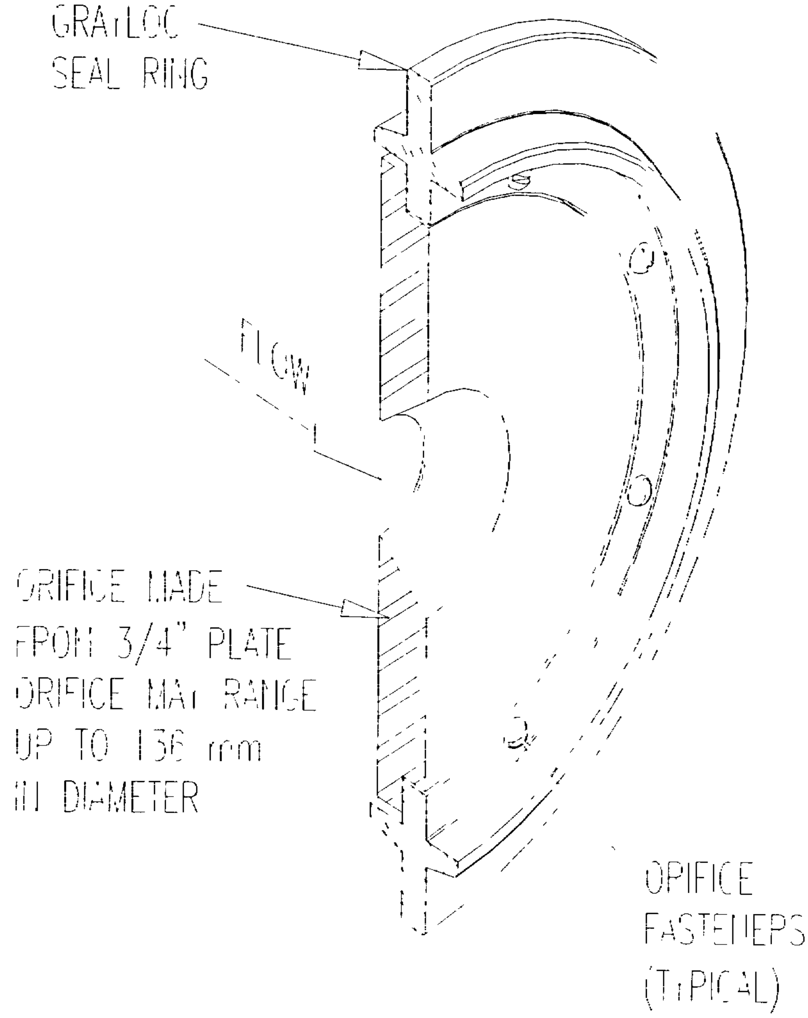

FIGURE 5.5: Blowdown Orifice

5. AUXILLARY SYSTEMS

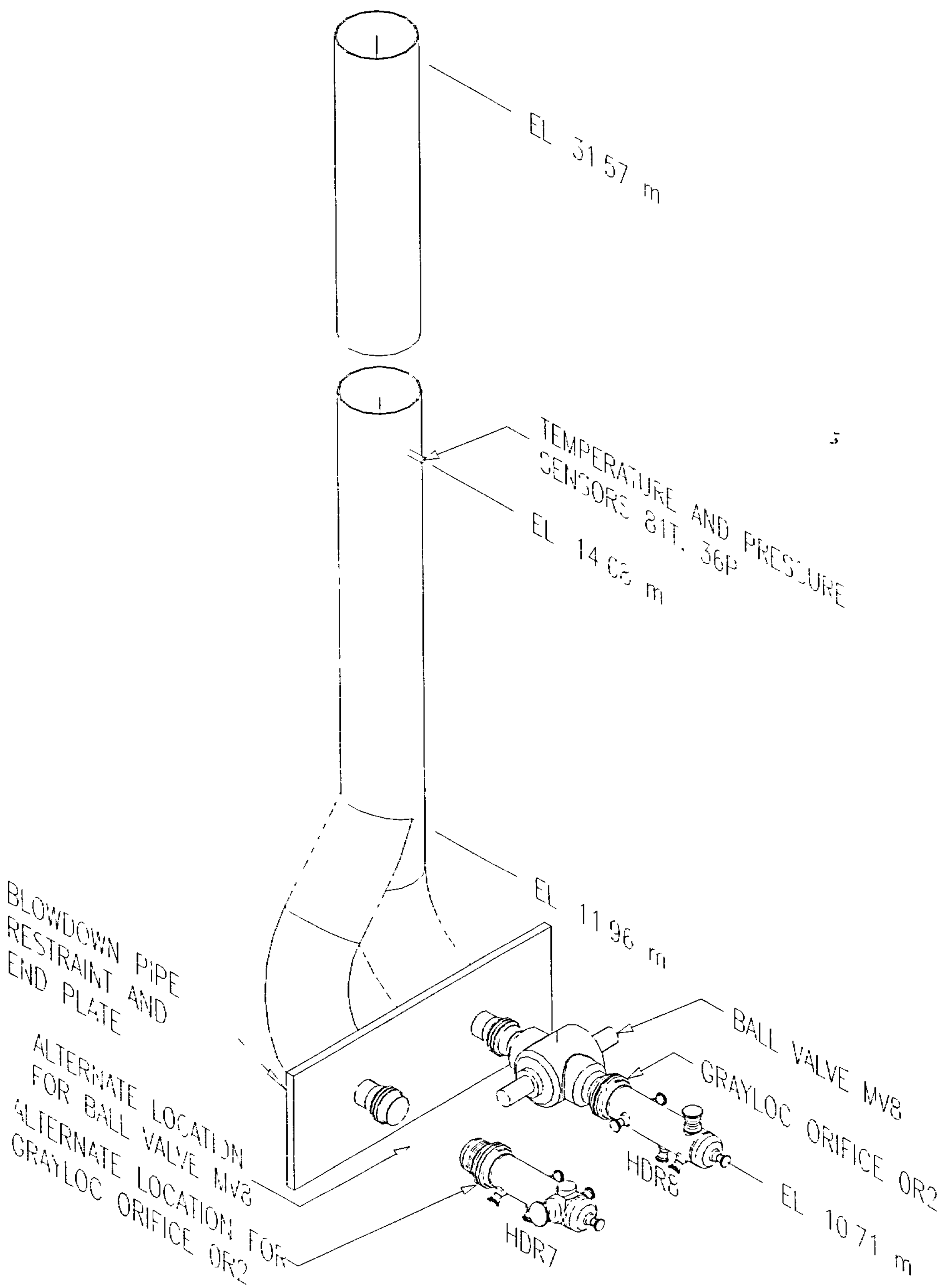

FIGURE 5.6: Blowdown Line Elevation Diagram

5. AUXILLARY SYSTEMS

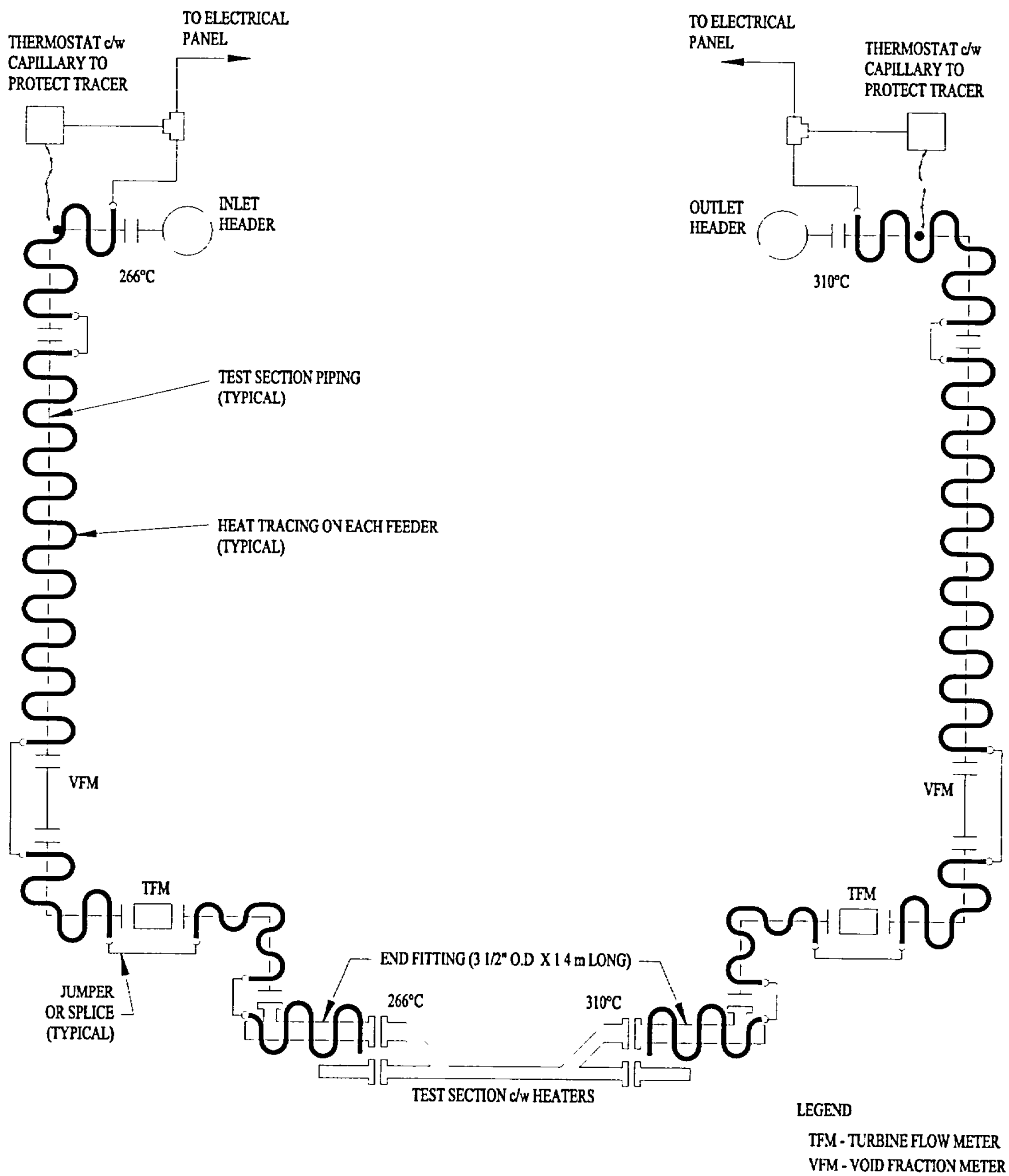

FIGURE 5.7: Trace Heating Arrangement

5. AUXILLARY SYSTEMS

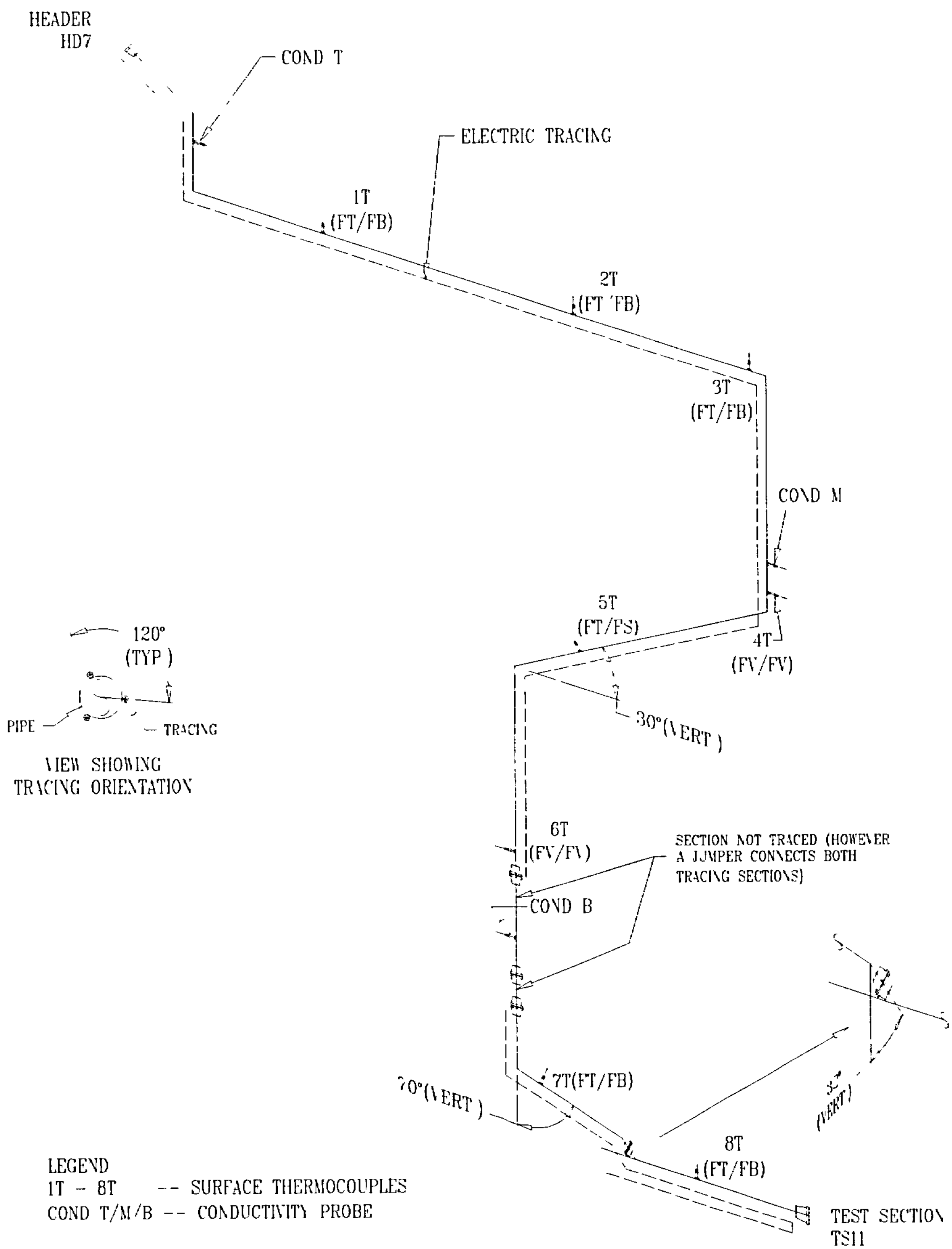

FIGURE 5.8: Modification to Trace Heating and Instrumentation on TS11 Outlet Feeder

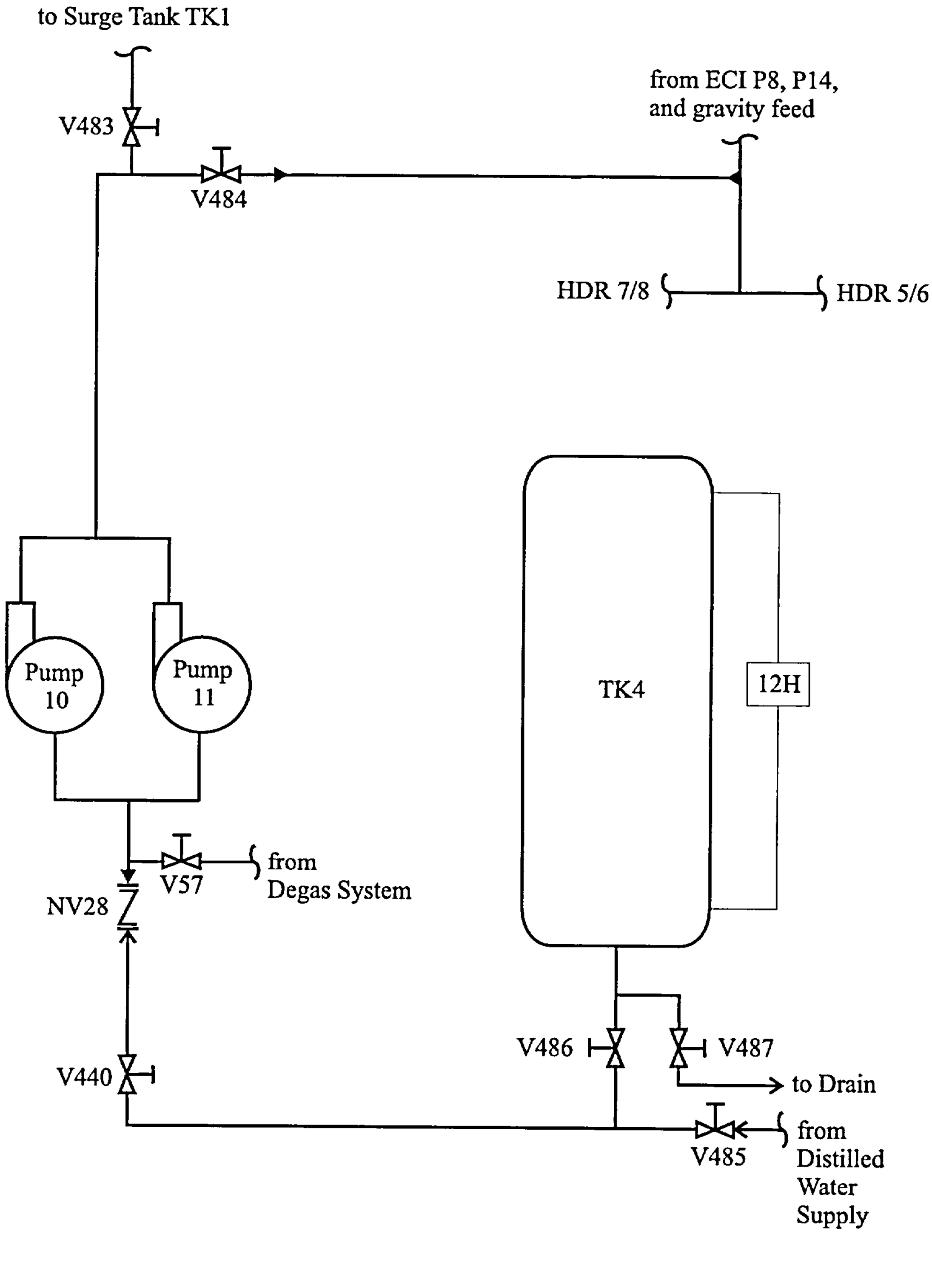

FIGURE 5.9: Metered Make-Up Water Addition System Schematic

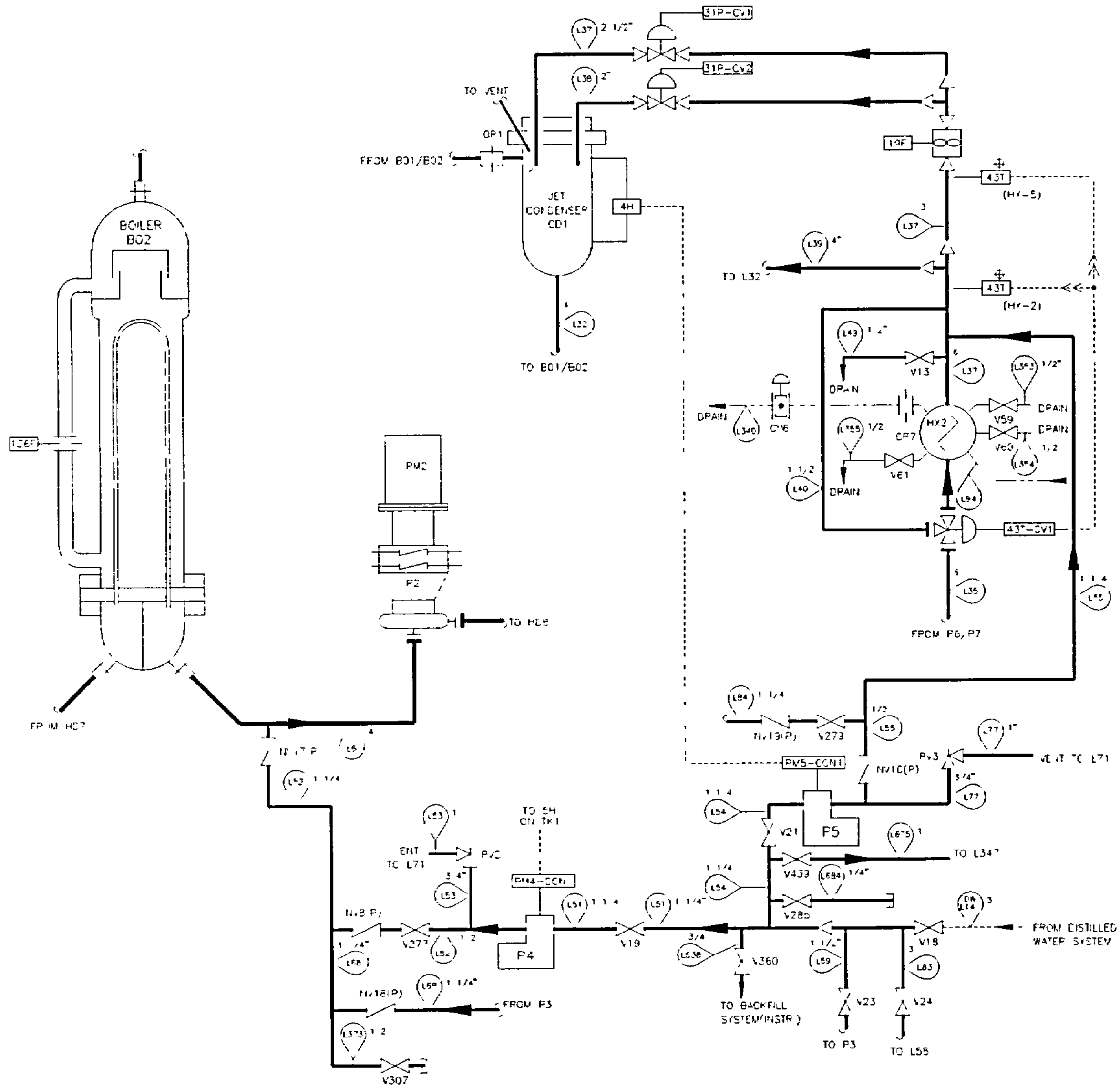

FIGURE 5.10: Non-Metered Make-Up Water Addition System Schematic

6. INSTRUMENTATION AND DATA ACQUISITION

6.100 INSTRUMENTATION

6.110 Introduction

RD-14M is extensively instrumented to measure parameters such as temperatures, pressures, flows, levels, and voids (gamma densitometers and conductivity probes). Each instrument in RD-14M is hard-wired into a panel near the data-acquisition system. A subset of available instruments is sampled during an experiment. The experimenter can choose the instruments to be recorded by the data-acquisition system for a particular experiment. This is done in software by providing a scan list of instruments to be sampled. There are a few instruments used for alarm, control, and trip functions that are recorded for all experiments.

All instruments provide a proportional 0-5 V, 1-5 V, or ± 5 V output signal to the data-acquisition system. All measurements involve a series of components, typically a sensing element, a transmitter, cables, a signal conditioner, and an amplifier.

Tables 6.1-6.3 are lists that summarize RD-14M instruments on the primary side, secondary side, and ECI system, respectively, and are sorted by measurement type (e.g., temperature, pressure, flow). Table 6.4 contains miscellaneous instruments.

Table 6.1 does not include the FES thermocouples. Also, the primary-side instruments in the table that do not have a device type are instruments that have not been used in any tests to date (the instruments are likely not installed but taps are available).

Tables 6.1-6.4 list the following:

- **Device Code**: a unique alpha-numeric identifier assigned to a specific instrument location according to predetermined codes, as specified on construction blueprints (an exception to this uniqueness is the FES thermocouples - see Section 6.122).
- **Device Type**: an identifier assigned to describe the type of RD-14M instrument (in some cases it identifies the manufacturer) and components used for the measurement.
- **Measurement Location**: keywords or abbreviations used to describe the measurement location of an instrument.
- **Reference**: Figure and Station Numbers from diagrams found in other sections of this document, or a specific engineering drawing, found in Appendix B. The station number identifies the location of the instrument in the corresponding figure.

Table 6.5 summarizes the different types of instruments available in RD-14M. Each of these is described in the sections to follow.

6. INSTRUMENTATION AND DATA ACQUISITION

6.120 Temperature Measurements

Temperature measurements are made using Type-K thermocouples (Nickel - 10% Chromium (+) and Nickel - 5% Chromium (-)), or resistance temperature devices (RTD's). Type-K thermocouples can be used over the range -200 to 1250°C, but are more commonly used for the 0 to 1000°C range where the linearity is better. Even over this range, Type-K thermocouples are non-linear. If the thermocouple conditioning circuitry does not correct for non-linearity, then a correction should be applied to the indicated temperature (this will be included in the uncertainty analysis report). This is the case for temperature measurements made with Ectron and Bailey amplifiers/transmitters. Thermocouple channels using Ronan and Promac amplifiers/transmitters automatically correct for the non-linearity of the Type-K thermocouple in its hardware. These devices are summarized in Table 6.5.

6.121 Fluid Temperature Measurements

The thermocouples used in fluid temperature measurements are sheathed in stainless-steel closed-end tubes (shields) to prevent corrosion and mechanical damage from high-temperature steam/water flows. The thermocouples are designed such that the actual junction is in the tip of the protective thin-walled shield and has a very low thermal inertia. Thermocouples measuring fluid temperature are typically mounted such that the tip of the protective shield is at the centerline of the piping component.

6.122 FES Sheath Temperature Measurements

The FES sheath temperatures are measured with factory-made thermocouples that were installed on the inside of the heating-element sheath, and then contacted to the inside surface of the sheath using a swedging technique that was developed in-house. The thermocouples are imbedded in the MgO annulus layer between the inside heater element and the outside sheath (see Figure 2.17).

All instrument locations are identified uniquely by their device code except for the FES thermocouples. If a thermocouple fails and cannot be repaired, it is taken out of service and the junction (wiring) used for the failed thermocouple is switched to another FES thermocouple. There are more thermocouples available on an FES than are typically recorded for any given test. The device code stays with that junction, so the new FES thermocouple location takes on the device code of the failed FES thermocouple.

6.123 Surface Temperature Measurements

Surface temperatures can be measured using 1/16-inch, K-type thermocouples (with Ronan transmitters) strapped to the outside surface with a metallic hose-clamp. These thermocouples are encased in Thermon (Grade T-63), a high-temperature heat transfer cement, and wrapped with insulation to ensure accurate outer wall temperature measurements.

6. INSTRUMENTATION AND DATA ACQUISITION

6.124 Thermocouple Transmitters/Amplifiers

As previously mentioned, there are four types of thermocouple transmitters/amplifiers used in RD-14M: Bailey, Ectron, Ronan, and Promac. The respective RD-14M device types and manufacturer model numbers are given in Table 6.5.

The Bailey solid-state transmitters/amplifiers are installed in the RD-14M control room and are connected to thermocouples via thermocouple extension wire. These transmitters/amplifiers do not have cold-junction compensation, nor is the output corrected for non-linearity in the Type-K thermocouple. Cold-junction compensation is provided by an Acromag Model 350 Reference junction.

The Ectron solid-state transmitters/amplifiers are installed in the RD-14M control room and are also connected to thermocouples via thermocouple extension wire. These transmitters/amplifiers have integral cold-junction compensation, however the output is not corrected for non-linearity in the Type-K thermocouple.

The Ronan solid-state transmitters/amplifiers are located in cabinets throughout the experimental loop. These transmitters/amplifiers have integral cold-junction compensation, and the output is corrected for non-linearity in the Type-K thermocouple. The current non-linearity correction is for a span of 0-1000°C. In some previous tests, where a span of 100-350°C was used, a different non-linearity correction is to be applied [6.1].

The Promac solid-state transmitters/amplifiers are located in cabinets throughout the experimental loop. These transmitters/amplifiers also have integral cold junction compensation and the output is corrected for non-linearity in the Type-K thermocouple. The current non-linearity correction is for a span of 0-350°C. The non-linearity correction is obtained by adjusting the midpoint to the proper value with a potentiometer during the calibration procedure.

Calibrations for the thermocouple transmitters and amplifiers described above are carried out using the following procedures:

1) The output from the thermocouple amplifier/transmitter (normally connected to the data acquisition system) is connected to an accurate digital voltmeter in the RD-14M control room via a plug-in jumper cable.
2) The thermocouple is then physically disconnected from the amplifier/transmitter, and a hand-held thermocouple calibrator is connected in its place. This calibrator is essentially an accurate millivolt source that mimics the response of a Type-K thermocouple.
3) The calibrator's millivolt signal is set to the value corresponding to 0°C, and then set to the full scale value (either 350 or 1000°C), and the amplifier/transmitter output

voltage is read. If necessary, the amplifier/transmitter zero and span are adjusted to give the desired output voltages at 0°C and at full scale.

4) The output voltage from the thermocouple/conditioning circuitry is recorded. This measured voltage can then be compared with that from previous calibrations to check for calibration drift.
5) The calibrator is set for five intermediate temperatures and the amplifier/transmitter output voltages are recorded.

The above procedure calibrates the thermocouple conditioning circuitry. The actual thermocouple junction itself is not calibrated.

6.125 RTD Temperature Measurements

The Resistance Temperature Devices (RTDs) are used for temperature measurements whenever accuracy in excess of that provided with thermocouples is required. The zero and span set-points for an RTD are more stable than those of thermocouples, and the device is more linear (as with the thermocouples, accuracy can be increased by applying a non-linearity correction).

Problems with RTDs are usually related to the sensor itself. The platinum wire sensor is physically larger than a thermocouple junction and is wound over the length of some sort of support. The measurement is sensitive to any sharp temperature gradient along this length. Also, the thermal response of an RTD is slow (compared with a thermocouple), due to poor contact of the platinum sensor wire with the measuring point and the large thermal inertia of the protective sheath. The problems associated with RTD temperature measurements in RD-14M have led to many of them being replaced with thermocouples over the years.

Two different types of RTD transmitters have been used, as indicated in Table 6.5.

The RTD sensors/transmitters are calibrated as a unit. The RTD is physically removed from the loop and calibrated against a standard (reference) RTD by immersing both RTDs in a temperature controlled salt bath.

6.130 Pressure and Differential Pressure Measurements

Gauge and differential pressure measurements are carried out in RD-14M using strain gauge and capacitance-type pressure transducers.

Pressure cells connect to the loop components via liquid-filled sense lines. All pressure cells in the loop are located below the points of measurement to ensure that sensing lines are always full during a test. For gauge pressure measurements, the shortest possible horizontal sense line is used. The sense lines for differential pressure cells include horizontal legs at the loop end to prevent emptying of the vertical portion of sense lines. The sense lines are arranged and filled so that there is zero head at the cell.

6. INSTRUMENTATION AND DATA ACQUISITION

Before each experiment, the zero offset voltages of all differential pressure cells are checked. This is done with primary-side loop conditions of 2 MPa, zero flow, and fluid at ambient temperature. If the offset is greater than the accuracy of the cell (e.g., 0.25% FS), then the cell is re-zeroed.

6.131 Strain Gauge Transducers/Transmitters

Table 6.5 summarizes the different types of strain gauge pressure transducers/transmitters used in RD-14M.

The BLH, Dynisco, and Transducer Inc. transducers/transmitters (with Ectron amplifiers) have a foil strain gauge. Operational experience has shown that these instruments are prone to zero drift due to the foils having residual memory.

Druck transmitters have a silicon-based stain gauge that has no zero drift and no residual memory. Output from the transmitter is a 4 to 20 mA signal that is proportional to the applied gauge pressure.

The pressure range of each strain gauge transducer is calibrated with the cell, wiring, and amplifiers as a unit, against a pressure standard reference source (EATON, Druck, or Fluke). The reference source is connected to the cell and the output voltage of the cell is recorded as a function of the reference pressure. The zero and span of the cell are adjusted to give the desired output voltages (i.e., 1-5 V), corresponding to the range of the cell.

6.132 Capacitance-Type Pressure Transmitters

Table 6.5 summarizes the different types of capacitive pressure transmitters used in RD-14M. The two types are the Rosemount model 1151 series and model 3051 series. Both of these cell types have a variable-capacitance sense element. The differential capacitance between the sensing diaphragm and fixed capacitor plates is electronically converted to a 4 to 20 mA signal that is proportional to the applied gauge or differential pressure. This current is applied to a precision resistor to produce a suitable voltage signal that is measured by the data-acquisition system.

There have been three types of Rosemount 1151s installed in RD-14M. The original 1151s installed were analogue cells (these were pressure cells previously installed in RD-14). New Rosemount pressure transducers initially installed in RD-14M were first generation smart cells, then later on second generation smart cells were installed. Many of the analogue cells have since been converted to second generation Rosemount pressure cells, by using a conversion kit that only replaced the electronic components of the cell, and not the cell itself. The RD-14M calibration database, part of the COG Safety Thermalhydraulics database [6.2], has a field that indicates the type of cell installed.

The Rosemount 3051 is a newer generation cell designed to replace the 1151. The 3051 is a smart cell, and has a greater accuracy and is less susceptible to drift due to ambient temperature change than the 1151. Rosemount 3051 differential pressure transmitters also have reduced sensitivity to span and zero shift with static pressure when compared to the 1151 transmitters.

For calibration of the Rosemount transmitters, the instrument is removed from its location in the experimental facility and calibrated against a standard calibrated (reference) test cell.

For all smart cells, a microprocessor controls transmitter operation so that the transmitter calibration is not dependent on range. The transmitter is initially calibrated over the maximum possible range. Following calibration, the transmitter range can be changed, within limits, to be a fraction of the calibrated range. Zero and span adjustments can be made after installation without affecting the calibration.

6.140 Flow Measurement

Flow is measured or calculated using various devices, as summarized in Table 6.5. The different devices are turbine, vortex, and orifice flowmeters.

6.141 Turbine Flowmeters

Turbine flowmeters (TFMs) are designed and calibrated for single-phase liquid flow. Both unidirectional and bidirectional TFMs are in service in the loop. There are two manufacturers of TFMs used in RD-14M, as indicated in Table 6.5. It should be noted that turbine flowmeters only provide qualitative measurements under two-phase steam/water flow conditions.

Some of the features of these instruments are they are operable with fluid temperatures up to 400°C, have high overrange capability, and can be operated bidirectionally. The advantages of turbine flowmeters in the RD-14M configuration are accuracy, repeatability, extended flow range, rapid response time, and retention of calibration.

In RD-14M the availability and performance of turbine flowmeters is strongly affected by rotor and bearing integrity. Meters must be regularly reconditioned by replacing the bearings, and in some cases, the rotor. A discussion of turbine flowmeter performance is provided in Section 8.200.

For calibrations, turbine flowmeters are removed from the loop and calibrated individually against a master turbine flowmeter located in the RD-14M Flow Calibration Facility.

6.142 Mass Flowmeters

Mass flows are calculated for the boiler feedwater by a mass flow computer using readouts from turbine flowmeters installed on each boiler feedwater line. The density is derived from a temperature measurement, assuming saturation conditions. Values for the flow coefficient used in the computer are experimentally determined from regular calibrations of the TFMs in the RD-14M Flow Calibration Facility.

6.143 Vortex Flowmeters

Vortex flowmeters were originally installed on the four ECI injection lines, but were replaced by turbine flowmeters as the accuracy of the vortex meters was affected by vibrations caused by the ECI pumps. The only remaining vortex flowmeter in service in RD-14M is situated on the ECI pump P14 bypass line. Vortex flowmeters are unidirectional.

6.144 Orifice Flowmeters

The boiler steam mass flows are calculated by the steam mass flow computer using the differential pressure across an orifice and the density derived from a temperature measurement, assuming saturation conditions. Values for the flow coefficient used in the computer are experimentally determined from calibrations of the orifice in the RD-14M Flow Calibration Facility.

Mass flow rates are not calculated, but can be, for the orifices located on the boiler downcomer lines and the header interconnects. The mass flow rates may be calculated using the equation for sharp edged orifices.

6.150 Level Measurements

All level measurements are made using Rosemount model 1151 series differential pressure cells, with each ΔP measurement density compensated to indicate the actual fluid level in a vessel. Calibrations are performed on the ΔP cells, as well as the density compensators, on a regular basis.

There are some ΔP cells on loop inventory tanks that are calibrated directly for mass. The calibrations are obtained by draining fluid from the vessel and calibrating the weight of fluid versus the ΔP cell voltage output.

6.160 Void Measurements

Void is inferred from two types of devices (summarized in Table 6.5): gamma densitometers and conductivity probes.

6.161 Gamma Densitometers

The RD-14M gamma densitometers consist of 1 to 3 collimated beams from a radioactive Cesium source, which is attenuated by passage through pipes in the RD-14M loop containing process water. Each beam has a detector mounted on the opposite side of the pipe. The attenuated beam changes the current passing through an ionized gas and the current is converted to a 0-5 V output signal, with each beam having a separate output. The current signals are related to the density or void fraction of the steam/water mixture in the pipe.

6.162 Conductivity Probes

Conductivity probes have been installed in various locations of RD-14M to qualitatively detect void. These instruments were developed in-house.

6.170 Power

Power is calculated by two systems, as summarized in Table 6.5.

6.171 Power Supply Controllers and Power Meters

One system that provides a power measurement relies on direct measurement of the voltage and current supplied by a power supply. For each power supply, measurements of the supplied voltage and current are fed into a Wattmeter (power card). The Wattmeter provides a voltage signal output that is proportional to the actual power output of the power supply. This voltage signal is then fed into the data-acquisition system, thus providing a direct measurement of the power (on a per power supply basis only).

The voltage output of the Wattmeter is also fed into the corresponding power-supply controller located in the RD-14M control room. This is the feedback signal that the controller uses in controlling the power-supply output.

The power measurements provided by this system are less accurate than those provided by the Fluke system, which is discussed in the next section. However, the Fluke system is substantially slower than the direct power measurements. For this reason, the powers measured by the Fluke system should be used under steady-state power conditions. During transient changes in power, the direct measurement of power is the only system capable of recording the transient.

Isolation amplifiers were installed between the outputs of the Wattmeters (power cards) and the data-acquisition system in 1997 to reduce line noise [6.3]. Prior to the addition of the isolation amplifiers, line noise occurred in the voltage signal from the Wattmeters, which manifested itself as noise in the measured power of the power supplies.

6.172 Fluke System

Power is calculated for each heated section from true RMS voltage and current measurements which are fed into the Fluke computer. Voltage is measured across each heated section, with the voltage taps for these measurements located on the busses at the ends of the heated sections where power is distributed to the seven fuel element simulators. Current is measured by thermal RMS meters, utilizing a current shunt to produce a voltage which is then fed to the Fluke computer. Power values are calculated by the Fluke computer, and an average of ten measurements, sampled over a period of 22 seconds, is used for each data point. The averaged values are written to a data file. While the Fluke computer provides accurate power readings, the measurement is slow due to the period required for data collection and averaging. To measure and record the powers for each of ten heated sections requires a period of 220 seconds.

The Fluke system is a stand-alone system, separate from the main data-acquisition system, and generates it's own data file (synchronized to the main data-acquisition system).

6.180 Measurements for Pumps

The primary pumps of the loop are instrumented to provide current, speed and torque measurements. The secondary pumps are instrumented to measure speed.

6.200 DATA ACQUISITION SYSTEMS

6.210 Main System

The main data-acquisition system consists of a Digital Equipment Corporation MicroVAX II computer, an input multiplexer, and a number of 12-bit analogue-to-digital converters. The data are stored on a disk during acquisition and later transferred to permanent storage devices.

The maximum number of input channels is 768, and the maximum scan rate with 600 channels of data collection is approximately 50 ms/scan (20 Hz), based on past loop operational experience.

6.220 Auxiliary Systems

Each data channel that feeds into the main system multiplexer is also routed to a jack panel. The jack panel allows for the connection of high-input-impedance analogue devices, such as digital voltmeters and recorders, to desired data channels for simultaneous (independent) measurement. A two-channel Hewlett Packard X-Y recorder and three digital voltmeters are permanently mounted near the jack panel for this purpose. Other portable instruments, such as oscilloscopes, can also be used.

The jack panel also allows for the connection of auxiliary data-acquisition systems. Three auxiliary data-acquisition systems have been used:

- 16-channel Vaxstation - This system allows for the display of up to 16 data channels. No data are actually recorded.
- 48-channel personal computer system - This system allows for the graphical display of up to 48 data channels.
- High-speed data-acquisition system - This system is personal computer (PC) based, and allows for the high-speed acquisition (over 100 Hz) of up to 64 data channels. Data are stored locally on the PC. This system can be started (triggered) by the main data-acquisition system, and can be accurately time synchronized with the main data-acquisition system.

REFERENCES

[6.1] Melnyk, A.J., "Effect of Non-Linear Behaviour of Thermocouples on RD-14M Measurements," memorandum to COG Working Party #5 members, THB-91-497, 1991 November 25.

[6.2] Swartz, R.S., "Migration of the FoxPro Database to MS-Access," memorandum to COG Working Party #5 members, STHB-99-053, 1999 April 12.

[6.3] Sanderson, T.V., Melnyk, A.J., and Ingham, P.J., "Improvements to RD-14M Power Measuring System," memorandum to COG Working Party #5 members, STHB-97-159, 1997 June 21.

6. INSTRUMENTATION AND DATA ACQUISITION

TABLE 6.1

SUMMARY OF PRIMARY-SIDE INSTRUMENTS

TEMPERATURE				
RD-14M	RD-14M		Reference	
Device Code	Device Type	Measurement Location	Figure No.	Station No.
210T-D3[1]	KTC-B	TS5 INLET T	2.1	20
210T-D3[1]	KTC-R	TS5 INLET T	2.1	20
213T-D1[1]	KTC-B	TS5 OUTLET T	2.1	43
213T-D1[1]	KTC-R	TS5 OUTLET T	2.1	43
213T-D3[1]	KTC-B	HS5 OUT FDR	2.1	58
213T-D3[1]	KTC-R	HS5 OUT FDR	2.1	58
251T-D1[2]	KTC-B	HS5 INLET	2.1	29
251T-D1[2]	KTC-R	HS5 INLET	2.1	29
251T-D1[2]	RTD	HS5 INLET	2.1	29
252T-D1[2]	KTC-B	HS5 OUTLET	2.1	33
252T-D1[2]	KTC-R	HS5 OUTLET	2.1	33
252T-D1[2]	RTD	HS5 OUTLET	2.1	33
210T-D1		HS5 IN FDR	2.1	2
210T-D2		HS5 IN FDR	2.1	7
211T-D1		HS5 INLET EF T	2.1	26
212T-D1		HS5 OUTLET EF T	2.1	36
213T-D2		HS5 OUT FDR	2.1	55
291T-D1		HS5 INLET T	2.1	30
291T-D2		HS5 MID T	2.1	31
291T-D3		HS5 OUTLET T	2.1	32
230T-D1[1]	KTC-B	TS10 OUTLET T	2.2	43
230T-D1[1]	KTC-R	TS10 OUTLET T	2.2	43
230T-D3[1]	KTC-B	HS10 OUT FDR	2.2	58
230T-D3[1]	KTC-R	HS10 OUT FDR	2.2	58
233T-D3[1]	KTC-B	TS10 INLET T	2.2	20
233T-D3[1]	KTC-R	TS10 INLET T	2.2	20
261T-D1[2]	KTC-B	HS10 INLET	2.2	29
261T-D1[2]	KTC-R	HS10 INLET	2.2	29
261T-D1[2]	RTD	HS10 INLET	2.2	29
262T-D1[2]	KTC-B	HS10 OUTLET	2.2	33
262T-D1[2]	KTC-R	HS10 OUTLET	2.2	33
262T-D1[2]	RTD	HS10 OUTLET	2.2	33
296T-D1	KTC-R	HS10 INLET T	2.2	30
230T-D2		HS10 OUT FDR	2.2	55
230T-S1		HS10 OUT FDR	2.2	43

6. INSTRUMENTATION AND DATA ACQUISITION

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
231T-D1		HS10 OUTLET EF T	2.2	36
232T-D1		HS10 INLET EF T	2.2	26
233T-D1		HS10 IN FDR	2.2	2
233T-D2		HS10 IN FDR	2.2	7
233T-S1		HS10 INLET FDR	2.2	20
261T-S1		HS10 INLET	2.2	29
262T-S1		HS10 OUTLET	2.2	33
296T-D2		HS10 CENTRE FL	2.2	31
296T-D3		HS10 OUTLET T	2.2	32
296T-S1		HS10 CENTRE	2.2	31
214T-D3[1]	KTC-B	TS6 INLET T	2.3	19
214T-D3[1]	KTC-R	TS6 INLET T	2.3	19
217T-D1[1]	KTC-B	TS6 OUTLET T	2.3	42
217T-D1[1]	KTC-R	TS6 OUTLET T	2.3	42
217T-D3[1]	KTC-B	HS6 OUT FDR	2.3	57
217T-D3[1]	KTC-R	HS6 OUT FDR	2.3	57
253T-D1[2]	KTC-B	HS6 INLET	2.3	28
253T-D1[2]	KTC-R	HS6 INLET	2.3	28
253T-D1[2]	RTD	HS6 INLET	2.3	28
254T-D1[2]	KTC-B	HS6 OUTLET	2.3	32
254T-D1[2]	KTC-R	HS6 OUTLET	2.3	32
254T-D1[2]	RTD	HS6 OUTLET	2.3	32
214T-D1		HS6 IN FDR	2.3	2
214T-D2		HS6 IN FDR	2.3	8
215T-D1		HS6 INLET EF T	2.3	25
216T-D1		HS6 OUTLET EF T	2.3	35
217T-D2		HS6 OUT FDR	2.3	53
292T-D1		HS6 INLET T	2.3	29
292T-D2		HS6 MID T	2.3	30
292T-D3		HS6 OUTLET T	2.3	31
234T-D1[1]	KTC-B	TS11 OUTLET T	2.4	42
234T-D1[1]	KTC-R	TS11 OUTLET T	2.4	42
234T-D3[1]	KTC-B	HS11 OUT FDR	2.4	57
234T-D3[1]	KTC-R	HS11 OUT FDR	2.4	57
237T-D3[1]	KTC-B	TS11 INLET T	2.4	19
237T-D3[1]	KTC-R	TS11 INLET T	2.4	19
263T-D1[2]	KTC-B	HS11 INLET	2.4	28
263T-D1[2]	KTC-R	HS11 INLET	2.4	28
263T-D1[2]	RTD	HS11 INLET	2.4	28
264T-D1[2]	KTC-B	HS11 OUTLET	2.4	32

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TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
264T-D1[2]	KTC-R	HS11 OUTLET	2.4	32
264T-D1[2]	RTD	HS11 OUTLET	2.4	32
234T-D2		HS11 OUT FDR	2.4	53
235T-D1		HS11 OUTLET EF T	2.4	35
236T-D1		HS11 INLET EF T	2.4	25
237T-D1		HS11 IN FDR	2.4	2
237T-D2		HS11 IN FDR	2.4	8
297T-D1		HS11 INLET T	2.4	29
297T-D2		HS11 MID T	2.4	30
297T-D3		HS11 OUTLET T	2.4	31
218T-D3[1]	KTC-B	TS7 INLET T	2.5	20
218T-D3[1]	KTC-R	TS7 INLET T	2.5	20
221T-D1[1]	KTC-B	TS7 OUTLET T	2.5	42
221T-D1[1]	KTC-R	TS7 OUTLET T	2.5	42
221T-D3[1]	KTC-B	HS7 OUT FDR	2.5	60
221T-D3[1]	KTC-R	HS7 OUT FDR	2.5	60
255T-D1[2]	KTC-B	HS7 INLET	2.5	29
255T-D1[2]	KTC-R	HS7 INLET	2.5	29
255T-D1[2]	RTD	HS7 INLET	2.5	29
256T-D1[2]	KTC-B	HS7 OUTLET	2.5	33
256T-D1[2]	KTC-R	HS7 OUTLET	2.5	33
256T-D1[2]	RTD	HS7 OUTLET	2.5	33
218T-D1		HS7 IN FDR	2.5	2
218T-D2		HS7 IN FDR	2.5	7
219T-D1		HS7 INLET EF T	2.5	26
220T-D1		HS7 OUTLET EF T	2.5	36
221T-D2		HS7 OUT FDR	2.5	56
293T-D1		HS7 INLET T	2.5	30
293T-D2		HS7 MID T	2.5	31
293T-D3		HS7 OUTLET T	2.5	32
238T-D1[1]	KTC-B	TS12 OUTLET T	2.6	42
238T-D1[1]	KTC-R	TS12 OUTLET T	2.6	42
238T-D3[1]	KTC-B	HS12 OUT FDR	2.6	60
238T-D3[1]	KTC-R	HS12 OUT FDR	2.6	60
241T-D3[1]	KTC-B	TS12 INLET T	2.6	20
241T-D3[1]	KTC-R	TS12 INLET T	2.6	20
265T-D1[2]	KTC-B	HS12 INLET	2.6	29
265T-D1[2]	KTC-R	HS12 INLET	2.6	29
265T-D1[2]	RTD	HS12 INLET	2.6	29
266T-D1[2]	KTC-B	HS12 OUTLET	2.6	33

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TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
266T-D1[2]	KTC-R	HS12 OUTLET	2.6	33
266T-D1[2]	RTD	HS12 OUTLET	2.6	33
238T-D2		HS12 OUT FDR	2.6	56
239T-D1		HS12 OUTLET EF T	2.6	36
240T-D1		HS12 INLET EF T	2.6	26
241T-D1		HS12 IN FDR	2.6	2
241T-D2		HS12 IN FDR	2.6	7
298T-D1		HS12 INLET T	2.6	30
298T-D2		HS12 MID T	2.6	31
298T-D3		HS12 OUTLET T	2.6	32
222T-D3[1]	KTC-B	TS8 INLET T	2.7	19
222T-D3[1]	KTC-R	TS8 INLET T	2.7	19
225T-D1[1]	KTC-B	TS8 OUTLET T	2.7	41
225T-D1[1]	KTC-R	TS8 OUTLET T	2.7	41
225T-D3	KTC-B	HS8 OUT FDR	2.7	58
257T-D1[2]	KTC-B	HS8 INLET	2.7	28
257T-D1[2]	KTC-R	HS8 INLET	2.7	28
257T-D1[2]	RTD	HS8 INLET	2.7	28
258T-D1[2]	KTC-B	HS8 OUTLET	2.7	32
258T-D1[2]	KTC-R	HS8 OUTLET	2.7	32
258T-D1[2]	RTD	HS8 OUTLET	2.7	32
294T-D2	KTC-R	HS8 MID T	2.7	30
222T-D1		HS8 IN FDR	2.7	2
222T-D2		HS8 IN FDR	2.7	7
223T-D1		HS8 INLET EF T	2.7	25
224T-D1		HS8 OUTLET EF T	2.7	35
225T-D2		HS8 OUT FDR	2.7	54
294T-D1		HS8 INLET T	2.7	29
294T-D3		HS8 OUTLET T	2.7	31
242T-D1[1]	KTC-B	TS13 OUTLET T	2.8	41
242T-D1[1,3]	KTC-R	TS13 OUTLET T	2.8	41
242T-D2	KTC-R	HS13 OUT FDR	2.8	54
242T-D3	KTC-B	HS13 OUT FDR	2.8	58
245T-D2	KTC-R	TS13 IN FLUID	2.8	7
245T-D3[1]	KTC-B	TS13 INLET T	2.8	19
245T-D3[1,4]	KTC-R	TS13 INLET T	2.8	19
267T-D1[2]	KTC-B	HS13 INLET	2.8	28
267T-D1[2]	KTC-R	HS13 INLET	2.8	28
267T-D1[2]	RTD	HS13 INLET	2.8	28
268T-D1[2]	KTC-B	HS13 OUTLET	2.8	32

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
268T-D1[2]	KTC-R	HS13 OUTLET	2.8	32
268T-D1[2]	RTD	HS13 OUTLET	2.8	32
299T-D2	KTC-R	HS13 CENTER	2.8	30
243T-D1		HS13 OUTLET EF T	2.8	35
244T-D1		HS13 INLET EF T	2.8	25
245T-D1		HS13 IN FDR	2.8	2
299T-D1		HS13 INLET T	2.8	29
299T-D3		HS13 OUTLET T	2.8	31
226T-D3[1]	KTC-B	TS9 INLET T	2.9	20
226T-D3[1]	KTC-R	TS9 INLET T	2.9	20
229T-D1[1]	KTC-B	TS9 OUTLET T	2.9	42
229T-D1[1]	KTC-R	TS9 OUTLET T	2.9	42
229T-D3	KTC-B	HS9 OUT FDR	2.9	60
259T-D1[2]	KTC-B	HS9 INLET	2.9	29
259T-D1[2]	KTC-R	HS9 INLET	2.9	29
259T-D1[2]	RTD	HS9 INLET	2.9	29
260T-D1[2]	KTC-B	HS9 OUTLET	2.9	33
260T-D1[2]	KTC-R	HS9 OUTLET	2.9	33
260T-D1[2]	RTD	HS9 OUTLET	2.9	33
226T-D1		HS9 IN FDR	2.9	2
226T-D2		HS9 IN FDR	2.9	7
227T-D1		HS9 INLET EF T	2.9	26
228T-D1		HS9 OUTLET EF T	2.9	36
229T-D2		HS9 OUT FDR	2.9	55
295T-D1		HS9 INLET T	2.9	30
295T-D2		HS9 MID T	2.9	31
295T-D3		HS9 OUTLET T	2.9	32
247T-D3[1]	KTC-B	TS14 INLET T	2.10	20
247T-D3[1]	KTC-R	TS14 INLET T	2.10	20
249T-D1[1]	KTC-B	TS14 OUTLET T	2.10	42
249T-D1[1]	KTC-R	TS14 OUTLET T	2.10	42
249T-D3	KTC-B	HS14 OUT FDR	2.10	60
269T-D1[2]	KTC-B	HS14 INLET	2.10	29
269T-D1[2]	KTC-R	HS14 INLET	2.10	29
269T-D1[2]	RTD	HS14 INLET	2.10	29
270T-D1[2]	KTC-B	HS14 OUTLET	2.10	33
270T-D1[2]	KTC-R	HS14 OUTLET	2.10	33
270T-D1[2]	RTD	HS14 OUTLET	2.10	33
246T-D1		HS14 INLET EF T	2.10	26
247T-D2		HS14 IN FDR	2.10	7

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Station No.
248T-D1		HS14 OUTLET EF T	2.10	36
249T-D2		HS14 OUT FDR	2.10	55
300T-D1		HS14 INLET T	2.10	30
300T-D2		HS14 MID T	2.10	31
300T-D3		HS14 OUTLET T	2.10	32
124T	KTC-B	P1 INLET	2.11	29
125T	KTC-B	P1 OUTLET	2.11	33
122T	KTC-B	P2 INLET	2.12	30
123T	KTC-B	P2 OUTLET	2.12	34
23T-D2	KTC-B	HDR5	2.22	9
24T	RTD	HDR5	2.22	5
5T-D2	KTC-B	HDR6	2.23	11
6T	RTD	HDR6	2.23	10
11T-D2	KTC-B	HDR7	2.24	12
12T	RTD	HDR7	2.24	5
17T-D2	KTC-B	HDR8	2.25	8
18T	RTD	HDR8	2.25	12
11T-D3[5]	KTC-R	HDR7 BOTTOM	2.26	n/a
14T	RTD	BO2 INLET	2.27	n/a
15T	RTD	BO2 OUTLET	2.27	n/a
26T	RTD	BO1 OUTLET	2.27	n/a
3T	RTD	BO1 INLET	2.27	n/a
60T-D1	KTC-B	BO1 INLET	2.27	n/a
60T-D2	KTC-B	BO1 OUTLET	2.27	n/a
61T-D1	KTC-B	BO2 INLET	2.27	n/a
61T-D2	KTC-B	BO2 OUTLET	2.27	n/a
1T-D22	KTC-B	BO1 TOP	2.29	n/a
1T-D23	KTC-B	BO1 MID	2.29	n/a
1T-D25	KTC-B	B1-TE1-S37	2.29	n/a
1T-D26	KTC-R	B1-TE1-S25	2.29	n/a
1T-D27	KTC-B	B1-TE1-S12	2.29	n/a
1T-D29	KTC-R	B1-TE1-S84	2.29	n/a
1T-D30	KTC-R	B1-TE1-S92	2.29	n/a
1T-D31	KTC-R	B1-TE6-S37	2.29	n/a
1T-D32	KTC-R	B1-TE6-S25	2.29	n/a
1T-D33	KTC-R	B1-TE6-S12	2.29	n/a
1T-D34	KTC-R	B1-TE6-S50	2.29	n/a
1T-D35	KTC-R	B1-TE6-S84	2.29	n/a
1T-D36	KTC-R	B1-TE6-S92	2.29	n/a
2T-D13	KTC-R	B2-TB4-S37	2.29	n/a

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
2T-D14	KTC-R	B2-TB4-S25	2.29	n/a
2T-D15	KTC-R	B2-TB4-S12	2.29	n/a
2T-D16	KTC-R	B2-TB4-S50	2.29	n/a
2T-D21	KTC-R	B2-TB8-S12	2.29	n/a
2T-D22	KTC-B	B2-TB8-S50	2.29	n/a
2T-D23	KTC-B	B2-TB8-S84	2.29	n/a
2T-D24	KTC-R	B2-TB8-S92	2.29	n/a
2T-D25	KTC-R	B2-TE1-S37	2.29	n/a
2T-D26	KTC-R	B2-TE1-S25	2.29	n/a
2T-D27	KTC-B	B2-TE1-S12	2.29	n/a
2T-D29	KTC-B	B2-TE1-S84	2.29	n/a
2T-D30	KTC-B	B2-TE1-S92	2.29	n/a
2T-D32	KTC-R	B2-TE6-S25	2.29	n/a
2T-D34	KTC-R	B2-TE6-S50	2.29	n/a
2T-D36	KTC-R	B2-TE6-S92	2.29	n/a
1T-D28		BO1 T	2.29	n/a
2T-D17		BO2 T	2.29	n/a
2T-D18		BO2 T	2.29	n/a
2T-D19		BO2 T	2.29	n/a
2T-D20		BO2 T	2.29	n/a
2T-D28		BO2 T	2.29	n/a
2T-D31		BO2 T	2.29	n/a
2T-D33		BO2 T	2.29	n/a
2T-D35		BO2 T	2.29	n/a
1TFB	KTC-P	HS11 FDR OSRF	7.1	18
1TFT	KTC-P	HS11 FDR OSRF	7.1	18
2TFB	KTC-P	HS11 FDR OSRF	7.1	17
2TFT	KTC-P	HS11 FDR OSRF	7.1	17
3TFB	KTC-P	HS11 FDR OSRF	7.1	16
3TFT	KTC-P	HS11 FDR OSRF	7.1	16
4TFVL	KTC-P	HS11 FDR OSRF	7.1	13
4TFVR	KTC-P	HS11 FDR OSRF	7.1	13
5TFS	KTC-P	HS11 FDR OSRF	7.1	11
5TFT	KTC-P	HS11 FDR OSRF	7.1	11
6TFVL	KTC-P	HS11 FDR OSRF	7.1	9
6TFVR	KTC-P	HS11 FDR OSRF	7.1	9
7TFB	KTC-P	HS11 FDR OSRF	7.1	6
7TFT	KTC-P	HS11 FDR OSRF	7.1	6
8TFB	KTC-P	HS11 FDR OSRF	7.1	3
8TFT	KTC-P	HS11 FDR OSRF	7.1	3

6. INSTRUMENTATION AND DATA ACQUISITION

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
206T-D10	KTC-E	HS13 OUT-BOT	7.2	E
206T-D11	KTC-E	HS13 OUT-SIDE	7.2	E
206T-D12	KTC-E	HS13 OUT-TOP	7.2	E
206T-D13	KTC-E	HS13 CEN-BOT	7.2	D
206T-D14	KTC-E	HS13 CEN-SIDE	7.2	D
206T-D15	KTC-E	HS13 CEN-TOP	7.2	D
206T-D16	KTC-E	HS13 IN-BOT	7.2	C
206T-D17	KTC-E	HS13 IN-SIDE	7.2	C
206T-D18	KTC-E	HS13 IN-TOP	7.2	C
SURF 1	KTC-R	HS13 LOFBS	7.2	F
SURF 2	KTC-R	HS13 LOFTS	7.2	F
SURF 3	KTC-R	PT13 OUT- BOT	7.2	E
SURF 4	KTC-R	PT13 OUT-SID	7.2	E
SURF 5	KTC-R	PT13 OUT-TOP	7.2	E
SURF 6	KTC-R	PT13 CEN-BOT	7.2	D
SURF 7	KTC-R	PT13 CEN-SID	7.2	D
SURF 8	KTC-R	PT13 CEN-TOP	7.2	D
SURF 9	KTC-R	PT13 IN-BOT	7.2	C
SURF 10	KTC-R	PT13 IN-SID	7.2	C
SURF 11	KTC-R	PT13 IN-TOP	7.2	C
SURF 12	KTC-R	HS13 LIFBS	7.2	B
SURF 13	KTC-R	HS13 LIFTS	7.2	B
SURF 14	KTC-R	HS13 UOFBS	7.2	G
SURF 15	KTC-R	HS13 UOFTS	7.2	G
SURF 16	KTC-R	HS13 UIFBS	7.2	A
SURF 17	KTC-R	HS13 UIFTS	7.2	A
301T-D1	KTC-R	HS5 IN ORNG	B.2	n/a
302T-D1	KTC-R	HS5 OUT ORNG	B.2	n/a
303T-D1	KTC-R	HS6 IN ORNG	B.2	n/a
304T-D1	KTC-R	HS6 OUT ORNG	B.2	n/a
305T-D1	KTC-R	HS7 IN ORNG	B.2	n/a
306T-D1	KTC-R	HS7 OUT ORNG	B.2	n/a
307T-D1	KTC-R	HS8 IN ORNG	B.2	n/a
308T-D1	KTC-R	HS8 OUT ORNG	B.2	n/a
309T-D1	KTC-R	HS9 IN ORNG	B.2	n/a
310T-D1	KTC-R	HS9 OUT ORNG	B.2	n/a
311T-D1	KTC-R	HS10 IN ORNG	B.3	n/a
312T-D1	KTC-R	HS10 OUT ORNG	B.3	n/a
313T-D1	KTC-R	HS11 IN ORNG	B.3	n/a
314T-D1	KTC-R	HS11 OUT ORNG	B.3	n/a

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
315T-D1	KTC-R	HS12 IN ORNG	B.3	n/a
316T-D1	KTC-R	HS12 OUT ORNG	B.3	n/a
317T-D1	KTC-R	HS13 IN ORNG	B.3	n/a
318T-D1	KTC-R	HS13 OUT ORNG	B.3	n/a
319T-D1	KTC-R	HS14 IN ORNG	B.3	n/a
320T-D1	KTC-R	HS14 OUT ORNG	B.3	n/a

[1] These devices have used both KTC-B and KTC-R device types.
[2] These devices have used KTC-B, KTC-R, and RTD device types.
[3] Modified to measure HS13 outlet feeder wall temperature for B96 tests
[4] Modified to measure HS13 inlet feeder wall temperature for B96 tests
[5] Installed on bottom instrument tap of HDR7 end-cap.

GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
80P-D1	GP-R	HS5 INLET P	2.1	15
111P-D1	GP-R	HS5 OUTLET P	2.1	44
81P-D1		HS5 INLET EF P	2.1	24
82P-D1		HS5 OUTLET EF P	2.1	38
95P-D1	GP-R	HS10 INLET P	2.2	15
116P-D1	GP-R	HS10 OUTLET P	2.2	44
96P-D1		HS10 OUTLET EF P	2.2	38
97P-D1		HS10 INLET EF P	2.2	24
83P-D1	GP-R	HS6 INLET P	2.3	18
112P-D1	GP-R	HS6 OUTLET P	2.3	41
84P-D1		HS6 INLET EF P	2.3	23
85P-D1		HS6 OUTLET EF P	2.3	37
98P-D1	GP-R	HS11 INLET P	2.4	18
117P-D1	GP-R	HS11 OUTLET P	2.4	41
143P-D1	GP-D	HS11 CENTER	2.4	30
99P-D1		HS11 OUTLET EF P	2.4	37
100P-D1		HS11 INLET EF P	2.4	23
86P-D1	GP-R	HS7 INLET P	2.5	18
113P-D1	GP-R	HS7 OUTLET P	2.5	44
87P-D1		HS7 INLET EF P	2.5	24
88P-D1		HS7 OUTLET EF P	2.5	38
101P-D1	GP-R	HS12 INLET P	2.6	18

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GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
118P-D1	GP-R	HS12 OUTLET P	2.6	44
102P-D1		HS12 OUTLET EF P	2.6	38
103P-D1		HS12 INLET EF P	2.6	24
89P-D1	GP-R	HS8 INLET P	2.7	18
114P-D1	GP-R	HS8 OUTLET P	2.7	42
145P-D1	GP-D	HS8 CENTER	2.7	30
90P-D1		HS8 INLET EF P	2.7	23
91P-D1		HS8 OUTLET EF P	2.7	37
104P-D1	GP-R	HS13 INLET P	2.8	18
119P-D1	GP-R	HS13 OUTLET P	2.8	42
HS13 P	GP-R	HS13 CENTER	2.8	30
105P-D1		HS13 OUTLET EF P	2.8	37
106P-D1		HS13 INLET EF P	2.8	23
92P-D1	GP-R	HS9 INLET P	2.9	16
115P-D1	GP-R	HS9 OUTLET P	2.9	45
93P-D1		HS9 INLET EF P	2.9	24
94P-D1		HS9 OUTLET EF P	2.9	38
107P-D1	GP-R	HS14 INLET P	2.10	16
107P-D2	GP-D	HS14 INLET	2.10	30
120P-D1	GP-R	HS14 OUTLET P	2.10	45
120P-D2	GP-D	HS14 OUTLET	2.10	32
108P-D1		HS14 OUTLET EF P	2.10	38
109P-D1		HS14 INLET EF P	2.10	24
133P-D1		P1 OUTLET P	2.11	33
134P-D1		P2 OUTLET P	2.12	34
12P-D1	GP-R	HDR5	2.22	6
12P-D2	GP-D	HDR5	2.22	6
13P-D1	GP-TI	HDR5	2.22	6
13P-D2	GP-TI	HDR5	2.22	6
4P-D1	GP-R	HDR6	2.23	8
4P-D2	GP-D	HDR6	2.23	8
5P-D1	GP-TI	HDR6	2.23	8
5P-D2	GP-TI	HDR6	2.23	8
6P-D1	GP-R	HDR7	2.24	6
6P-D2[1]	GP-D	HDR7	2.24 (2.4)	6 (30)
7P-D1	GP-TI	HDR7	2.24	6
7P-D2	GP-TI	HDR7	2.24	6
10P-D1	GP-R	HDR8	2.25	9
10P-D2	GP-D	HDR8	2.25	9
11P-D1	GP-TI	HDR8	2.25	9

GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
11P-D2	GP-TI	HDR8	2.25	9
38P-D4	GP-R	BO1 TUBE B11 P	2.30	n/a
39P-D4	GP-R	BO2 TUBE B11	2.30	n/a
38P-D1		BO1 TUBE B1 P	2.30	n/a
38P-D2		BO1 TUBE B1 P	2.30	n/a
38P-D3		BO1 TUBE B1 P	2.30	n/a
38P-D5		BO1 TUBE B11 P	2.30	n/a
38P-D6		BO1 TUBE B11 P	2.30	n/a
38P-D7		BO1 TUBE E4 P	2.30	n/a
38P-D8		BO1 TUBE E4 P	2.30	n/a
38P-D9		BO1 TUBE E4 P	2.30	n/a
39P-D1		BO2 TUBE B1 P	2.30	n/a
39P-D2		BO2 TUBE B1 P	2.30	n/a
39P-D3		BO2 TUBE B1 P	2.30	n/a
39P-D5		BO2 TUBE B11 P	2.30	n/a
39P-D6		BO2 TUBE B11 P	2.30	n/a
39P-D7		BO2 TUBE E4 P	2.30	n/a
39P-D8		BO2 TUBE E4 P	2.30	n/a
39P-D9		BO2 TUBE E4 P	2.30	n/a
121P-D1	GP-TI	P2 OUT PRESS		
122P-D1	GP-TI	P1 OUT PRESS		

[1] Normally installed on HDR7, but was located at HS11 CENTER for R9701-3 and C9707.

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
2F-DP	DP-R/S	2F TFM DP	2.12	36,41
B11-BT1	DP-TI	B1-TB11-BT	2.31	n/a
B11-DP1	DP-TI	B1-TB11-DP	2.31	n/a
B1-BT1	DP-TI	B1-TB1-BT	2.31	n/a
B1-DP1	DP-TI	B1-TB1-DP	2.31	n/a
E4-BT1	DP-TI	B1-TE4-BT	2.31	n/a
E4-DP1	DP-TI	B1-TE4-DP	2.31	n/a
B11-BT2	DP-TI	B2-TB11-BT	2.31	n/a
B11-DP	DP-TI	B2-TB11-DP	2.31	n/a
B11-DP2	DP-TI	B2-TB11-DP	2.31	n/a
B1-BT2	DP-TI	B2-TB1-BT	2.31	n/a

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
B1-DP	DP-TI	B2-TB1-DP	2.31	n/a
B1-DP2	DP-TI	B2-TB1-DP	2.31	n/a
E4-DP	DP-TI	B2-TB4-DP	2.31	n/a
E4-BT2	DP-TI	B2-TE4-BT	2.31	n/a
E4-DP2	DP-TI	B2-TE4-DP	2.31	n/a
3Q-D1	DP-R/S	BO1 DELP	2.11	12,19
4Q-D1	DP-R/S	BO1-P1	2.11	19,29
10Q-D1	DP-R/S	BO2 DELP	2.12	11,18
11Q-D1	DP-R/S	BO2-P2	2.12	18,30
16Q-D1	DP-R/S	HDR5-BO1	2.22/2.11	6/12
57Q-D1	DP-R/S	HDR5-HDR6	2.22/2.23	6/8
73Q-D1	DP-R/S	HDR5-HDR7	2.22/2.24	6/6
36Q-D1	DP-R/S	HDR6-HDR7	2.23/2.24	8/6
36Q-D2	DP-R/S	HDR6-HDR7	2.23/2.24	8/6
37Q-D1	DP-R/S	HDR6-HS5	2.23/2.1	8/15
38Q-D1	DP-R/S	HDR6-HS6	2.23/2.3	8/18
39Q-D1	DP-R/S	HDR6-HS7	2.23/2.5	8/18
40Q-D1	DP-R/S	HDR6-HS8	2.23/2.7	8/18
41Q-D1	DP-R/S	HDR6-HS9	2.23/2.9	8/16
9Q-D1	DP-R/S	HDR7-BO2	2.24/2.12	6/11
58Q-D1	DP-R/S	HDR7-HDR8	2.24/2.25	6/9
35Q-D1	DP-R/S	HDR8-HDR5	2.25/2.22	9/6
35Q-D2	DP-R/S	HDR8-HDR5	2.25/2.22	9/6
52Q-D1	DP-R/S	HDR8-HS10	2.25/2.2	9/15
53Q-D1	DP-R/S	HDR8-HS11	2.25/2.4	9/18
54Q-D1	DP-R/S	HDR8-HS12	2.25/2.6	9/18
55Q-D1	DP-R/S	HDR8-HS13	2.25/2.8	9/18
56Q-D1	DP-R/S	HDR8-HS14	2.25/2.10	9/16
29Q-D1	DP-R/S	HS10	2.2	15,44
29Q-D2	DP-R/S	HS10	2.2	15,44
42Q-D1	DP-R/S	HS10-HDR5	2.2/2.22	44/6
30Q-D1	DP-R/S	HS11	2.4	18,41
30Q-D2	DP-R/S	HS11	2.4	18,41
43Q-D1	DP-R/S	HS11-HDR5	2.4/2.22	41/6
31Q-D1	DP-R/S	HS12	2.6	18,44
31Q-D2	DP-R/S	HS12	2.6	18,44
71Q-D1	DP-R/S	HS12 INLET EF	2.6	18,30
72Q-D1	DP-R/S	HS12 OUTLET EF	2.6	32,44
44Q-D1	DP-R/S	HS12-HDR5	2.6/2.22	44/6
32Q-D1	DP-R/S	HS13	2.8	18,42

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
32Q-D2	DP-R/S	HS13	2.8	18,42
DP1-D1	DP-R/S	HS13 IN DP	2.8	13,30
DP1-D2	DP-R/S	HS13 IN DP	2.8	13,30
DP2-D1	DP-R/S	HS13 OUT DP	2.8	30,45
DP2-D2	DP-R/S	HS13 OUT DP	2.8	30,45
45Q-D1	DP-R/S	HS13-HDR5	2.8/2.22	42/6
33Q-D1	DP-R/S	HS14	2.10	16,45
33Q-D2	DP-R/S	HS14	2.10	16,45
46Q-D1	DP-R/S	HS14-HDR5	2.10/2.22	45/6
24Q-D1	DP-R/S	HS5	2.1	15,44
24Q-D2	DP-R/S	HS5	2.1	15,44
67Q-D1	DP-R/S	HS5 INLET EF	2.1	15,30
68Q-D1	DP-R/S	HS5 OUTLET EF	2.1	32,44
47Q-D1	DP-R/S	HS5-HDR7	2.1/2.24	44/6
25Q-D1	DP-R/S	HS6	2.3	18,41
25Q-D2	DP-R/S	HS6	2.3	18,41
48Q-D1	DP-R/S	HS6-HDR7	2.3/2.24	41/6
26Q-D1	DP-R/S	HS7	2.5	18,44
26Q-D2	DP-R/S	HS7	2.5	18,44
49Q-D1	DP-R/S	HS7-HDR7	2.5/2.24	44/6
27Q-D1	DP-R/S	HS8	2.7	18,42
27Q-D2	DP-R/S	HS8	2.7	18,42
69Q-D1	DP-R/S	HS8 INLET EF	2.7	18,29
70Q-D1	DP-R/S	HS8 OUTLET EF	2.7	31,42
50Q-D1	DP-R/S	HS8-HDR7	2.7/2.24	42/6
28Q-D1	DP-R/S	HS9	2.9	16,45
28Q-D2	DP-R/S	HS9	2.9	16,45
51Q-D1	DP-R/S	HS9-HDR7	2.9/2.24	45/6
5Q-D1	DP-R/S	P1 DELP	2.11	29,33
5Q-D2	DP-R/S	P1 DELP	2.11	29,33
6Q-D1	DP-R/S	P1-HDR6	2.11/2.23	33/8
12Q-D1	DP-R/S	P2 DELP	2.12	30,34
12Q-D2[1]	DP-R/S	P2 DELP	2.12	30,34
12Q-D2[1]	DP-TI	P2 DELP	2.12	30,34
13Q-D1	DP-R/S	P2-HDR8	2.12/2.25	34/9
200F-D1	DP-R/S		2.14	5
201F-D1	DP-R/S	HIC S	2.14	37
230F-D1	DP-R/S	EHIC L411	2.14	46

[1] These devices have used both DP-R/S and DP-TI device types.

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VOLUMETRIC FLOW				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
177F-D1	TFM	HS5 INLET F	2.1	10
178F-D1	TFM	HS5 OUTLET F	2.1	51
187F-D1	TFM	HS10 INLET F	2.2	10
188F-D1	TFM	HS10 OUTLET F	2.2	51
179F-D1	TFM	HS6 INLET F	2.3	15
180F-D1	TFM	HS6 OUTLET F	2.3	45
189F-D1	TFM	HS11 INLET F	2.4	15
190F-D1	TFM	HS11 OUTLET F	2.4	45
181F-D1	TFM	HS7 INLET F	2.5	15
182F-D1	TFM	HS7 OUTLET F	2.5	51
191F-D1	TFM	HS12 INLET F	2.6	15
192F-D1	TFM	HS12 OUTLET F	2.6	51
183F-D1	TFM	HS8 INLET F	2.7	11
184F-D1	TFM	HS8 OUTLET F	2.7	49
193F-D1	TFM	HS13 INLET F	2.8	11
194F-D1	TFM	HS13 OUTLET F	2.8	49
185F-D1	TFM	HS9 INLET F	2.9	10
186F-D1	TFM	HS9 OUTLET F	2.9	52
195F-D1	TFM	HS14 INLET F	2.10	10
196F-D1	TFM	HS14 OUTLET F	2.10	52
1F	TFM	P1 OUTLET	2.11	38
2F	TFM	P2 OUTLET	2.12	39
246F-D1	TFM	HIC L411	2.14	47

VOID - GAMMA DENSITOMETERS				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
15VF	VFM-V	HS5 INLET V	2.1	17
16VF	VFM-V	HS5 OUTLET V	2.1	49
25VF	VFM-V	HS10 INLET V	2.2	17
26VF	VFM-V	HS10 OUTLET V	2.2	49
17VF	VFM-V	HS6 INLET V	2.3	13
18VF	VFM-V	HS6 OUTLET V	2.3	49
27VF	VFM-V	HS11 INLET V	2.4	11
28VF	VFM-V	HS11 OUTLET V	2.4	49
19VF	VFM-V	HS7 INLET V	2.5	11
20VF	VFM-V	HS7 OUTLET V	2.5	46
29VF	VFM-V	HS12 INLET V	2.6	11

6. INSTRUMENTATION AND DATA ACQUISITION

VOID - GAMMA DENSITOMETERS				
RD-14M	RD-14M		Reference	
Device Code	Device Type	Measurement Location	Figure No.	Station No.
30VF	VFM-V	HS12 OUTLET V	2.6	46
21VF	VFM-V	HS8 INLET V	2.7	15
22VF	VFM-V	HS8 OUTLET V	2.7	47
31VF	VFM-V	HS13 INLET V	2.8	15
32VF	VFM-V	HS13 OUTLET V	2.8	47
23VF	VFM-V	HS9 INLET V	2.9	18
24VF	VFM-V	HS9 OUTLET V	2.9	47
33VF	VFM-V	HS14 INLET V	2.10	18
34VF	VFM-V	HS14 OUTLET V	2.10	47
11VF-DT1	VFM	BO1 INLET	2.11	11
11VF-DT2	VFM	BO1 INLET	2.11	11
11VF-DT3	VFM	BO1 OUTLET	2.11	21
11VF-DT4	VFM	BO1 OUTLET	2.11	21
1VF-DTX	VFM-IV	P1 OUTLET	2.11	36
1VF-DTY	VFM-IV	P1 OUTLET	2.11	36
1VF-DTZ	VFM-IV	P1 OUTLET	2.11	36
12VF-DT1	VFM	BO2 OUTLET	2.12	20
12VF-DT2	VFM	BO2 OUTLET	2.12	20
12VF-DT3	VFM	BO2 INLET	2.12	10
12VF-DT4	VFM	BO2 INLET	2.12	10
4VF-DTX	VFM-IV	P2 OUTLET	2.12	37
4VF-DTY	VFM-IV	P2 OUTLET	2.12	37
4VF-DTZ	VFM-IV	P2 OUTLET	2.12	37
35VF	VFM-V	HIC W	2.14	41
36VF	VFM-V	HIC E	2.14	36
37VF	VFM-V	HIC W	2.14	16
38VF	VFM-V	HIC E	2.14	26

VOID - CONDUCTIVITY PROBES				
RD-14M	RD-14M		Reference	
Device Code	Device Type	Measurement Location	Figure No.	Station No.
COND 1[1]	COND	HD7 2 O'CLK	2.26	n/a
COND 2[2]	COND	HD7 4 O'CLK	2.26	n/a
COND 3[3]	COND	HD7 6 O'CLK	2.26	n/a
COND 4[3]	COND	HD7 8 O'CLK	2.26	n/a
COND 5[3]	COND	HD7 10 O'CLK	2.26	n/a
COND 6[3]	COND	HD7 12 O'CLK	2.26	n/a
COND 7	COND	HS13 INLET FDR	2.8	14

6. INSTRUMENTATION AND DATA ACQUISITION

VOID - CONDUCTIVITY PROBES				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
COND 8	COND	HS13 INLET	2.8	28
COND 9	COND	HS13 OUTLET	2.8	32
COND 10	COND	HS13 OUT FDR	2.8	46
COND A	COND	BO2 INLET		
COND B[4]	COND			
COND M	COND	HS11 FDR MID	7.1	14
COND T	COND	HS11 FDR TOP	7.1	20

[1] Installed on HDR7 end-cap. Relocated to bottom tap position for R94 and Y9501-7 tests.
[2] Installed on HDR7 end-cap. Relocated to top tap position for R94 and Y9501-7 tests.
[3] Installed on HDR7 end-cap.
[4] BO2 OUTLET prior to 1998. The location was then changed to HS11 FDR BOT (Station 8, Figure 7.1).

TABLE 6.2

SUMMARY OF SECONDARY-SIDE INSTRUMENTS

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
136T-D1	KTC-B	BO1 DWNCMR	3.2	127
136T-D2	KTC-B	BO1 DWNCMR	3.2	125
137T-D1	KTC-B	BO2 DWNCMR	3.2	110
137T-D2	KTC-B	BO2 DWNCMR	3.2	108
29T	KTC-B	BO1 STEAM	3.2	136
30T	RTD	BO1 STEAM	3.2	135
31T-D1	KTC-B	BO2 STEAM	3.2	142
32T	RTD	BO2 STEAM	3.2	143
33T-D1	KTC-B	CD1 OUTLET	3.2	2
34T	KTC-B	P6/7 OUTLET	3.2	17
37T	RTD	BO1/2 FDWTR	3.2	92
43T	KTC-B	CD1 SPRAY	3.2,3.3	65A/65B,20
331T-D1	KTC-R	BO1/2 FDWTR	3.3	23
332T-D1	KTC-R	BO1 FDWTR	3.3	46
333T-D1	KTC-R	BO2 FDWTR	3.3	35
74T-D1[1]	KTC-B	SB1-TB1-S4	3.10	n/a
74T-D1[1]	KTC-R	SB1-TB1-S4	3.10	n/a
74T-D2[1]	KTC-B	SB1-TB11-S8	3.10	n/a
74T-D2[1]	KTC-R	SB1-TB11-S8	3.10	n/a
74T-D3[1]	KTC-B	SB1-TE4-S12	3.10	n/a
74T-D3[1]	KTC-R	SB1-TE4-S12	3.10	n/a
74T-D4	KTC-R	SB1-TC5-S16	3.10	n/a
74T-D5	KTC-R	SB1-TB6-S96	3.10	n/a
74T-D6	KTC-B	SB1-TD4-S96	3.10	n/a
74T-D7	KTC-R	SB1-TB1-S84	3.10	n/a
74T-D8	KTC-R	SB1-TB11-S84	3.10	n/a
74T-D9	KTC-B	SB1-TE1-S92	3.10	n/a
74T-D10	KTC-R	SB1-TE6-S92	3.10	n/a
75T-D1	KTC-R	SB2-TB1-S4	3.10	n/a
75T-D2	KTC-R	SB2-TB11-S8	3.10	n/a
75T-D3[1]	KTC-B	SB2-TE4-S12	3.10	n/a
75T-D3[1]	KTC-R	SB2-TE4-S12	3.10	n/a
75T-D4[1]	KTC-B	SB2-TC5-S16	3.10	n/a
75T-D4[1]	KTC-R	SB2-TC5-S16	3.10	n/a
75T-D5[1]	KTC-B	SB2-TB6-S96	3.10	n/a

6. INSTRUMENTATION AND DATA ACQUISITION

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
75T-D5[1]	KTC-R	SB2-TB6-S96	3.10	n/a
75T-D6	KTC-B	SB2-TD4-S96	3.10	n/a
75T-D7	KTC-R	SB2-TB1-S84	3.10	n/a
75T-D8	KTC-R	SB2-TB11-S84	3.10	n/a
75T-D9	KTC-B	SB2-TE1-S92	3.10	n/a
75T-D10	KTC-B	SB2-TE6-S92	3.10	n/a

[1] These devices have used both KTC-B and KTC-R device types.

GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
1P	GP-R	BO1 DRUM	3.2	127
2P	GP-R	BO2 DRUM	3.2	110
31P-D1	GP-R	CD1 PRESS	3.2	151

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference Figure No.	Reference Station No.
135F[1]	DP-R/S	BO1 DWNCMR	3.2	126
135F[1]	ORFM	BO1 DWNCMR	3.2	126
136F[1]	DP-R/S	BO2 DWNCMR	3.2	109
136F[1]	ORFM	BO2 DWNCMR	3.2	109
3F-D2	DP-R	BO1 STEAM DP	3.2	137
4F-D2	DP-R	BO2 STEAM DP	3.2	141
5F	ORFM	BO1 FDWTR	B.1	n/a
6F	ORFM	BO2 FDWTR	B.1	n/a

[1] These devices have used both DP-R/S and ORFM device types.

VOLUMETRIC FLOW				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
5F-D1	TFM	BO1 FDWTR	B.1	n/a
5F-D2	TFM	BO1 FDWTR	B.1	n/a
6F-D1	TFM	BO2 FDWTR	B.1	n/a
6F-D2	TFM	BO2 FDWTR	B.1	n/a
19F	TFM	CD1 SPRAY	3.2	70
235F-D2	TFM	BO1 FDWTR	3.3	37
236F-D2	TFM	BO2 FDWTR	3.3	26

MASS FLOW				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
235F-M1	FDW-F	BO1 FW M FLOW	3.3	37
236F-M1	FDW-F	BO2 FW M FLOW	3.3	26
3F-M1	STM-F	BO1 STM M F	3.2	137
4F-M1	STM-F	BO2 STM M F	3.2	141
5F-M1	FDW-F	BO1 FW M FLOW	B.1	n/a
6F-M1	FDW-F	BO2 FW M FLOW	B.1	n/a

LEVEL				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
2H-D1	DP-R	BO1 DRUM LEVEL	3.4	n/a
3H-D1	DP-R	BO2 DRUM LEVEL	3.4	n/a
4H	DP-R	CD1	3.11	n/a
8H-D1	DP-R	BO1 LEVEL	3.4	n/a
9H-D1	DP-R	BO2 LEVEL	3.4	n/a

TABLE 6.3

SUMMARY OF ECI INSTRUMENTS

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
48T	KTC-B	ECI TANK	4.4	7
48T-D1	KTC-R	ECI TANK	4.4	7
111T-D1	KTC-R	ECI-HDR5	4.5/4.6	47/46
112T-D1	KTC-R	ECI-HDR6	4.5/4.6	31/29
113T-D1	KTC-R	ECI-HDR7	4.5/4.6	69/66
114T-D1	KTC-R	ECI-HDR8	4.5/4.6	85/83
321T-D1	KTC-R	P14 OUTLET	4.4	30

GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
27P	GP-R	ECI TANK	4.4	8
77P	GP-TI	ECI LINE	4.4	77
144P-D1	GP-TI	P14 OUT PRESS	4.4	27

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
ECI DP1	DP-R	77P-HDR5	4.4/2.22	77/6
ECI DP2	DP-R	77P-HDR6	4.4/2.23	77/8
ECI DP3	DP-R	77P-HDR7	4.4/2.24	77/6
ECI DP4	DP-R	77P-HDR8	4.4/2.25	77/9
OR25-DP	ORFM	ECI INJ LINE	4.4	75

VOLUMETRIC FLOW				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
8F[1]	VORTX	ECI HDR5	4.5/4.6	42/40
9F[1]	VORTX	ECI HDR6	4.5/4.6	26/23
10F[1]	VORTX	ECI HDR7	4.5/4.6	64/60
11F[1]	VORTX	ECI HDR8	4.5/4.6	80/77
231F-D1	TFM	ECI HDR5	4.5/4.6	42/40
232F-D1	TFM	ECI HDR6	4.5/4.6	26/23
233F-D1	TFM	ECI HDR7	4.5/4.6	64/60
234F-D1	TFM	ECI HDR8	4.5/4.6	80/77
245F	VORTX	P14 BYPASS	4.4	41

[1] Devices installed prior to 231F-D1, 232F-D1, 233F-D1, 234F-D1

LEVEL				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
1H	DP-R	ECI TANK	4.4	9,10
13H-D1	DP-R	P14 WELL	4.4	20,21

6. INSTRUMENTATION AND DATA ACQUISITION

TABLE 6.4

SUMMARY OF MISCELLANEOUS INSTRUMENTS

TEMPERATURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
16T	KTC-R	INV TANK	5.3	n/a
45T	RTD	SRG TANK	5.1	n/a
81T[1]	KTC-B	BLWDWN LINE	5.6	n/a
81T[1]	KTC-R	BLWDWN LINE	5.6	n/a
322T-D1[1]	KTC-B	SRG TK OUT		
322T-D1[1]	KTC-R	SRG TK OUT		
356T-D1	KTC-B	SRG TK L26 TEM	5.2	12

[1] These devices have used both KTC-B and KTC-R device types.

GAUGE PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
26P-D1	GP-R	SRG TANK	5.1	n/a
36P-D1	GP-TI	BLWDWN LINE	5.6	n/a

DIFFERENTIAL PRESSURE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
64Q-D1	DP-R/S	SRG TK-HDR5 DP	5.2/2.22	n/a / 6

VOLUMETRIC FLOW				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
15F	TFM	SRG TANK	5.2	14
237F-D1	TFM	INV TANK FLOW	5.3	n/a

LEVEL				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
5H	DP-R	SRG TANK	5.1	n/a

VOLUME				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
7H-D1	DP-R	INV TANK	5.3	n/a

MASS				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
12H-D1	DP-R	INV ADD TK4	5.9	n/a

POWER SUPPLY VOLTAGE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
PS1-1V	VOLT	PS1 VOLTS		
PS2-1V	VOLT	PS2 VOLTS		
PS3-1V	VOLT	PS3 VOLTS		
PS4-1V	VOLT	PS4 VOLTS		

POWER SUPPLY POWER				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
PS1-1W	POWER	PS1 POWER		
PS2-1W	POWER	PS2 POWER		
PS3-1W	POWER	PS3 POWER		
PS4-1W	POWER	PS4 POWER		

6. INSTRUMENTATION AND DATA ACQUISITION

PUMP CURRENT				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
PM1-1A	PM-AMP	P1 AMPS		
PM2-1A	PM-AMP	P2 AMPS		

PUMP SPEED				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
PM1-1Y	RPM	P1 SPEED		
PM2-1Y	RPM	P2 SPEED		

PUMP TORQUE				
RD-14M Device Code	RD-14M Device Type	Measurement Location	Reference	
			Figure No.	Station No.
TM1	TORQUE	PUMP 1		
TM2	TORQUE	PUMP 2		

TABLE 6.5

SUMMARY OF INSTRUMENT DEVICE TYPES

Parameter	Primary Device Type	RD-14M Device Type Label	Description
Temperature	Type-K thermocouple	KTC-B	Bailey model #740 amplifier and Acromag model 350 reference junction (no correction for non-linearity)
		KTC-E	Ectron model #683/687 amplifier (no correction for non-linearity)
		KTC-P	Promac model XZ3-T amplifier (correction for non-linearity)
		KTC-R	Ronan model #X54-216L amplifier (correction for non-linearity)
	RTD	RTD	Rosemount sensor with Accutech model AI-2000 temperature transmitter
		RTD	Rosemount sensor with Rosemount model 444RL temperature transmitter
Pressure	Strain gauge	GP-TI (gauge) DP-TI (differential)	BLH, Dynisco and Transducer Inc. transducers with Ectron amplifiers
		GP-D (gauge)	Druck model PTX-600 series
	Capacitance	GP-R (gauge) DP-R/S (differential)	Rosemount model 3051 and 1151 series
Flow	Turbine	TFM	Flow Technology Inc. standard line series
		TFM	FMSI (Flow Measurement Systems Inc.) with frequency to analog converter model PC202
		FDW-F	Liquid mass flow output based on TFM and temperature
	Vortex	VORTX	YEW (Yokogawa Hokushin Electric) model #YF100 flowmeter with model #YFA11 flow converter
	Orifice	STM-F	Steam mass flow output based on orifice ΔP and temperature
		DP-R DP-R/S ORFM	Mass flow can be calculated from orifice ΔP and temperature
Level	Capacitance pressure cell	DP-R	Rosemount model 1151 series
Void	Gamma densitometer	VFM (two-beam) VFM-V (one-beam) VFM-IV (three-beam)	AECL custom design using a Cesium source
	Conductivity probe	COND	AECL custom design
Voltage	Voltmeter	VOLT	Power supply voltage
Current	Ammeter	AMP	Heated section current
Power	Wattmeter	POWER	A "power card" calculates power based on voltage and current from the voltmeter and ammeter
	True RMS meter	n/a	Computer calculates power based on voltage and current supplied by Fluke RMS meters
Current	Ammeter	PM-AMP	Primary pump current
Speed	Tachometer	RPM	Primary pump speed
Torque	Torque meter	TORQUE	Primary pump torque

7. SPECIAL CASE INSTRUMENTATION

7. SPECIAL CASE INSTRUMENTATION

7.100 TS11 OUTLET FEEDER TRACE HEATING INSTRUMENTATION

In 1999 January, the trace heating on TS11 outlet feeder was replaced (see Section 5.500). Instrumentation specific to a series of tests related to the effects of trace heating was installed on the outlet feeder of test section 11. Conductivity probes and feeder surface temperatures at various locations on the outside surface of the feeder were installed. An elevation diagram showing the locations of these instruments is given in Figure 7.1. This figure is similar to Figure 2.4, however it shows only the outlet feeder and the trace-heating specific instrumentation.

Feeder surface temperatures at various locations on the outside surface of the outlet feeder of TS11 were installed. There are two outside pipework surface thermocouples, approximately 180° apart, at each of six horizontal and inclined locations. The device codes are 1TFT/1TFB, 2TFT/2TFB, 3TFT/3TFB, 5TFT/5TFS, 7TFT/7TFB and 8TFT/8TFB, where FT indicates the thermocouple location is on the top of the horizontal or inclined section of the feeder, and FB the bottom. Because of pipework restrictions and space limitations, one outside surface thermocouple was placed on the side of the inclined feeder section, approximately 90° from the top thermocouple location (hence 5TFS).

On the vertical feeder piping there are two outside pipework surface thermocouples, approximately 180° apart, at each of two locations. The device codes are 4TFVL/4TFVR and 6TFVL/6TFVR, where FV indicates that the thermocouple location is on a vertical feeder section, and L/R are for left/right side of the vertical pipe.

Conductivity probe measurements were also added to get a better idea of the void distribution in the outlet feeder of TS11. Three conductivity probes were installed at different locations on the vertical outlet feeder pipework. The device codes COND T, COND M and COND B, where T, M and B refer to the top, middle, and bottom vertical runs of the outlet.

7.200 HS13 SURFACE TEMPERATURE INSTRUMENTS

Section 6.123 describes surface thermocouples. For single-channel, high-temperature blowdown tests, some surface thermocouples were added. The approximate locations of these instruments are shown in Figure 7.2. Station C is approximately 0.55 m from the start of the pressure tube (at the power supply), with Station D approximately 3.43 m, and Station E approximately 5.78 m. Note that the figure is the same as Figure 2.8 (elevation diagram for HS13 feeders), with stations added for this instrumentation.

7. SPECIAL CASE INSTRUMENTATION

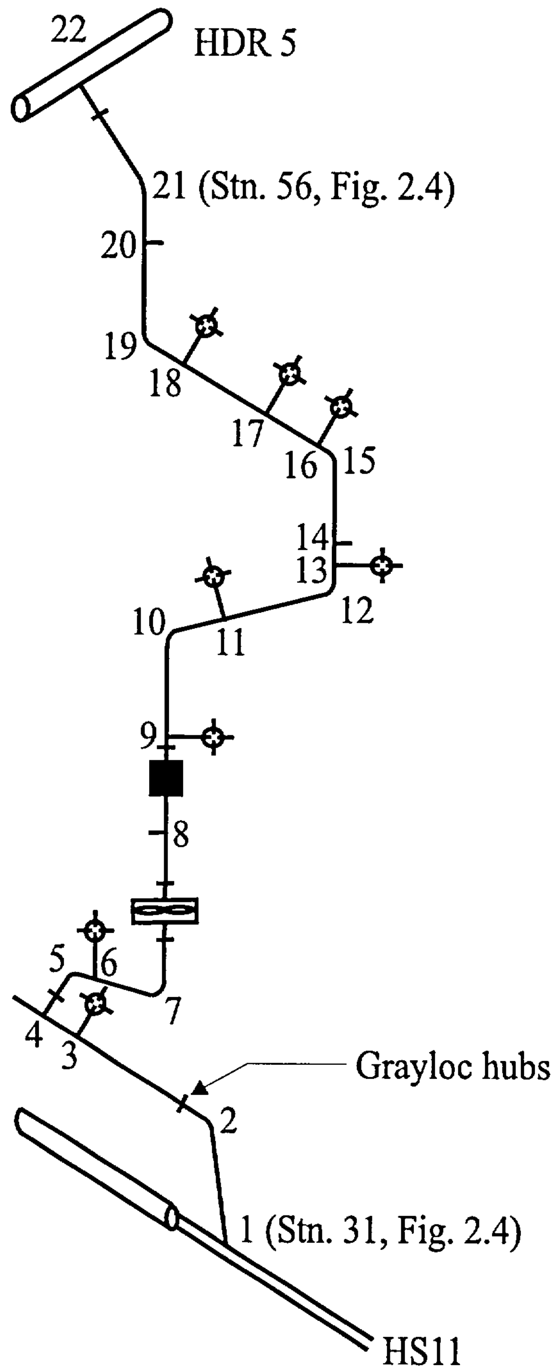

FIGURE 7.1: Elevation Diagram for Heated Section HS11 Outlet Feeder Trace Heating Instrumentation

7. SPECIAL CASE INSTRUMENTATION

FIGURE 7.1 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	ANGLE (°)
1	HS11 Outlet Tee	3.96		
	(same as Stn. 31, Figure 2.4)		0.30	0
2	Elbow (90°)/Reducer	3.96		
			0.72	0
3	Thermocouples (8TFT, 8TFB)	3.96		
			0.39	0
4	End-Fitting Tee	3.96		
			0.27	58
5	Elbow (107°)	4.18		
			0.56	20
6	Thermocouples (7TFT, 7TFB)	4.37		
			0.16	20
7	Elbow (70°)	4.42		
			0.89	90
8	Conductivity Probe (COND B)	5.31		
			0.60	90
9	Thermocouples (6TFVL, 6TFVR)	5.91		
			1.30	90
10	Elbow (60°)	7.21		
			0.49	30
11	Thermocouples (5TFT, 5TFS)	7.45		
			1.38	30
12	Elbow (60°)	8.15		
			0.13	90
13	Thermocouples (4TFVL, 4TFVR)	8.28		
			0.19	90
14	Conductivity Probe (COND M)	8.47		
			1.28	90
15	Elbow (90°)	9.75		
			0.11	0
16	Thermocouples (3TFT, 3TFB)	9.75		
			1.12	0
17	Thermocouples (2TFT, 2TFB)	9.75		
			1.61	0
18	Thermocouples (1TFT, 1TFB)	9.75		
			0.83	0

7. SPECIAL CASE INSTRUMENTATION

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	ANGLE (°)
19	Elbow (90°)	9.75		
			0.34	90
20	Conductivity Probe (COND T)	10.09		
			0.20	90
21	Elbow (54°)	10.29		
			0.26	36
22	Header HDR5 Centreline	10.71		

7. SPECIAL CASE INSTRUMENTATION

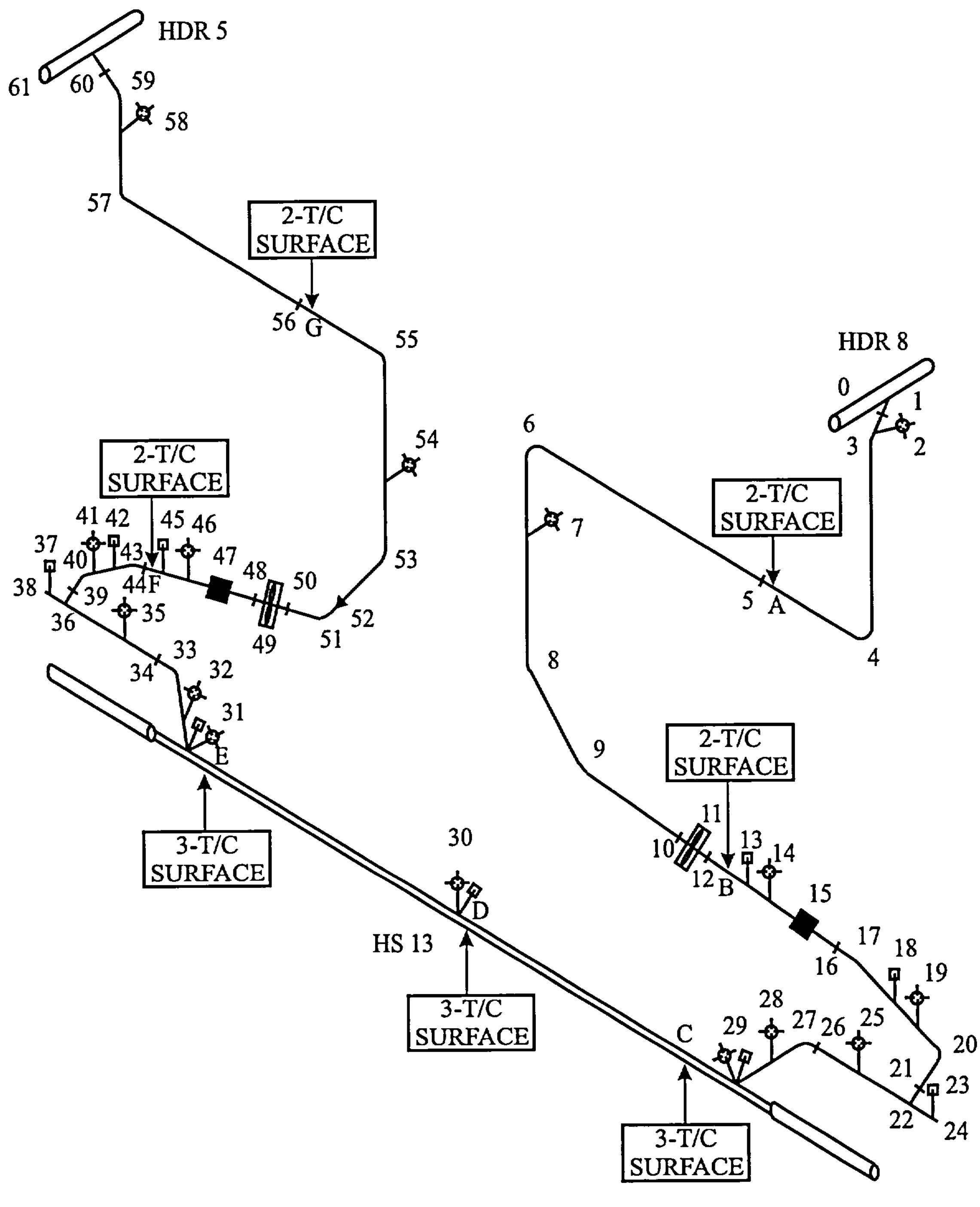

FIGURE 7.2: Surface Thermocouple Locations for Heated Section HS13 and Feeders

7. SPECIAL CASE INSTRUMENTATION

FIGURE 7.2 Legend

STATION NUMBER	DESCRIPTION
A	Feeder surface thermocouples: SURF 16 (bottom) and SURF 17 (top)
B	Feeder surface thermocouples: SURF 12 (bottom) and SURF 13 (top)
C	Pressure tube surface thermocouples: SURF 9 (bottom), SURF 10 (side), and SURF 11 (top), or 206T-D16 (bottom), 206T-D17 (side), and 206T-D18 (top).
D	Pressure tube surface thermocouples: SURF 6 (bottom), SURF 7 (side), and SURF 8 (top), or 206T-D13 (bottom), 206T-D14 (side), and 206T-D15 (top).
E	Pressure tube surface thermocouples: SURF 3 (bottom), SURF 4 (side), and SURF 5 (top), or 206T-D10 (bottom), 206T-D11 (side), and 206T-D12 (top).
F	Feeder surface thermocouples: SURF 1 (bottom) and SURF 2 (top)
G	Feeder surface thermocouples: SURF 14 (bottom) and SURF 15 (top)

All other station numbers are as in Figure 2.8.

8. CHARACTERIZATION OF LOOP COMPONENTS

Many components in RD-14M have been characterized under single-phase water, single-phase steam, and/or two-phase steam-water conditions. This chapter summarizes information available from these characterizations. Also included is additional information on instrumentation and heat losses.

8.100 ORIFICES

The RD-14M test facility uses orifices to balance flows in the feeders and to regulate flow from the RD-14M CANDU-6 ECI system. Due to the figure-of-eight loop geometry each orifice has a dimensionally similar counterpart located on the opposite side of the loop. The orifice tag number and the locations are provided in Table 8.1.

8.110 Orifice Dimensions

All RD-14M orifices were dimensionally inspected. The dimensions of the actual RD-14M orifices were documented [8.1]. The orifice dimensions are provided in Figure 8.1, a reduced engineering drawing (A2-60W15-1, revision 0).

8.120 Orifice Loss Coefficients

Flow resistance tests have been conducted on five RD-14M orifices, one from each dimensionally-similar pair, to determine flow resistance factors under single-phase and two-phase flow conditions [8.2]. The orifices tested were OR15, OR16, OR18, OR23 and OR24. These orifices were subjected to both forward and reverse flows.

8.121 Orifice k-factors

The loss coefficients (k-factors) were expressed as a function of Reynolds number (Re) using the following equation:

$$k = M \,\mathrm{Re}^{n} \tag{8.1}$$

where Re was calculated using the orifice throat diameter. The k-factor (dimensionless) was fitted to the data using the following equation:

$$\Delta P = k \rho \frac{V^2}{2} \tag{8.2}$$

where ΔP = average differential pressure measured across the orifice, Pa
ρ = average density of liquid, kg/m^3
V = average velocity of liquid through orifice throat, m/s

The values of the regression constants, M and n, are provided in Table 8.2 for orifices OR15, OR16, OR18, OR23 and OR24, for both forward and reverse flow.

Work was also carried out on characterizing the single-phase flow resistance for orifice OR25 (diameter of 35.5 mm), the main ECI line flow-limiting orifice [8.3]. Frictional resistance coefficient, k, was determined by applying the methodology used to determine hydraulic resistances of RD-14M loop components [8.4]. This methodology defines k by the equation:

$$\Delta P = k \cdot \rho \cdot g \cdot Q^2 \tag{8.3}$$

where ΔP = pressure drop, Pa
k = frictional resistance coefficient, m·s²/L²
ρ = fluid density, kg/m³
g = acceleration due to gravity = 9.81 m/s²
Q = volumetric flow rate, L/s

The estimated value of k for OR25 (diameter of 35.5 mm) is 0.048 $m \cdot s^2/L^2$. Note that using Equation (8.3), the flow resistance is derived as a dimensional number (units of $m \cdot s^2/L^2$). The flow resistance coefficient is often reported as a non-dimensional number based on Equation (8.2). The relationship between these two forms of k is given by:

$$k_{Eq\,8\,2} = k_{Eq\,8\,3} \cdot 2 \cdot 10^6 \;\; g \cdot A^2 \tag{8.4}$$

where g = acceleration due to gravity = 9.81 m/s^2, and
A = area of orifice throat (m^2).

The area term comes from the conversion between velocity, V, and flow rate, Q, in Equations (8.2) and (8.3).

Applying this to OR25 (diameter of 35.5 mm), the equivalent non-dimensional k is 0.923.

8.122 Orifice Two-Phase Multipliers

The two-phase multiplier is used for correlating the two-phase pressure loss through orifices. The two-phase multiplier, Φ^2_{fo}, is defined as follows:

$$\Phi^2_{fo} = \frac{DP_{2\phi}}{DP_{1\phi}} \tag{8.5}$$

where $DP_{2\phi}$ is the two-phase pressure loss across the orifice and $DP_{1\phi}$ is the pressure loss if the total mass flowed as single-phase liquid through the orifice.

The data was fitted to a modified version of the Chisholm and Rooney correlation [8.5]:

$$\Phi_{fo}^2 = 1 + \left(\frac{\rho_f}{\rho_g} - 1\right)\left(Bx(1-x)\left(1 - \frac{P}{P_c}\right)^a b(\alpha)^c + x^2\right) \tag{8.6}$$

where P = system pressure, MPa (a)
P_c = critical pressure, 22.12 MPa (a)
B = value from Equation (8.7) below
x = quality
α = void fraction
a = correlation coefficient
b = correlation coefficient
c = correlation coefficient

The value of B is given by:

$$B = \frac{\dfrac{\rho_f}{J\rho_g} + J - 2}{\dfrac{\rho_f}{\rho_g} - 1} \tag{8.7}$$

where for the range of data:

$$J = \sqrt{\frac{\rho_f}{\rho_m}} \tag{8.8}$$

and ρ_m, the homogeneous density, is given by:

$$\rho_m = \left(\frac{x}{\rho_g} + \frac{1-x}{\rho_f}\right)^{-1} \tag{8.9}$$

The values of the correlation coefficients are given in Table 8.3. These values are valid for all RD-14M orifices in predicting pressure loss under two-phase flow conditions.

8.200 TURBINE FLOWMETERS

Turbine flowmeters (TFMs) are used in the RD-14M facility to measure flow in the inlet and outlet feeders, the primary pump outlet flows, the ECI flow into the primary heat transport system, and the boiler feedwater flow. A list of the location, size, orientation, and device code of the primary-side TFMs is given in Table 8.4. A list of the location, size, and device code of the secondary-side TFMs is given in Table 8.5.

8.210 TFM Low Flow Characterization

The largest potential source of error for turbine flowmeters is due to non-linear behaviour at low flow rates. Generally, there is a linear relationship between actual flow and flow measured by TFMs. However, below a certain flow rate, the measured flow tends to underestimate the actual flow rate. The estimated minimum linear flow rate for 1-, 1.25-, and 3-inch TFMs is given in Table 8.6. For flows below the minimum linear flow rate, the flow rate is non-linear down to the minimum operating flow rate. The minimum operating flow rate is also provided in Table 8.6.

8.220 TFM Flow Resistance

Frictional resistance coefficients were presented in [8.6] and [8.7] for 1-, 1.25-, 1.5-, 2-, and 3-inch turbine flowmeters under single-phase liquid conditions. However the results in [8.7] were presented in error and therefore should not be used. The values of the frictional resistance coefficients are correctly presented in Table 8.7. The frictional resistance coefficients, k, were determined by applying the methodology used in Equation (8.3).

A study by Parrott [8.8] was conducted that subjected a 1.25-inch TFM to two-phase steam-water flow conditions. The 1.25-inch TFM was installed in five different orientations: horizontal, inclined 30°, declined 30°, vertical-up, and vertical-down. Pressure losses were measured across the operating TFM for a range of flows, void fractions, and system pressures.

Two-phase multipliers were determined for the 1.25-inch TFM under two-phase flow conditions using Equation (8.5). As well, the homogeneous equilibrium model (HEM) was used to calculate the two-phase multipliers using:

$$\Phi_{fo}^2 = \frac{\rho_f}{\rho_g \alpha + \rho_f (1-\alpha)} \qquad (8.10)$$

where ρ_f = average density of saturated liquid, kg/m^3
ρ_g = average density of saturated steam, kg/m^3
α = void fraction

Figure 8.2 compares the experimentally determined (observed) two-phase multipliers (Equation (8.5)), to those predicted using the HEM. The data in Figure 8.2 includes mass flow rates between 0.6 and 1.2 kg/s, void fractions between 0.1 and 0.8, and nominal pressures of 1 and 4.5 MPa (g). The figure shows that the HEM reasonably predicts (typically within 30%)

the two-phase multiplier for the horizontal, inclined 30°, and vertical-up orientations for values less than 5, but underpredicts the two-phase multiplier for values greater than 5.

For the declined 30° and vertical-downward orientations, the HEM typically overpredicted the two-phase multiplier. The void at the TFM was suspected to be closer to zero than what was actually measured. This was suspected because the TFM was located at a lower elevation in the test section than where void was measured, which was acting like a water trap [8.8]. Therefore the data for the declined 30° and vertical-downward orientations for void fractions less than 0.7 will not be used for model validation. For void fractions greater than 0.7, the water-trap effect appeared not to occur so data for the declined 30° and vertical-downward orientations may be used for code validation.

8.230 Volumetric Measurement of Two-Phase Flow Using a 1.25-inch TFM

The ability of the 1.25-inch TFM to measure the volumetric flow rate of a two-phase mixture was determined in [8.8]. The output signal from the TFM was compared to the calculated volumetric flow rate. The calculated volumetric flow rate was computed assuming homogeneous flow through the TFM using:

$$Q = \frac{\dot{m}_{total}}{\rho_m} \tag{8.11}$$

where $\rho_m = \alpha\rho_g + (1 - \alpha)\rho_f$. The TFM measured the volumetric flow of a homogeneous two-phase mixture reasonably well for total flow rates greater than 0.6 kg/s. For lower flows ($\dot{m} \approx 0.2$ kg/s), the two-phase mixture was suspected not to be homogeneous, therefore the calculated volumetric flow was not expected to agree with the TFM measured flow. Instead, the low-flow data were correlated using the following equation, which uses a modified density term:

$$Q = \frac{\dot{m}_{total}}{a\rho_m^b} \tag{8.12}$$

The values and standard errors for the constants are provided in Table 8.8 for the horizontal, inclined 30°, and vertical-up orientations.

Figure 8.3 shows the volumetric flow rate calculated using Equation (8.12) plotted against the measured volumetric flow rate.

The data for the declined 30° and vertical-downward orientations were omitted from the correlation because it was suspected that the void fraction in the TFM was different than what was measured at the void fraction meter. This was caused by the test section acting like a water trap. That is, it was suspected that the TFM was flooded even though the void fraction meter indicated void at a higher elevation. See Reference [8.8] for details.

8.300 END-FITTINGS

In RD-14M, an end-fitting simulator is connected to each end of the ten horizontal heated sections. The end-fittings located upstream of the heated sections are referred to as the inlet end-fittings, and the end-fittings downstream of the heated sections are referred to as the outlet end-fittings.

In RD-14M, the end-fitting simulators are offset from the heated sections to accommodate in-line electrical connections to the fuel element simulators. In the following sections, the end-fitting used in the experiments does not include the lateral pipe used to offset the end-fitting. The end-fitting is described as the section between the nominal 1.5-inch, schedule 40 Grayloc feeder nozzle (e.g., Station 22, Figure 2.1), and the nominal 3-inch Grayloc fitting near the shield plug (e.g., Station 27, Figure 2.1) (see Section 2.220).

8.310 Flow Resistance

Single-phase and two-phase flow resistance tests were conducted with an RD-14M end-fitting installed in the RD-14M Component Characterization Facility. Correlations for the single-phase liquid loss coefficients, the single-phase steam expansion, and the two-phase multipliers were presented in Reference [8.9]. The correlations are also presented here for completeness.

8.311 Single-Phase Liquid Water

Single-phase liquid water data was correlated using the following expression (which accounts for the loss coefficient's dependency on Reynolds number):

$$h_L = \frac{(a\,\mathrm{Re})^{-1} + b}{2}\rho V^2 \qquad (8.13)$$

where h_L = frictional pressure loss, Pa
Re = feeder Reynolds number at 1.5-inch schedule-40 pipe
ρ = fluid density, kg/m^3
V = average velocity at feeder, m/s
a = correlation coefficient (see Table 8.9)
b = correlation coefficient (see Table 8.9)

The values of the correlation coefficients for single-phase liquid water flow through both inlet and outlet RD-14M end-fittings are provided in Table 8.9. Reference [8.9] also provides values of the correlation coefficients for partial flow paths through the end-fitting. These include the flow paths between the feeder and the liner tube near the shield plug, and between the liner tube and the channel near the shield plug.

Two values of the correlation coefficients are given in Table 8.9 for the inlet end-fitting. For single-phase liquid flow, the values of *a* and *b* for Re>86000 should be used. The values of *a* and *b* for Re>300000 should be used for single-phase steam flow as discussed below.

8.312 Single-Phase Steam

The frictional head loss for single-phase steam flow through the end-fitting can be calculated using Equation (8.14). Equation (8.14) includes the expansion factor, *Y*, to accommodate for the steam behaving as a compressible fluid, as follows:

$$h_L = \frac{1}{Y^2}\frac{b}{2}\rho V^2 \tag{8.14}$$

where h_L = frictional pressure loss, Pa
ρ = fluid density, kg/m^3
V = average velocity at feeder, m/s
b = correlation coefficient from Table 8.9
Y = expansion factor

The expansion factor was fitted to a linear function of the normalized head loss:

$$Y = mh_L^{'} + 1 \tag{8.15}$$

where $h_L^{'}$ = normalized head loss
= h_L/P
m = -0.693 for an inlet end-fitting
= 0 for an outlet end-fitting
P = absolute pressure 1.5-inch feeder, Pa (a)

8.313 Two-Phase Steam-Liquid

The two-phase frictional head loss through the end-fitting can be calculated using:

$$h_L = \phi_{fo}^2 \frac{b}{2}\rho_F V_F^2 \tag{8.16}$$

where ϕ_{fo}^2 = two-phase multiplier

b = loss coefficient for single-phase water flow (see Table 8.9)

ρ_F = fluid density of saturated liquid, kg/m^3

V_F = fluid velocity assuming all mass flows as saturated liquid through the feeder, m/s

Before calculating the head loss, the two-phase multiplier can be calculated using the following empirical formula:

$$\phi_{fo}^2 = 1 + \left(\frac{\rho_F}{\rho_G} - 1\right)\alpha^{\left(P\rho A^2/m^2\right)^a m^b P^c} \tag{8.17}$$

where ρ_F = density of saturated liquid at pressure P, kg/m^3

ρ_G = density of saturated steam at pressure P, kg/m^3

α = void fraction at 1.5-inch feeder

P = absolute pressure at 1.5-inch feeder, Pa (a)

ρ = average density of two-phase mixture at 1.5-inch feeder, kg/m^3
= $\alpha\,\rho_{G,SAT} + (1-\alpha)\rho_{F,SAT}$

A = cross-sectional area at 1.5-inch feeder, m^2

$\dot{m}$ = total mass flow rate of two-phase mixture, kg/s

a = -0.71 for an inlet end-fitting
= -0.84 for an outlet end-fitting

b = -1.5 for an inlet end-fitting
= -1.2 for an outlet end-fitting

c = 0.47 for an inlet end-fitting
= 0.54 for an outlet end-fitting

Equation (8.17) should be used for homogeneous flows at pressures above 2 MPa. For pressures below 2 MPa the use of Equation (8.17) should be limited to total mass flows below 3 kg/s.

8.320 Flow Resistance Across End-Fitting Shield Plug

Flow resistance tests were performed using an RD-14M end-fitting to determine the hydraulic resistance from the dead-end space to the channel. Flow will occur along this flow path during blowdown. Details of the test conditions, test procedures, and uncertainty analysis, may be found in Reference [8.10]. Results of single-phase liquid, single-phase steam, and two-phase steam-water tests are presented below.

8.321 Single-Phase Liquid and Single-Phase Steam Flow

Loss coefficients, k, for both single-phase liquid and single-phase steam were calculated using Equation (8.2), where V was the average velocity of fluid through the gap between the shield plug and the liner tube. The fluid velocity through the gap was calculated using:

$$V = \frac{\dot{m}}{\rho A} \tag{8.18}$$

where $\dot{m}$ = average fluid mass flow rate, kg/s
ρ = average upstream density, kg/m^3
A = area of gap, m^2
= $\pi\left(d_o^2 - d_t^2\right)/4$
d_o = inner diameter of liner tube
= 0.0548 m
d_t = outer diameter of shield plug
= 0.0540 m

A best-fit curve was fitted to the single-phase data using the following equation:

$$k = a + \frac{b}{\mathrm{Re}} \tag{8.19}$$

Reynolds number, *Re*, was defined by:

$$\mathrm{Re} = \frac{4\dot{m}}{\pi d \mu} \tag{8.20}$$

where d = hydraulic diameter
= 0.0008 m
μ = dynamic viscosity, kg/m·s

The values for a and b in Equation (8.19) were determined using a non-linear regression technique. The correlation coefficients were determined to be:

a = 22.1 ± 0.4
b = $3.91 \times 10^6 \pm 0.43 \times 10^6$

The ±-values given for the correlation coefficients are the standard errors of estimate.

8.322 Two-Phase Steam-Water Flow

Two-phase multipliers were calculated using Equation (8.5). The two-phase multipliers were reasonably well represented by the homogeneous equilibrium model (HEM) given in Equation (8.10). Figure 8.4 shows the two-phase multipliers plotted as a function of void fraction. Figure 8.4 also shows the (HEM) for comparison to the data.

8.330 Heat Transfer

A series of transient tests was conducted in the RD-14M Component Characterization Facility to determine the heat transfer characteristics of an RD-14M end-fitting. The test series included heat-up tests in which steam or water was injected into a cool water-filled end-fitting and cool-down tests in which sub-cooled water was injected into a steam-filled end-fitting.

Values of the thermal time constants and overall heat transfer coefficients for single-phase liquid heat-up transients, and values of the thermal time constants for two-phase steam-water heat-up and cool-down transients were presented in detail in Reference [8.11]. These values are also presented here for completeness.

8.331 Heat-Up Transient: Hot Water Injected into a Cool Water-Filled End-Fitting

The values of the thermal time constant, τ, for both the end-fitting metal mass and the liquid in the dead-end space, were found to be a function of the injected energy rate, $E_{in} = m_{in}h_{in}$ (kW). Data was correlated using the linear regression technique with the following equations:

$$\tau_{metal} = \frac{a_{metal}}{E_{in}} + b_{metal} \tag{8.21}$$

$$\tau_{dead-end} = \frac{a_{dead-end}}{E_{in}} + b_{dead-end} \tag{8.22}$$

The results of the regression are presented in Table 8.10.

Values of UA, the product of the overall heat transfer coefficient and the heat transfer surface area, were also found to be dependent on the rate of injected energy, $E_{in} = m_{in}h_{in}$. Values of UA were separately calculated for heat transferred to the end-fitting metal mass and the liquid in the dead-end space using the following equations:

$$UA_{metal} = \left(\frac{\rho VC}{\tau}\right)_{metal} \tag{8.23}$$

$$UA_{dead-end} = \left(\frac{\rho VC}{\tau}\right)_{dead-end} \tag{8.24}$$

where ρ = spatially and time averaged density, kg/m^3
V = volume, m^3
C = spatially and time averaged specific heat, kJ/kg·K
τ = thermal time constant, s.

The values of UA, E_{in}, and τ are provided in Table 8.11.

8.332 Heat-Up Transient: Steam Injected into the Channel End of a Cool Water-Filled End-Fitting

For steam injected into the channel end of a cool water-filled end-fitting, the thermal time constants were calculated for the heat-up period of time from initial steam injection to the state of saturation. Linear regression was used to correlate the data using the following equations:

$$\tau_{metal} = \frac{a_{metal} P^{0.5}}{E_{in}} + b_{metal} \tag{8.25}$$

$$\tau_{dead-end} = \frac{a_{dead-end} P^{0.5}}{E_{in}} + b_{dead-end} \tag{8.26}$$

where P was the pressure at the end-fitting (in kPa (a)). Correlation coefficients are provided in Table 8.10.

8.333 Cool-Down Transient: Water Injected into a Steam-Filled End-Fitting

Sub-cooled water was injected to either the channel end or the feeder end of a steam filled end-fitting. Equations (8.25) and (8.26) were used to correlate the data. The results of the regression are provided in Table 8.10 for the cases of water injected to either the channel end or the feeder end of the end-fitting.

8.400 <u>INLET HEADER</u>

An instrumented RD-14M inlet header was installed in the RD-14M Component Characterization Facility. A series of tests was conducted to investigate flow and phase distribution in the feeders and phase distribution in the header [8.12]. The effect of mass flow rate, pressure and void fraction was examined.

8.410 Flow and Phase Distribution to the Feeders

For two-phase flow injection to the RD-14M inlet header through the inlet turret, the following observations were made. For two-phase inlet mass flows greater than 3.75 kg/s, void was distributed to all five feeders. For two-phase inlet mass flows less than 3.75 kg/s, void was distributed to only some of the feeders. System pressure had no effect on the void distribution in the feeders. As the header inlet void fraction increased, the feeder void fractions also increased in all feeders containing void. For details see Reference [8.12].

8.420 Phase Distribution in the Inlet Header

Hydraulic jumps occurred in the inlet header under some two-phase test conditions [8.12]. Also, flow and void through feeders at the same cross-section and elevation significantly differed under certain conditions. This suggested asymmetric phase distribution in the header in both the axial and the latitudinal directions. Both these phenomena will uncover feeder nozzles, void the feeders, and cause undesirable thermalhydraulic conditions in the primary heat transport system. Under other boundary conditions, void symmetry in the inlet header was well established.

8.500 PUMPS

8.510 Primary Pumps

8.511 Pump Characteristics

The single- and two-phase performance characteristics of the RD-14M pumps in forward rotation were determined in a extensive series of tests [8.13]. The single-phase head, torque, and efficiency characteristics for forward flow are given in Figure 8.5. The two-phase performance of the RD-14M pumps has been extensively studied and is reported elsewhere [8.14-8.19].

8.512 Pump Rundowns

Using a ramp generator, a rundown profile similar to that of a reactor pump, as shown in Figure 8.6, is used in experiments in which a pump trip is simulated. The free rundown characteristics of the two primary pumps, P1 and P2, were also determined [8.20]. Plots of representative free rundowns for each pump are shown in Figure 8.7. A linear regression analysis of pump rundown data yielded a rundown rate of 188.1 rpm/s for pump P1 ($R^2 = 99.95$), and a rate of 213.6 rpm/s for pump P2 ($R^2 = 99.94$) [8.20]. It takes approximately 18 s for P1 to rundown from full speed, and approximately 16 s for P2 to fully rundown.

8.513 Stalled Pump Flow Resistance

The flow resistance across the pumps when stalled was also determined [8.20]. A linear regression was done using the following equation:

$$\Delta P = k \cdot Q^2 \qquad (8.27)$$

where ΔP = pressure drop (across stalled pump), kPa
k = frictional resistance coefficient, $kPa \cdot s^2/L^2$
Q = loop volumetric flow rate, L/s

The results gave k = -0.4038 (standard error = 5.22×10^{-4}) for pump P1, and k = -0.7249 (standard error = 1.88×10^{-4}) for pump P2.

8.520 Secondary-Side Pumps

The two secondary-side circulating pumps, P6 and P7 (see Figure 3.12 are horizontal, single-stage Bingham centrifugal pumps with high-head/low-flow characteristics as shown in Figure 8.8.

8.530 ECI Pumps

8.531 Pump P14

The high-pressure ECI pump, P14, is an eleven-stage, constant-speed, 250 hp submersible pump manufactured by Pleuger. Performance characteristics are detailed in References [8.21], [8.22], and [8.23].

Three sets of characterizations are presented. The first is for the pump prior to the installation of the 146-mm pump inlet line (see Section 4.310) [8.21]. Previously, the pump used an inlet line of 74 mm. The second is for the pump after the installation of the 146-mm pump inlet line [8.22]. The third is for the large pump inlet line, but with a 15-mm orifice installed in place of the 35-mm orifice (OR25) [8.23].

Figure 8.9 shows the pump performance for all three characterizations, and Figure 8.10 shows the ECI flow versus the pump pressure (some of the pump flow is diverted into the by-pass through the control valve - see Section 4.220).

The frictional loss in the discharge line of P14 was also determined [8.22], using the following equation:

$$\Delta P = k\rho\frac{V^2}{2} - \rho g \Delta H \qquad (8.28)$$

where ΔP = pressure drop from pump P14 discharge to just upstream of OR25, kPa
k = frictional loss coefficient in pump P14 discharge line
ρ = liquid density, kg/m^3
V = liquid velocity based on a 49.3-mm (ID) pipe, m/s
g = gravitational acceleration (9.81 m/s^2)
ΔH = correction elevation for static heads (7.87 m)

The right-most term in the above equation corrects for the elevation difference between the pump discharge and orifice OR25, and for the elevations of the sense lines for 77P and 114P-D1. The loss coefficient was found to be 20.4 ± 0.3. The discharge line is from the outlet of P14 to orifice OR25 (this includes check valve NV9, but not the orifice).

8.532 Pump P8

The low-pressure ECI pump, P8, is a Hayward-Gordon horizontal, single-stage, constant-speed, centrifugal pump. Performance characteristics are detailed in Reference [8.21]. Figure 8.11 shows the measured and manufacturer's performance curves. The measured discharge pressure from P8 can be adequately described by:

$$P_{P8} = a_0 + a_1 \cdot Q + a_2 \cdot Q^2 \tag{8.29}$$

where P_{P8} = Pump P8 discharge pressure, kPa (g)
Q = Flow rate, L/s
a_0 = 1490.7 ± 4.38, kPa (g)
a_1 = -9.4773 ± 1.8613, kPa·s/L
a_2 = -0.49915 ± 0.14142, kPa·s^2/L^2

The frictional loss in the discharge line of P8 was also determined [8.21], using Equation (8.2). The loss coefficient was found to be 34.91 ± 0.46. The discharge line is from the outlet of P8 to orifice OR25 (this includes check valve NV14, but not the orifice).

8.600 OVERALL FLOW RESISTANCES

Two sets of data have been used to calculate overall flow resistances in the primary heat transport system (see References [8.4] and [8.24]). Previous sections in this chapter presented detailed flow resistance data for specific loop components (e.g., orifices, TFMs, end-fittings) under single- and/or two-phase conditions. This section presents overall flow resistances of groups of components (e.g., inlet feeders which include orifices and TFMs), under single-phase liquid conditions.

M^{c}Gee's work [8.4] calculated constant values for the flow resistances of RD-14M components, whereas Parrott's work [8.24] calculated the flow resistances by taking into account a Reynolds number effect (predominant at low flows). Both sets of results are presented below.

M^{c}Gee's flow resistances were based on tests conducted at low temperature (~70°C), a primary pressure of 3 MPa (g), and total volumetric flows of 1.4 to 25.3 L/s. Equation (8.3) was used to relate the flow resistance to measured differential pressure and volumetric flow. A linear least-squares regression technique was used to determine the best fit to the data. Note that using Equation (8.3), the flow resistance is derived as a dimensional number (units of $m \cdot s^2/L^2$).

The flow resistances obtained are summarized in Table 8.12.

The flow resistance coefficient, k, is often reported as a non-dimensional number based on Equation (8.2). The relationship between these two forms of k is given in Equation (8.4).

Parrott's flow resistances were based on tests covering the following range of conditions:

Total volumetric flow:	0.6 L/s to 23.4 L/s
Liquid temperature:	21°C to 252°C
System pressure:	2 MPa (g) to 9 MPa (g)

The flow resistance coefficients were expressed as a function of Reynolds number using Equation (8.1), and fitted to the data using Equation (8.2), where the differential pressure, ΔP, is measured across each of the components, and the velocity, V, is based on the volumetric flow through an area of each component.

The flow resistance coefficients obtained are summarized in Tables 8.13 and 8.14.

Care should be taken in using the information in [8.24] with regards to the quoted R^2 statistic. Upon perusal of some data, it is suspected that the R^2 statistic is in error.

8.700 OVERALL HEAT LOSSES

Heat loss experiments were performed in RD-14M to determine the magnitude and distribution of heat losses in individual sections of the RD-14M loop [8.25]. These experiments verified that heat losses are significant during low power, natural circulation-type tests. The heat losses were found to be evenly distributed throughout the loop.

Heat losses through each loop component were calculated from experimentally measured temperatures, flow rates, input power, and pressures, using:

$$Q = Q_{in} - \rho \cdot v \ (H_{out} - H_{in}) \tag{8.30}$$

where Q = heat lost through loop component, W,
Q_{in} = measured thermal energy added, W,
ρ = estimated fluid density, kg/m^3,
v = measured fluid flow rate through loop component, m^3/s,
H_{out} = fluid enthalpy leaving loop component, J/kg, and
H_{in} = fluid enthalpy entering loop component, J/kg.

Heat losses were found to be evenly distributed around the loop, as follows:

- 37.6 ± 0.8 % to the cold leg (from boiler outlet to the end-fittings including the pumps, inlet headers, and inlet feeders),
- 33.0 ± 1.7 % to the test sections (including the inlet and outlet end-fittings), and
- 29.4 ± 2.2 % to the hot leg (from the outlet end-fittings to the boiler inlets including outlet feeders and outlet headers).

The uncertainties presented above and elsewhere in this section are the 95% confidence intervals.

Heat loss results were best represented as a function of temperature by the following equation:

$$Q = UA \cdot (T - 23)^{5/4} \tag{8.31}$$

where Q = heat loss, W,
UA = estimated heat transfer-area coefficient, W°C$^{-5/4}$, and
T = average temperature, °C.

The above equation indicates that the predominant factor in RD-14M heat losses is due to the heat transfer by natural convection in the air boundary layer surrounding loop components.

The estimated value of UA for the entire RD-14M loop is 226.5 W°C$^{-5/4}$. Estimates for heat transfer coefficients for various loop components are listed in Table 8.15.

8.800 ROSEMOUNT DIFFERENTIAL PRESSURE CELLS

Rosemount differential pressure (DP) cells are used to measure differential pressures throughout the RD-14M primary side.

8.810 Zero and Span Shift

Typically the Rosemount DP cells are zero-trimmed at a static pressure of 2 MPa (g). That is, the DP cells' output is adjusted to 0 kPa, with no flow in the loop, at a system pressure of 2 MPa (g).

For certain DP cells, the zero point will shift as the system pressure deviates from 2 MPa (g). The magnitudes of the zero shift for each DP cell have been documented in [8.26].

Linear regression was used to correlate the zero shift to the deviation in static pressure for each DP cell. The DP cell output should be corrected for zero shift using:

$$DP_{cor,zero} = DP_{measured} - zero\ shift \tag{8.32}$$

where
- $zero\ shift$ = $m(P - P_{cal})$
- P = static pressure, kPa (g)
- m = slope of fitted curve (see Table 8.16)
- P_{cal} = 2000 kPa (g) as per standard practice.

The value of the slope, *m*, was dependent on the DP cell calibrated range so the zero shift correction should only be applied if the DP cell range matches the range given in Table 8.16. If the range does not match, no correction should be applied. In this case, the analyst should compensate for the larger uncertainty in the measured differential pressure during the uncertainty analysis.

The DP cell span will also shift with static pressure. Table 8.16 lists a correction factor for span shift, *S*. This systematic error is correctable to ±0.25% of reading per 6.9 MPa static pressure shift. The DP cell output may be corrected for span shift using:

$$DP_{cor,span} = DP_{cor,zero} + span\ shift \tag{8.33}$$

where
- $DP_{cor,zero}$ = value from Equation (8.32), kPa
- $span\ shift$ = $S(DP_{cor,zero})(P-P_{cal})10^{-3}$
- S = see Table 8.16, MPa^{-1}
- P = static pressure, kPa (g)
- P_{cal} = pressure that cells were zero trimmed, kPa (g) = 2000 kPa (g) as per standard practice

Unlike the zero shift correction, the span shift correction was not dependent on the DP cell range. Therefore the span shift correction may be applied to the DP cell output no matter the range.

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8. CHARACTERIZATION OF LOOP COMPONENTS

TABLE 8.1

ORIFICE TAGS AND LOCATIONS

Orifice Tag No.	Location
OR9	Heated Section 5 Inlet Feeder
OR10	Heated Section 6 Inlet Feeder
OR12	Heated Section 8 Inlet Feeder
OR15	Heated Section 10 Inlet Feeder
OR16	Heated Section 11 Inlet Feeder
OR18	Heated Section 13 Inlet Feeder
OR21	ECI-line to Header 5
OR22	ECI-line to Header 6
OR23	ECI-line to Header 7
OR24	ECI-line to Header 8

TABLE 8.2

VALUES OF CONSTANTS FOR SINGLE-PHASE FLOW LOSS COEFFICIENTS

Orifice Tag No.	Flow Direction	M	n
OR15	forward	1.39	0
OR15	reverse	2.69	-0.105
OR16	forward	1.28	0
OR16	reverse	1.88	-0.0870
OR18	forward	0.858	0
OR18	reverse	0.781	-0.0409
OR23	forward	3.55	-0.0349
OR23	reverse	2.16	-0.0308
OR24	forward	2.46	-0.0338
OR24	reverse	1.98	-0.0453

TABLE 8.3

TWO-PHASE MULTIPLIER CORRELATION COEFFICIENTS FOR ORIFICES UNDER FORWARD AND REVERSE TWO-PHASE FLOW

Flow Direction	a	b	c
Forward	3.84	9.09	2.80
Reverse	2.73	10.4	2.00

TABLE 8.4

LIST OF PRIMARY-SIDE TURBINE FLOWMETERS

Device Code	Location	Nominal Size (inches)	Orientation[1]
177F-D1	HS5 Inlet	1	30°
179F-D1	HS6 Inlet	1	90°
185F-D1	HS9 Inlet	1	0°
187F-D1	HS10 Inlet	1	30°
189F-D1	HS11 Inlet	1	90°
195F-D1	HS14 Inlet	1	0°
178F-D1	HS5 Outlet	1.25	30°
180F-D1	HS6 Outlet	1.25	90°
181F-D1	HS7 Inlet	1.25	0°
182F-D1	HS7 Outlet	1.25	0°
183F-D1	HS8 Inlet	1.25	0°
184F-D1	HS8 Outlet	1.25	0°
186F-D1	HS9 Outlet	1.25	0°
188F-D1	HS10 Outlet	1.25	30°
190F-D1	HS11 Outlet	1.25	90°
191F-D1	HS12 Inlet	1.25	0°
192F-D1	HS12 Outlet	1.25	0°
193F-D1	HS13 Inlet	1.25	0°
194F-D1	HS13 Outlet	1.25	0°
196F-D1	HS14 Outlet	1.25	0°
1F	Pump1 Outlet	3	0°
2F	Pump2 Outlet	3	0°

[1]Orientation angle was measured from horizontal.

TABLE 8.5

LIST OF SECONDARY-SIDE TURBINE FLOWMETERS

Device Code	Location	Nominal Size (inches)
5F-D1/D2	Boiler 1 Feedwater[1]	1
6F-D1/D2	Boiler 2 Feedwater[1]	1
235F-D2	Boiler 1 Feedwater[2]	0.5
236F-D2	Boiler 2 Feedwater[2]	0.5
19F	Jet Condenser CD1 Spray Flow	2

[1] Used only during high-power operation.
[2] Used only during low-power operation.

TABLE 8.6

TFM PERFORMANCE CHARACTERISTICS[1]

TFM Size (inches)	Minimum Linear Flow Rate (L/s)	Minimum Operating Flow Rate (L/s)
1	0.075	0.025
1.25	0.100	0.030
3	0.750	0.400

[1] Values are for reconditioned turbine flowmeters only. Any bearing or rotor wear will significantly alter these values [8.6].

TABLE 8.7

FRICTIONAL RESISTANCE COEFFICIENTS OF TURBINE FLOWMETERS

	k ($m \cdot s^2/L^2$)	
TFM Size (inches)	Working TFM	Stalled TFM
1	1.0	1.6
1.25	0.19	0.33
1.5	0.167	n/a
2	0.035	n/a
3	0.0047	0.012

TABLE 8.8

VALUES OF CONSTANTS FOR 1.25" TFM TWO-PHASE LOW FLOW CORRELATION

Orientation	a	b
Horizontal	$9.95 \times 10^{-3} \pm 3.29 \times 10^{-3}$	1.78 ± 0.06
Inclined 30°	$4.51 \times 10^{-2} \pm 1.25 \times 10^{-2}$	1.48 ± 0.05
Vertical-Up	0.168 ± 0.064	1.25 ± 0.07

TABLE 8.9

END-FITTING SINGLE-PHASE WATER FLOW RESISTANCE CORRELATION COEFFICIENTS: FEEDER END TO CHANNEL END FLOW PATH

Orientation	a	b	Condition	Equation
Inlet End-Fitting	1.14×10^{-5}	3.54	Re > 86000	(8.13)
Inlet End-Fitting	0	3.66	Re > 300000	(8.14)
Outlet End-Fitting	0	5.18	Re > 86000	(8.13) & (8.14)

TABLE 8.10

END-FITTING THERMAL TIME CONSTANTS CORRELATION COEFFICIENTS

Condition	Injection Location	Heat Transfer to/from	Equation No.	a	b	R^2 Statistic
Hot Water Injected to Cool Water-Filled End-Fitting	Channel or Feeder	Metal Mass	(8.21)	11741 ± 250	7.3 ± 1.9	0.999
		Dead-End Liquid	(8.22)	11622 ± 605	59.4 ± 4.6	0.992
Steam Injected to Water-Filled End-Fitting	Channel	Metal Mass	(8.25)	81.5 ± 7.9	13.1 ± 3.8	0.891
		Dead-End Liquid	(8.26)	90.9 ± 12.1	6.9 ± 6.2	0.836
Water Injected to Steam-Filled End-Fitting	Channel	Metal Mass	(8.25)	116.6 ± 6.9	9.5 ± 3.4	0.963
		Dead-End Liquid	(8.26)	94.1 ± 19.1	98.9 ± 11.3	0.829
	Feeder	Metal Mass	(8.25)	98.1 ± 2.9	9.4 ± 1.3	0.991
		Dead-End Liquid	(8.26)	77.5 ± 20.1	90.5 ± 11.2	0.748

TABLE 8.11

VALUES OF τ AND UA FOR AN END-FITTING UNDER SINGLE-PHASE LIQUID INJECTION HEAT-UP CONDITIONS

Test No.	Hot Water Injection Location	E_{in} (kW)	τ_{metal} (s)	UA_{metal} (kW/K)	$\tau_{dead\text{-}end}$ (s)	$UA_{dead\text{-}end}$ (kW/K)
E9312	Channel End	372.5 ± 2.9	35.23 ± 0.26	0.500	98.51 ± 0.27	0.122
E9313	Channel End	84.8 ± 2.5	144.5 ± 0.35	0.122	190.5 ± 0.39	0.063
E9318	Channel End	1174 ± 42	17.94 ± 0.17	0.997	67.12 ± 0.17	0.180
E9344	Feeder End	1056 ± 116	20.87 ± 0.23	0.835	65.98 ± 0.22	0.184
E9354	Feeder End	84.1 ± 3.6	148.8 ± 0.66	0.119	202.2 ± 0.79	0.060

TABLE 8.12

FRICTIONAL RESISTANCE COEFFICIENTS - NO REYNOLDS NUMBER DEPENDANCY

a) ABOVE-HEADER COMPONENTS

Component	k ($m \cdot s^2/L^2$)
HDR5-BO1	3.50×10^{-3}
BO1 DP	3.93×10^{-2}
BO1-P1	8.40×10^{-4}
P1-HDR6	4.93×10^{-3}

Component	k ($m \cdot s^2/L^2$)
HDR7-BO2	3.68×10^{-3}
BO2 DP	4.02×10^{-2}
BO2-P2	1.11×10^{-3}
P2-HDR8	4.14×10^{-3}

Note: Pumps 1 and 2 are not included

b) BELOW-HEADER COMPONENTS

Heated	k ($m \cdot s^2/L^2$)		
Section Number	Inlet Feeder	Heated Section*	Outlet Feeder
5	3.19	4.12	0.34
6	3.57	4.50	0.49
7	0.76	4.45	0.48
8	0.85	4.05	0.35
9	3.34	4.14	0.65
10	3.31	3.82	0.33
11	2.93	3.79	0.40
12	0.69	3.63	0.44
13	0.86	4.13	0.35
14	3.28	4.30	0.70

* The heated section includes the inlet and outlet end-fittings.

TABLE 8.13

VALUES OF M AND n FOR ABOVE HEADER COMPONENTS

Location	Pipe Diameter, d (m)	M	n
HDR5-BO1	0.09718	4.23	0
BO1 DP	0.09718	609	-0.186
BO1-P1	0.09718	3.69	-0.0890
P1-HDR6	0.07792	4.78	-0.0609
HDR7-BO2	0.09718	4.72	-0.011
BO2 DP	0.09718	532	-0.183
BO2-P2	0.09718	3.07	-0.0712
P2-HDR8	0.07792	4.97	-0.084

TABLE 8.14

VALUES OF M AND n FOR BELOW HEADER COMPONENTS

Location	Pipe Diameter, d (m)	M	n
HS5*	0.02664	196	-0.148
HS6*	0.02664	170	-0.140
HS7*	0.03505	422	-0.125
HS8*	0.03505	388	-0.126
HS9*	0.02664	204	-0.152
HS10*	0.02664	195	-0.150
HS11*	0.02664	180	-0.141
HS12*	0.03505	387	-0.134
HS13*	0.03505	390	-0.124
HS14*	0.02664	181	-0.144
HDR6-HS5	0.02664	34.3	-0.0349
HDR6-HS6	0.02664	32.7	-0.0317
HDR6-HS7	0.03505	19.3	-0.0275
HDR6-HS8	0.03505	20.2	-0.0159
HDR6-HS9	0.02664	34.2	-0.0380
HS5-HDR7	0.03505	18.2	-0.0761
HS6-HDR7	0.03505	20.1	-0.0611
HS7-HDR7	0.03505	18.4	-0.0578
HS8-HDR7	0.03505	14.3	-0.0585
HS9-HDR7	0.03505	34.6	-0.0770
HDR8-HS10	0.02664	33.1	-0.0294
HDR8-HS11	0.02664	39.7	-0.0456
HDR8-HS12	0.03505	22.1	-0.0453
HDR8-HS13	0.03505	23.4	-0.0314
HDR8-HS14	0.02664	30.1	-0.0323
HS10-HDR5	0.03505	17.6	-0.0698
HS11-HDR5	0.03505	23.8	-0.0726
HS12-HDR5	0.03505	19.6	-0.0663
HS13-HDR5	0.03505	16.2	-0.0679
HS14-HDR5	0.03505	27.8	-0.0571

* The heated section includes the inlet and outlet end-fittings.

TABLE 8.15

ESTIMATED HEAT TRANSFER AREA COEFFICIENTS FOR HEAT LOSSES

Location	UA ($W°C^{-5/4}$)	Location	UA ($W°C^{-5/4}$)
TS5[1]	7.14 ± 0.17	TS5 OF[3]	4.06 ± 0.43
TS6[1]	6.38 ± 0.24	TS6 OF[3]	4.63 ± 0.45
TS7[1]	7.98 ± 0.22	TS7 OF[3]	8.07 ± 0.30
TS8[1]	7.63 ± 0.20	TS8 OF[3]	4.49 ± 0.14
TS9[1]	7.39 ± 0.26	TS9 OF[3]	3.62 ± 0.19
TS10[1]	6.48 ± 0.74	TS10 OF[3]	3.87 ± 0.55
TS11[1]	8.15 ± 0.28	TS11 OF[3]	4.59 ± 0.37
TS12[1]	9.84 ± 1.27	TS12 OF[3]	7.78 ± 1.32
TS13[1]	11.84 ± 0.19	TS13 OF[3]	2.18 ± 0.16
TS14[1]	9.60 ± 0.31	TS14 OF[3]	3.40 ± 0.50
TS5 IF[2]	0.73 ± 0.26	BO1-P1-HDR6[4]	32.16 ± 0.52
TS6 IF[2]	1.76 ± 0.33	BO2-P2-HDR8[4]	32.01 ± 1.03
TS7 IF[2]	3.03 ± 0.18		
TS8 IF[2]	3.10 ± 0.16		
TS9 IF[2]	2.30 ± 0.09		
TS10 IF[2]	1.16 ± 0.21		
TS11 IF[2]	2.34 ± 0.17		
TS12 IF[2]	4.65 ± 0.31		
TS13 IF[2]	4.41 ± 0.16		
TS14 IF[2]	3.00 ± 0.12		

1 The test section includes the heated section and the inlet and outlet end-fittings. The average distribution of heat losses across the test section were: heated section: 66 ± 4.2 %; inlet end-fitting: 17 ± 3.7 %; outlet end-fitting: 17 ± 3.7 %.

2 IF is the inlet feeder.

3 OF is the outlet feeder. Calculated heat loss from the outlet feeder of TS12 showed no significant variation with temperature. Average measured heat loss was 5.48 ± 0.28 kW

4 Data was unreliable for heat loss correlations for the outlet headers to boiler inlets, therefore it is not presented. The average distribution of heat losses from the boiler outlets to the inlet headers is: boiler outlet to pump inlet: 11 ± 5 %; pump inlet to pump outlet: 58 ± 10 %; pump outlet to inlet header: 31 ± 5 %.

TABLE 8.16

ROSEMOUNT DP CELLS ZERO AND SPAN SHIFT CORRECTION CONSTANTS

Device Code	Location	Serial Number	Calibrated Range (kPa)	m	S (MPa^{-1})
10Q-D1	BO2 DELP	C72664	±175	-3.94E-04	0.154%
11Q-D1	BO2-P2	C43536	±15	0	0.118%
12Q-D1	P2 DELP	C72682	±575	7.29E-04	0.080%
12Q-D2	P2 DELP	C87174	±100	0	0.118%
13Q-D1	P2-HDR8	C43537	±15	0	0.118%
16Q-D1	HDR5-BO1	C43535	±15	0	0.118%
24Q-D1	HS5	C00184810* C00184810* C67859	±6 ±25" H_2O ±575	0 0 5.78E-04	0 0 0.080%
24Q-D2	HS5	C67442	±175	0	0.154%
25Q-D1	HS6	C00184812* C00184812* C67861	±6 ±25" H_2O ±575	0 0 -6.52E-04	0 0 0.080%
25Q-D2	HS6	C67443	±175	2.96E-04	0.154%
26Q-D1	HS7	C00184809* C00184809* C67863	±6 ±25" H_2O ±575	0 0 0	0 0 0.080%
26Q-D2	HS7	C43541	±175	-3.69E-04	0.154%
27Q-D1	HS8	C00148612* C67865	±20 ±575	0 2.37E-04	0 0.080%
27Q-D2	HS8	C72670	±175	-1.76E-04	0.154%
28Q-D1	HS9	C00184811* C00184811* C67867	±6 ±25" H_2O ±575	0 0 6.94E-04	0 0 0.080%
28Q-D2	HS9	C67446	±175	-3.64E-04	0.154%
29Q-D1	HS10	C67869	±575	-1.69E-04	0.080%
29Q-D2	HS10	C67447	±175	9.60E-04	0.154%
3Q-D1	BO1 DELP	C72671	±175	1.21E-04	0.15%
30Q-D1	HS11	C67870	±575	9.91E-04	0.080%
30Q-D2	HS11	C67449	±175	1.19E-04	0.154%
31Q-D1	HS12	C43542	±175	-2.24E-04	0.154%
31Q-D2	HS12	C00148610* C67872	±20 ±575	0 4.71E-04	0 0.080%
32Q-D1	HS13	C00176680* C67873	±20 ±575	0 4.06E-04	0 0.080%
32Q-D2	HS13	C72665	±175	-4.52E-04	0.154%
33Q-D1	HS14	C67875	±575	4.86E-04	0.080%
33Q-D2	HS14	C67453	±175	-5.82E-04	0.154%

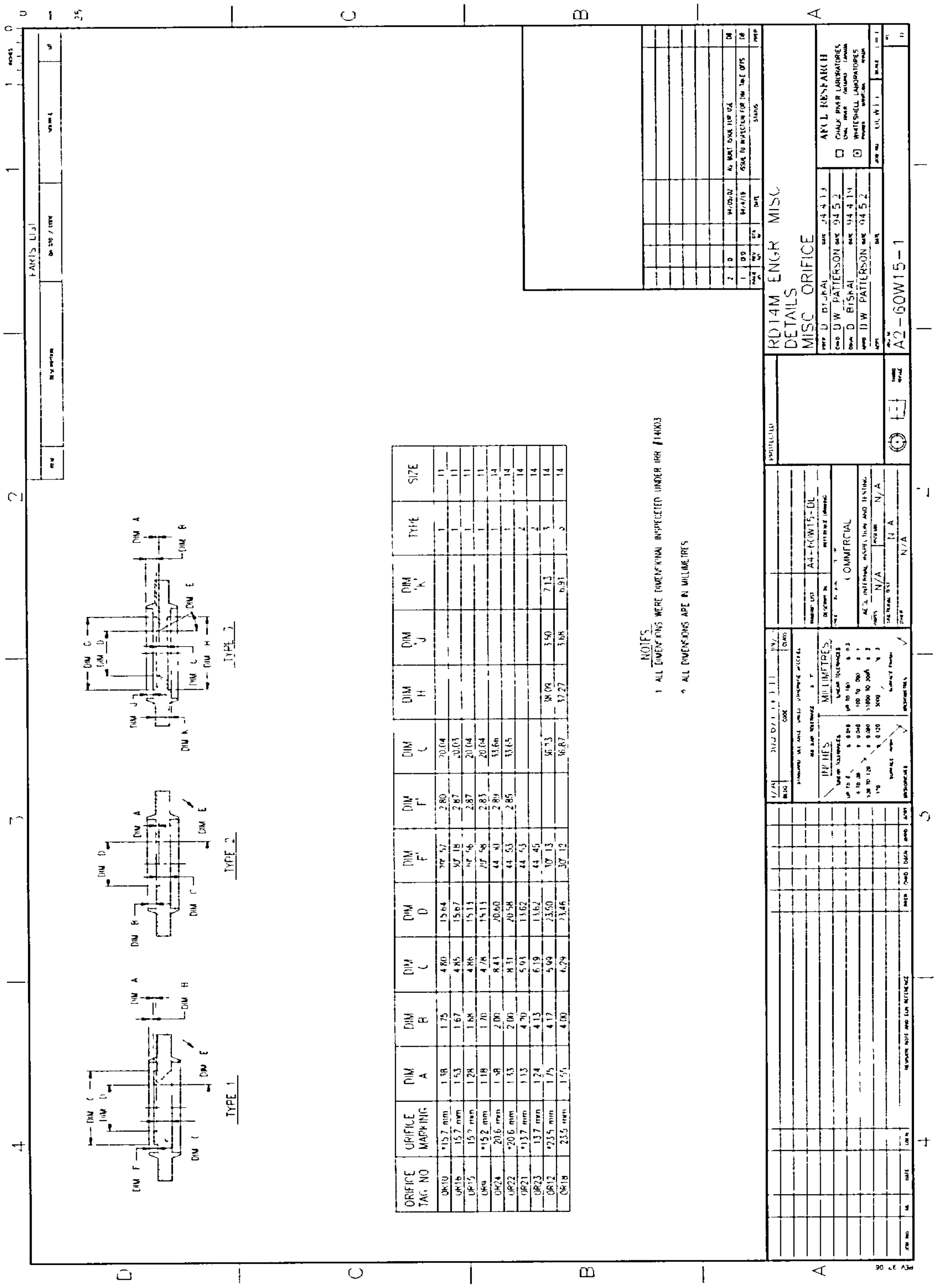
TABLE 8.16 (concluded)

ROSEMOUNT DP CELLS ZERO AND SPAN SHIFT CORRECTION CONSTANTS

Device Code	Location	Serial Number	Calibrated Range (kPa)	m	S (MPa^{-1})
35Q-D1	HDR8-HDR5	C00176679* C43548	±20 ±575	0 4.19E-04	0 0.080%
35Q-D2	HDR8-HDR5	C72659 C43543	±175 ±175	6.06E-05 -6.18E-04	0.154% 0.154%
36Q-D1	HDR6-HDR7	C87172 C43546	±20 ±575	0 -6.70E-05	0.127% 0.080%
36Q-D2	HDR6-HDR7	C43543 C43546	±175 ±575	-6.18E-04 -6.70E-05	0.154% 0.080%
37Q-D1	HDR6-HS5	C67860	±575	5.41E-04	0.080%
38Q-D1	HDR6-HS6	C67862	±575	-1.00E-03	0.080%
39Q-D1	HDR6-HS7	C67444	±175	-6.85E-04	0.154%
4Q-D1	BO1-P1	C43533	±15	0	0.118%
40Q-D1	HDR6-HS8	C67445	±175	1.30E-04	0.154%
41Q-D1	HDR6-HS9	C67868	±575	2.14E-04	0.080%
42Q-D1	HS10-HDR5	C67448	±175	-1.72E-04	0.154%
43Q-D1	HS11-HDR5	C67450	±175	-8.97E-04	0.154%
44Q-D1	HS12-HDR5	C67451	±175	-8.70E-04	0.154%
45Q-D1	HS13-HDR5	C67452	±175	-4.56E-04	0.154%
46Q-D1	HS14-HDR5	C67454	±175	-4.71E-04	0.154%
47Q-D1	HS5-HDR7	C72667	±175	3.64E-04	0.154%
48Q-D1	HS6-HDR7	C72669	±175	-1.41E-04	0.154%
49Q-D1	HS7-HDR7	C72663	±175	3.98E-04	0.154%
5Q-D1	P1 DELP	C72686	±575	1.83E-03	0.080%
5Q-D2	P1 DELP	C87175	±100	0	0.118%
50Q-D1	HS8-HDR7	C72661	±175	5.51E-04	0.154%
51Q-D1	HS9-HDR7	C72660	±175	-1.65E-04	0.154%
52Q-D1	HDR8-HS10	C72684	±575	8.64E-04	0.080%
53Q-D1	HDR8-HS11	C72676	±575	7.75E-04	0.080%
54Q-D1	HDR8-HS12	C72672	±575	1.45E-03	0.080%
55Q-D1	HDR8-HS13	C72679	±575	2.20E-04	0.080%
56Q-D1	HDR8-HS14	C72681	±575	1.66E-03	0.080%
57Q-D1	HDR5-HDR6	C72666	±300	4.16E-04	0.154%
58Q-D1	HDR7-HDR8	C72662	±300	-4.41E-04	0.154%
6Q-D1	P1-HDR6	C43534	±15	0	0.118%
64Q-D1	SRG TK-HDR5	C00146981*	±200	0	0
69Q-D1	HS8 INLET EF	298792*	±248	0	0
71Q-D1	HS12 INLET EF	298791*	±248	0	0
9Q-D1	HDR7-BO2	C43538	±15	0	0.118%

* Rosemount model 3051 differential pressure transducer.

8. CHARACTERIZATION OF LOOP COMPONENTS



ORIFICE TAG NO	ORIFICE MARKING	DIM A	DIM B	DIM C	DIM D	DIM F'	DIM F''	DIM G	DIM H	DIM J	DIM K	TYPE	SIZE
OR10	*15.7 mm	1.38	1.75	4.80	15.64	[illegible]	2.80	20.04				1	11
OR16	15.7 mm	1.53	1.67	4.85	15.67	30.18	2.87	20.03				1	11
OR15	15.2 mm	1.28	1.68	4.86	15.13	[illegible]	2.87	20.04				1	11
OR4	*15.2 mm	1.18	1.70	4.78	15.13	[illegible]	2.83	20.04				1	11
OR24	20.6 mm	1.58	2.00	8.43	20.60	[illegible]	2.89	33.66				1	14
OR22	*20.6 mm	1.33	2.00	8.31	20.58	44.53	2.85	33.65				1	14
OR21	*13.7 mm	1.13	4.20	5.93	13.62	44.53						2	14
OR23	13.7 mm	1.24	4.13	6.19	13.62	44.45						2	14
OR12	*23.5 mm	1.75	4.17	5.99	23.50	30.13		36.73	38.09	3.50	7.13	3	14
OR18	23.5 mm	1.55	4.00	6.29	23.46	30.12		36.87	37.27	3.88	6.91	3	14

FIGURE 8.1: Orifice Dimensions

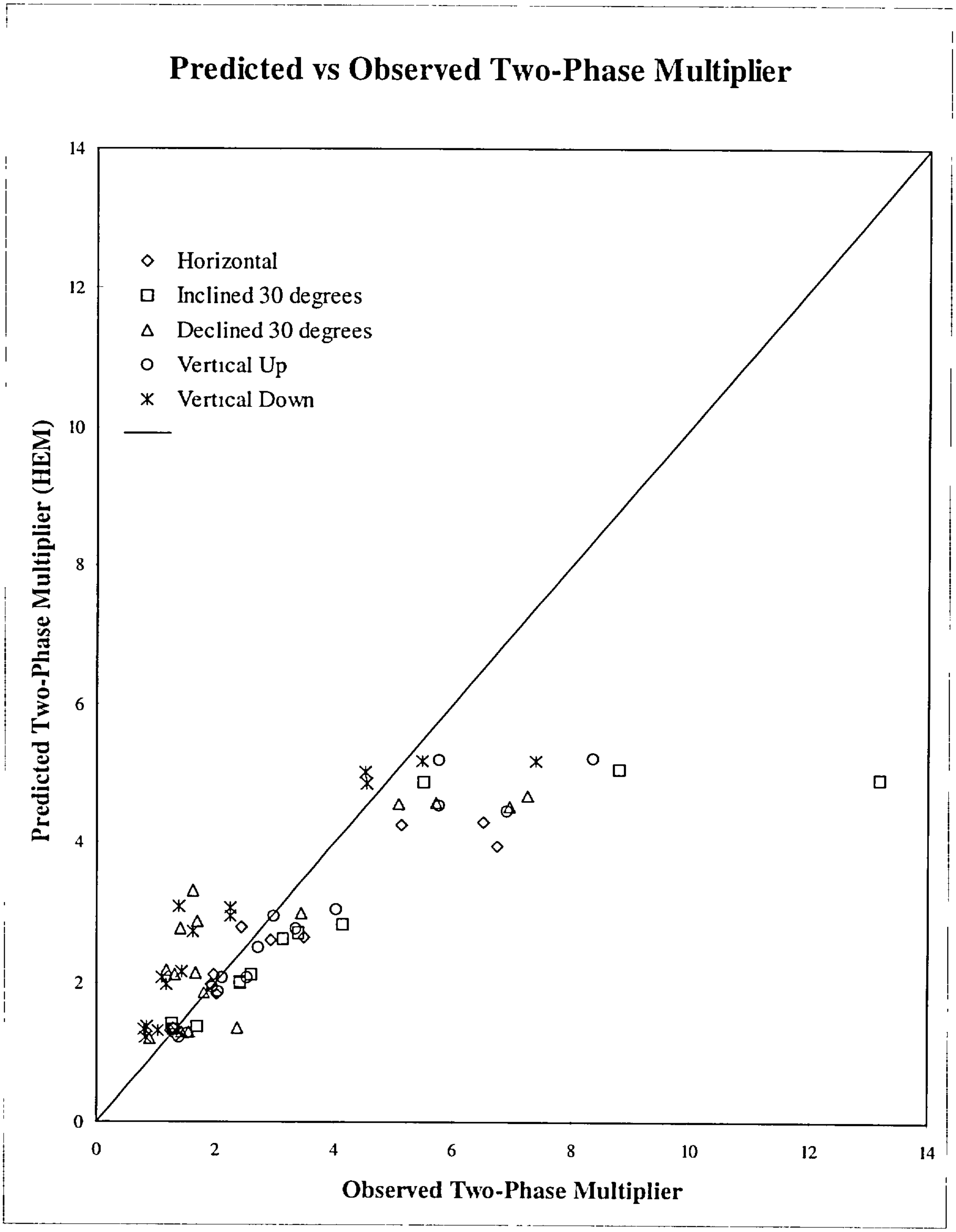


FIGURE 8.2: Predicted Two-Phase Multiplier (using HEM) for Flow Through a 1.25-inch TFM

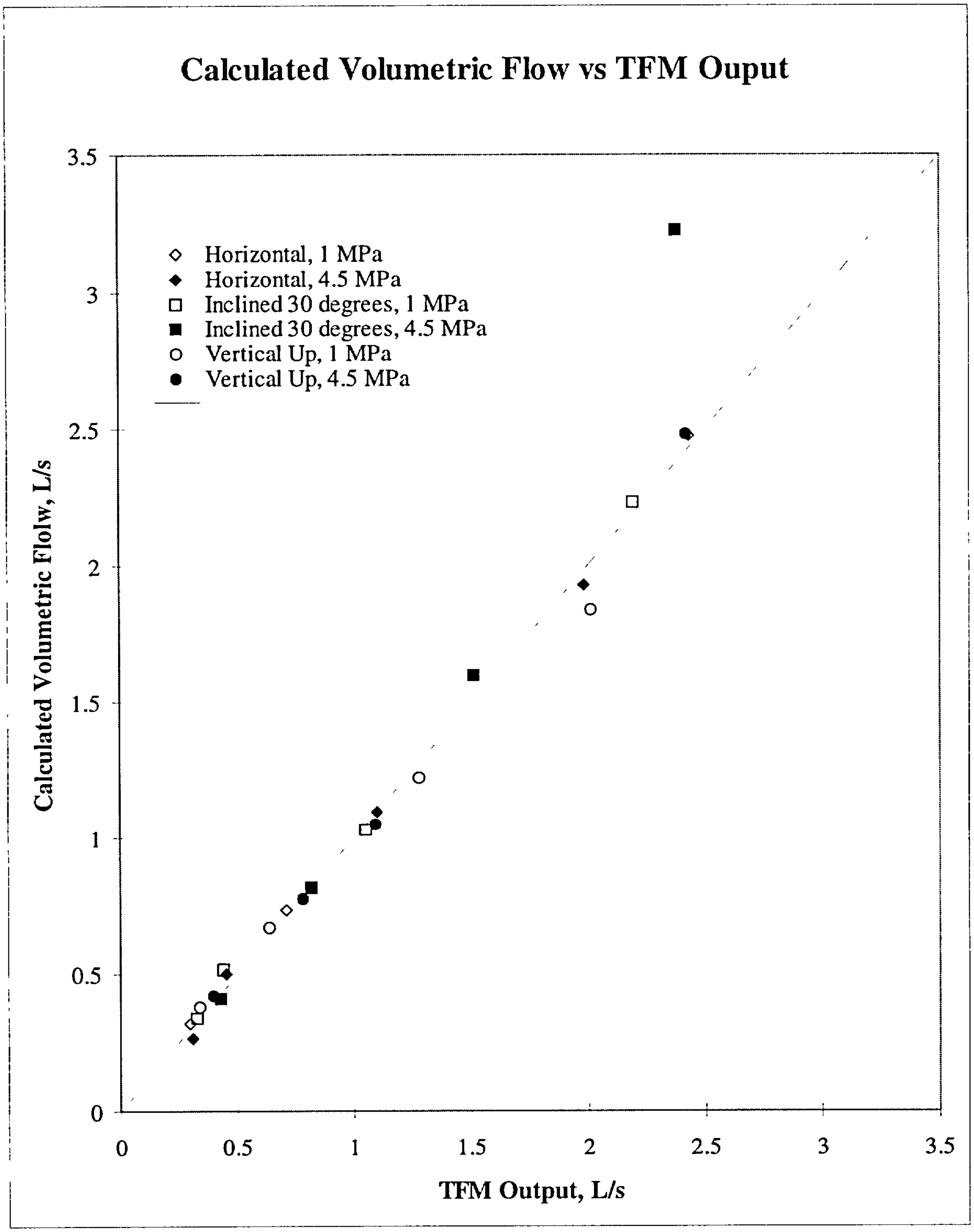


FIGURE 8.3: Calculated Volumetric Flow for Two-Phase Steam-Water Flow Through a TFM

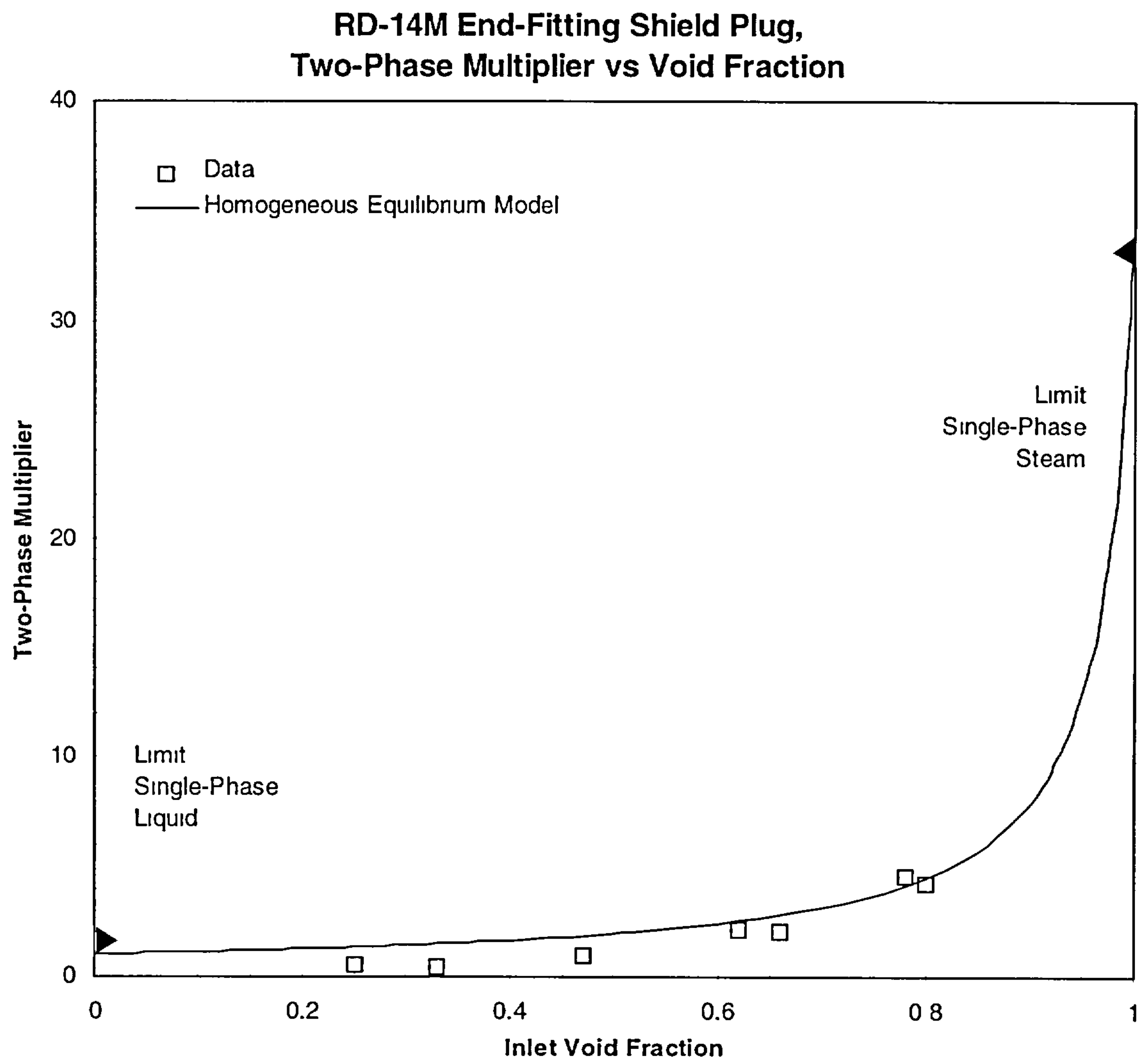
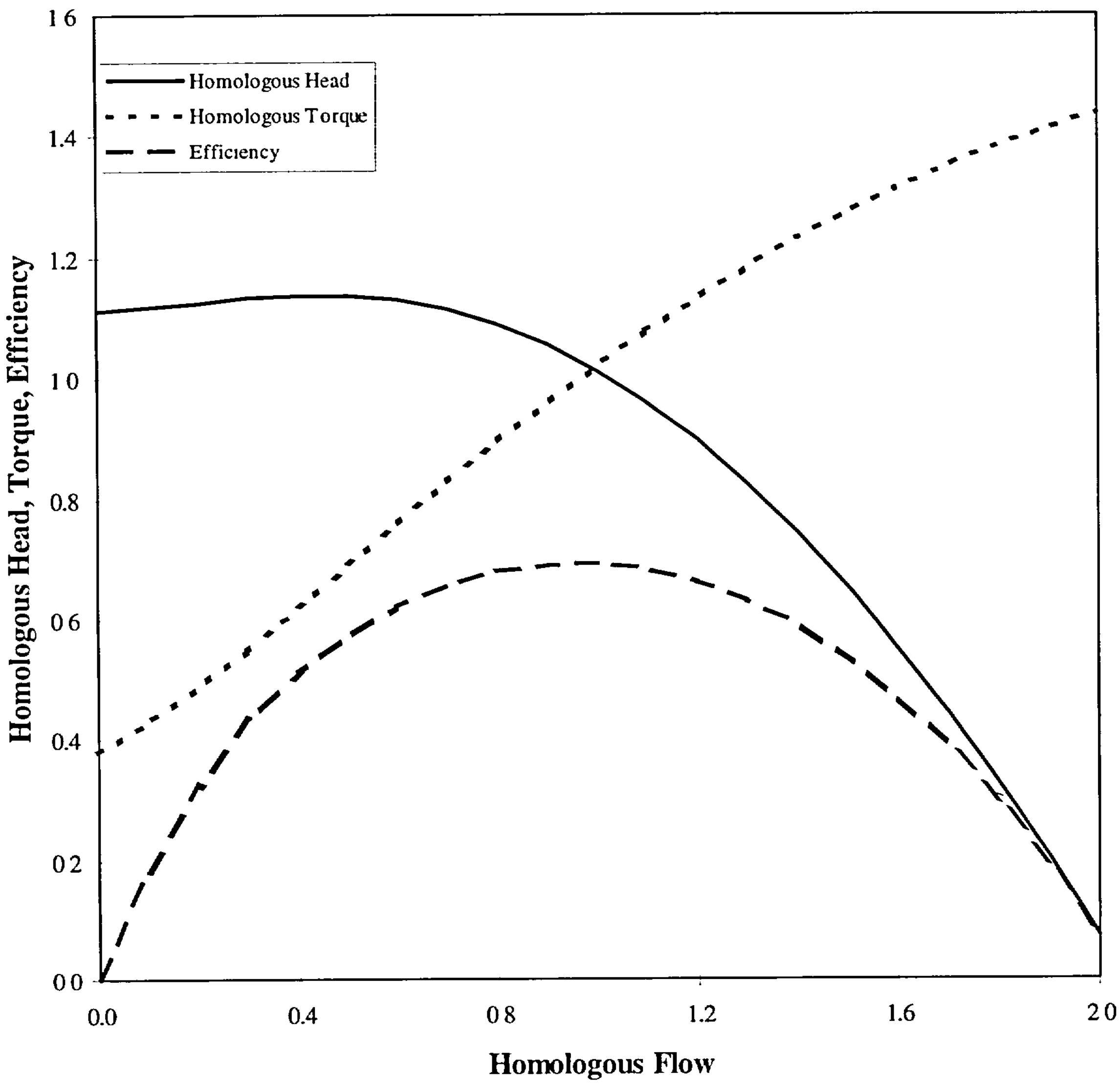


FIGURE 8.4: End-Fitting Two-Phase Multiplier Versus Void Fraction for Two-Phase Steam-Water Flow Past the Shield Plug: Dead-End Space to Channel Flow Path



Homologous Head = $(H \cdot N)/(H_r \cdot N^2)$;
Homologous Torque = $(t \cdot r_r \cdot N)/(t_r \cdot r \cdot N^2)$;
Homologous Flow = $(Q \cdot N_r)/(Q_r \cdot N)$;
$H_r = 225$ m; $t_r = 205$ N-m; $Q_r = 0.031$ m^3/s; $N_r = 3560$ rpm; $r_r = 778$ kg/m^3)

FIGURE 8.5: Primary Pump (P1, P2) Single-Phase Performance Characteristics

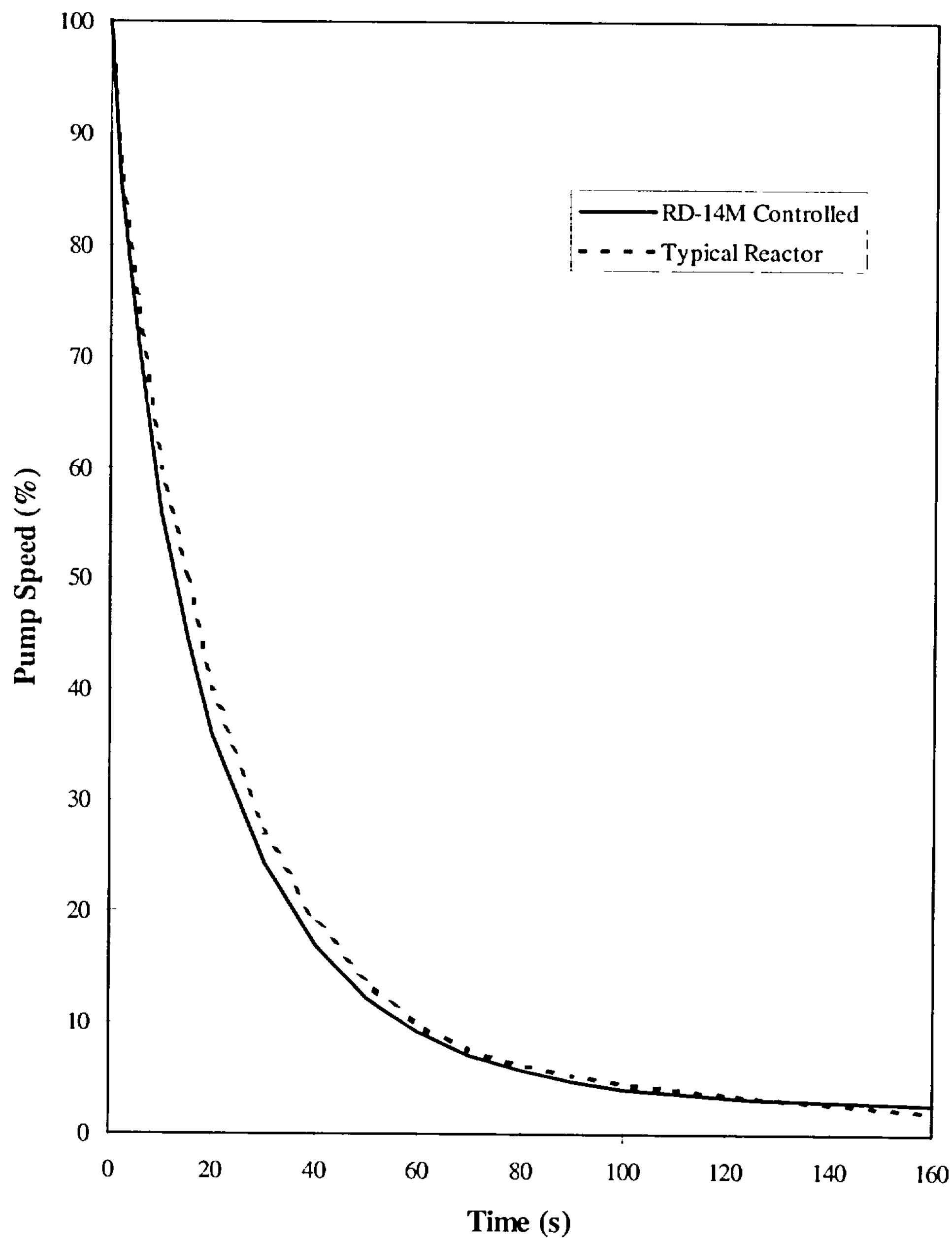


FIGURE 8.6: Comparison of Typical Reactor Pump Rundown with Controlled RD-14M Primary Pump Rundown

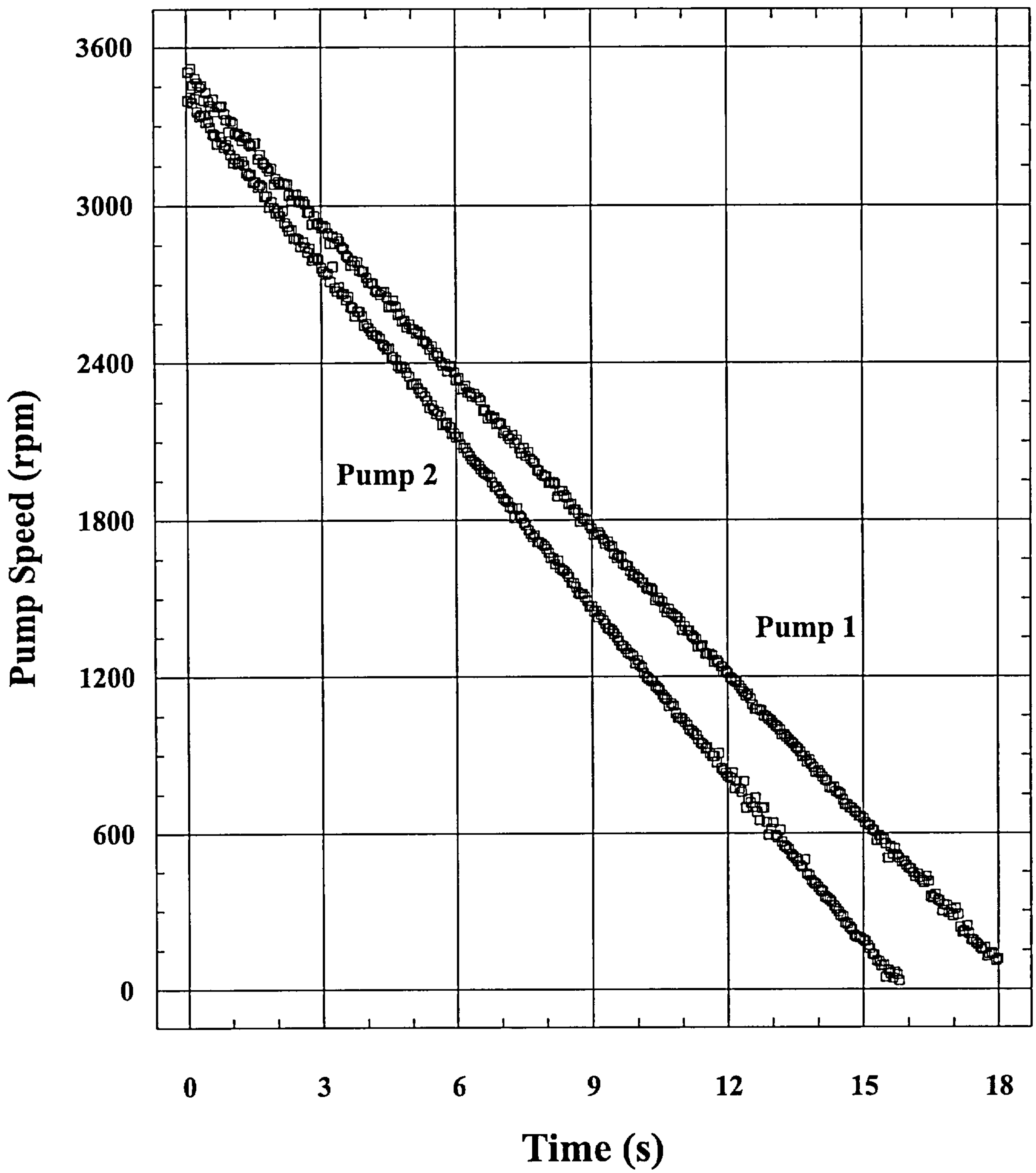


FIGURE 8.7: Representative Free Primary Pump Rundowns

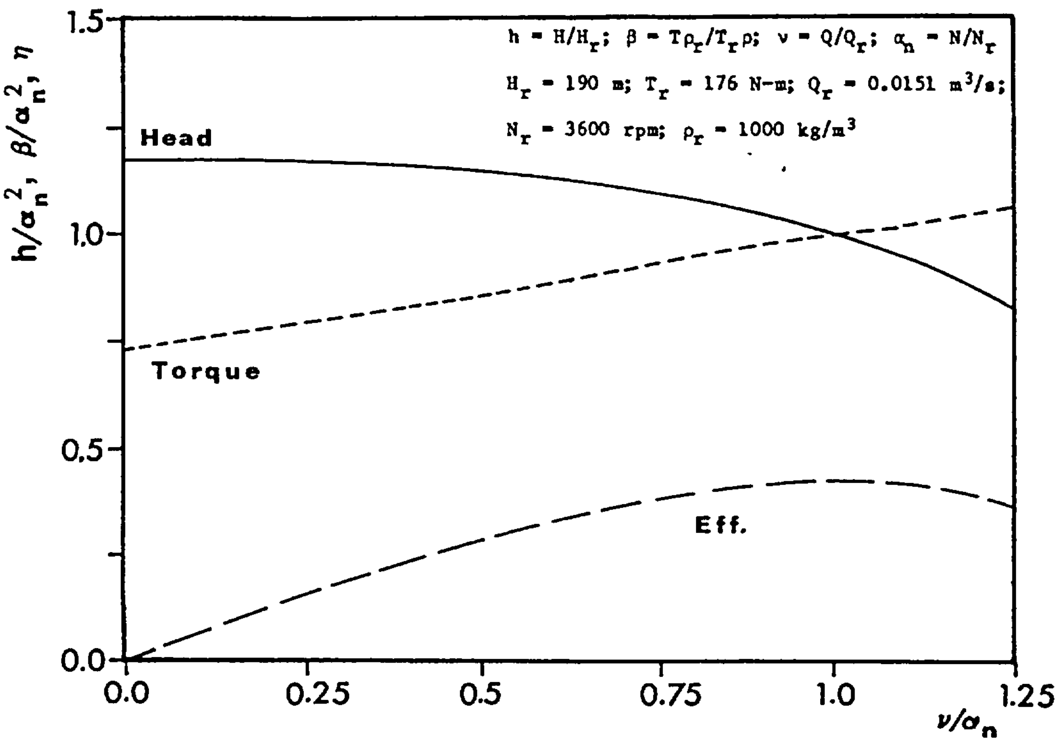


FIGURE 8.8: Pumps P6, P7 Single-Phase Homologous Head, Torque and Efficiency Characteristics

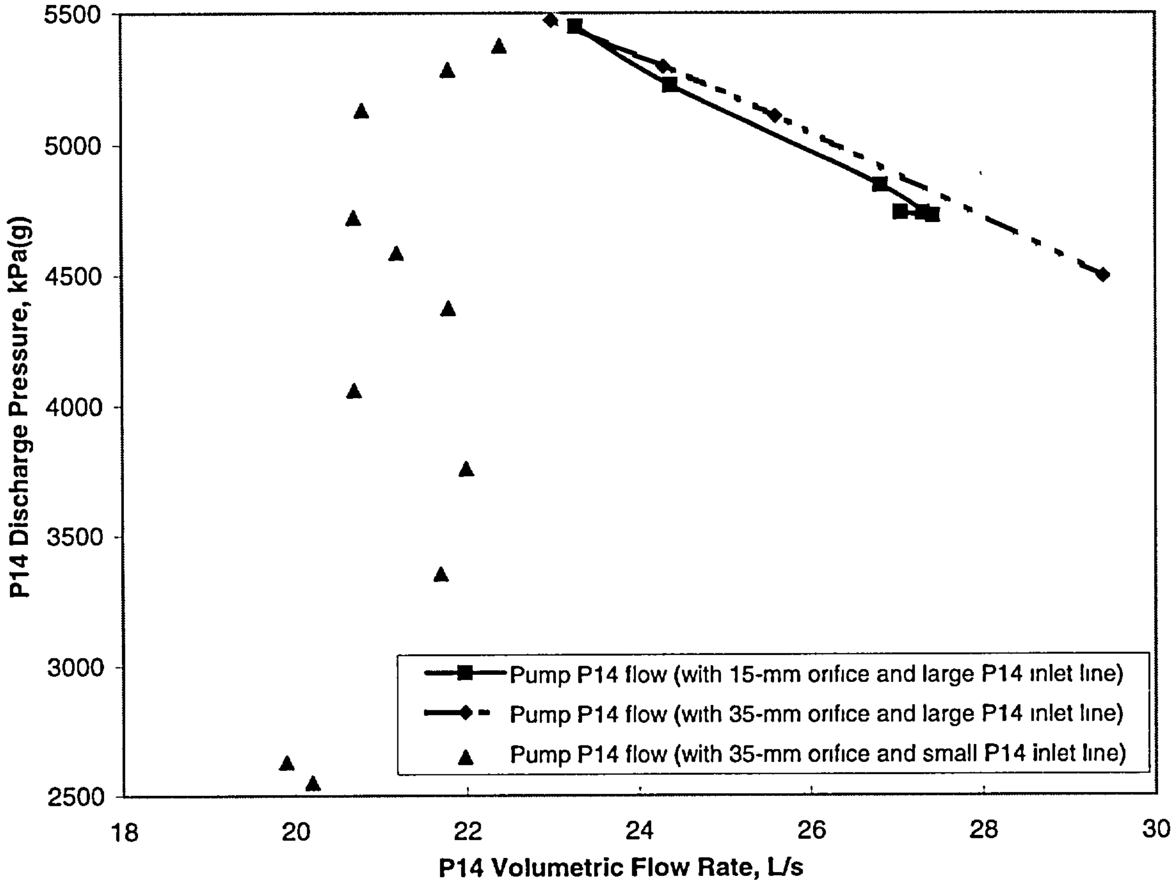


FIGURE 8.9: Pump P14 Performance Curve

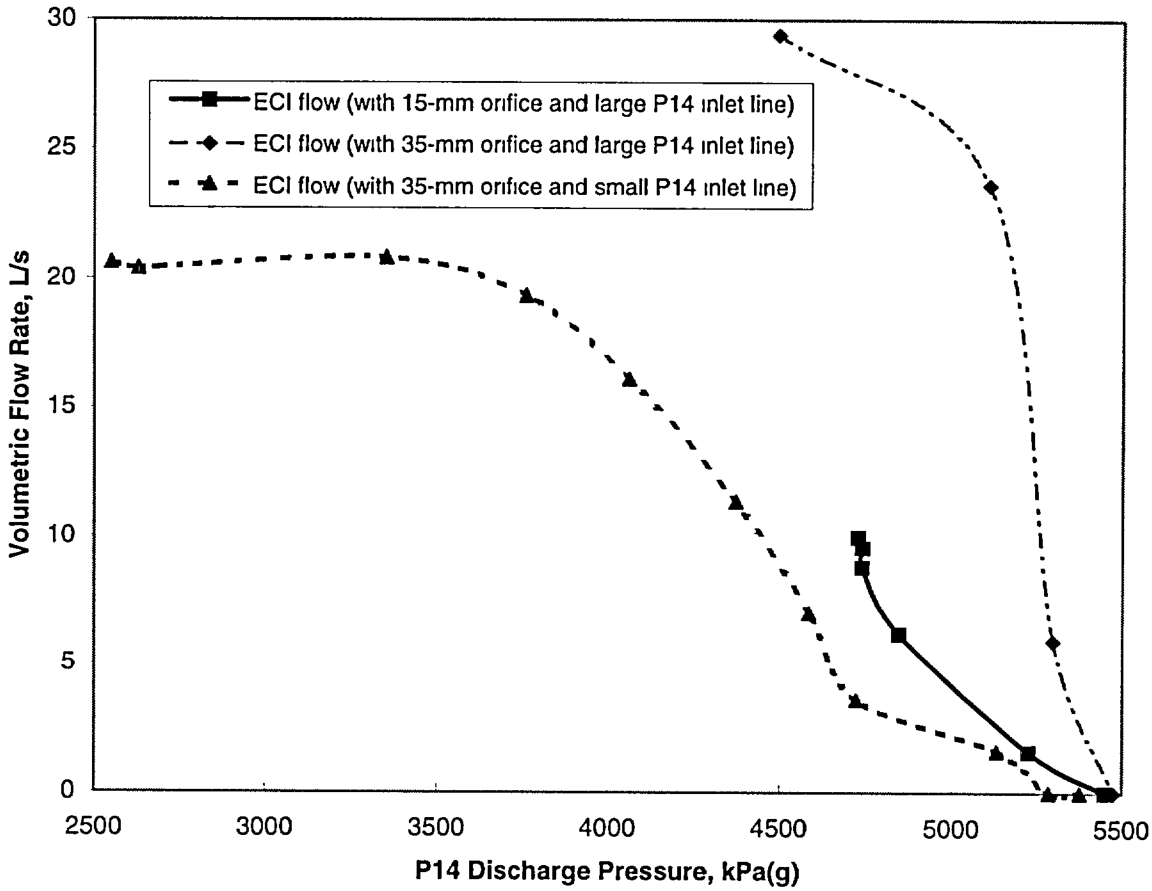


FIGURE 8.10: ECI Flow from P14 Characterization Tests

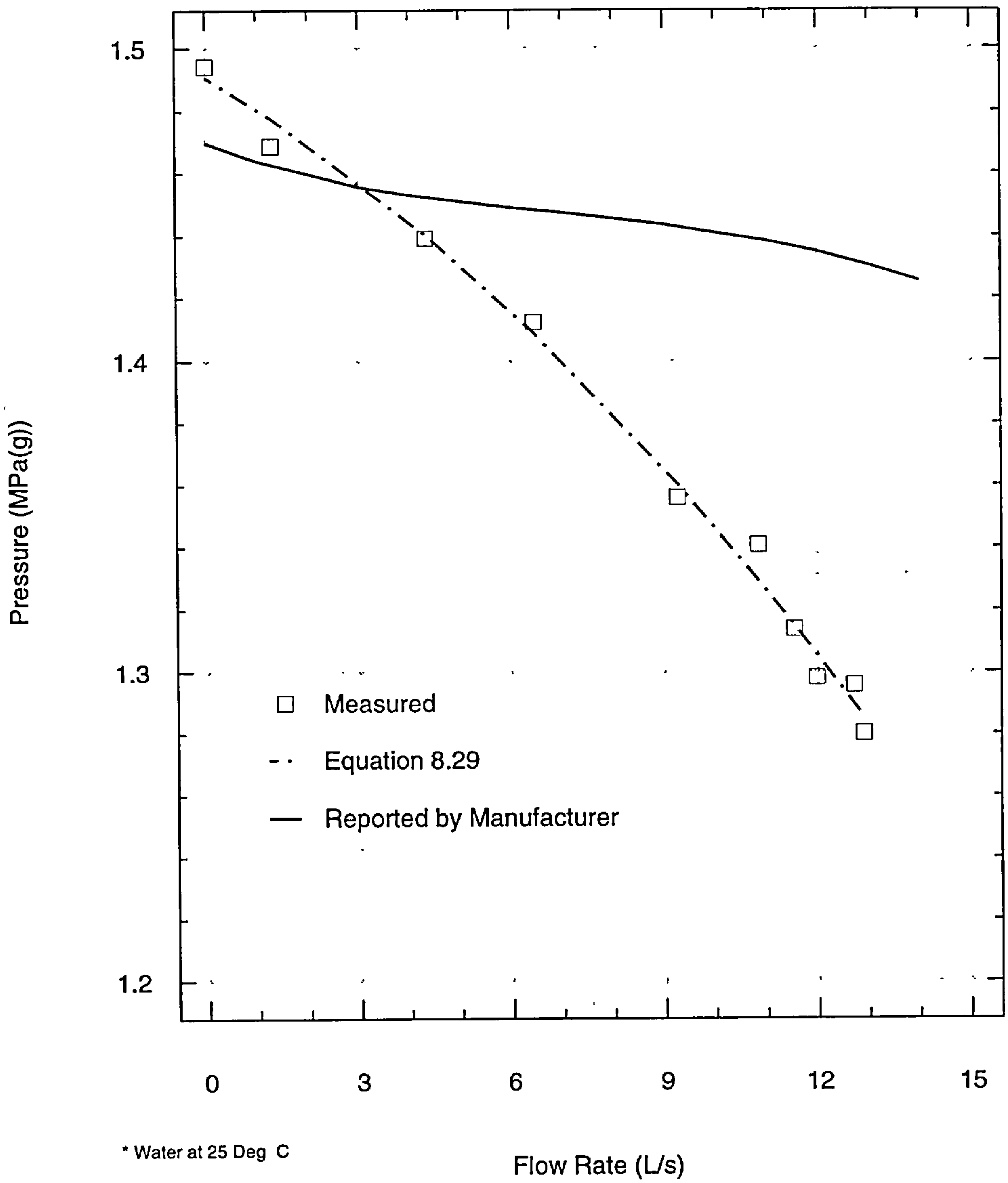


FIGURE 8.11: Pump P8 Performance Curve

9. SUMMARY

The RD-14M facility is a thermalhydraulic test facility designed with many of the key components of a CANDU reactor primary heat transport system:

- full-elevation;
- two-pass, figure-of-eight configuration;
- two full-height steam generators;
- two primary pumps;
- four headers (two per pass); and
- ten horizontal test sections (five per pass), each with inlet and outlet simulated end-fittings and a seven element fuel element simulator, and connected to a pair of headers via full-length feeders.

The RD-14M secondary heat transport system removes steam generated on the shell side of the steam generators, via a jet condenser.

Auxiliary systems include an emergency coolant injection (ECI) system, a pressurizer/surge tank, drain system for natural circulation tests, blowdown system, trace heating, and a make-up water addition system, giving RD-14M the versatility to be used to carry out many different types of experiments.

RD-14M is extensively instrumented on the primary and secondary sides, as well as auxiliary systems to measure various parameters including temperatures, gauge and differential pressures, flows, levels, voids, and powers.

The facility operates at typical CANDU primary system pressures (up to 10 MPa) and temperatures (up to 310°C) and is designed to produce the same fluid mass flux, transit time, pressure, and enthalpy distributions in the primary system as those in a typical CANDU reactor under both forced and natural circulation conditions.

This report has described the RD-14M facility in detail, including the geometry, components, instrumentation, characterization, scaling, and design rationale.

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

A.1 INTRODUCTION

The RD-14M loop is a multipurpose facility that can be used to investigate the behaviour of a figure-of-eight loop under various postulated accident conditions, and to provide data for code validation. This requires that the behaviour of the RD-14M loop correspond closely to that of the reactor loop over a wide range of flow conditions. The design of the facility and its components must, within practical limitations, reflect this requirement.

The design basis and scaling laws for the facility are presented in Reference [A.1] (and reprinted at the end of this appendix). Certain aspects of the RD-14M design were dictated by considerations other than the scaling laws. For example, the pre-existing RD-14 steam generators, pumps, and fuel element simulators were utilized in RD-14M for financial reasons. This in turn determined the scale of the facility and possible channel configurations. Five seven-element channels per pass were chosen as the most reasonable representation. Those items that are not detailed in Reference [A.1] (e.g., the design of components not entirely covered by the scaling laws developed), are the subject of this appendix.

It should be noted that it is impossible to scale the entire facility exactly. In fact, the scaling of certain complicated components such as the headers and the end-fittings are beyond the current state-of-the-art. Generally, the only model that will satisfy all of the scaling laws is the full-scale facility itself. In any facility, there will always be certain scaling parameters which must be compromised. These are chosen based on past experience, engineering judgement and financial limitations. In most cases, these compromises do not severely affect the simulation of the full-scale facility.

This appendix, in conjunction with Reference [A.1], outlines the rationale behind the current design of RD-14M.

A.2 PIPEWORK ABOVE THE HEADERS

Since the pre-existing steam generators and pumps were incorporated into the RD-14M design, it was anticipated that the pre-existing RD-14 pipework above the headers would be used as is. The final design, however, necessitated some minor modifications to certain piping sections to accommodate the new headers and feeders. Pipework designs for the simulation of either the Darlington or CANDU-6 geometries were developed, however only the CANDU-6 geometry has been installed.

Accurate scaling of the heat capacity of the pipework above the headers is not critical since it has only a small effect on loop behaviour. Of greater importance are the fluid volumes, fluid velocities (i.e., flow areas), and major pressure losses. The scaling ratios defined in Reference [A.1] for pipework above the headers are given in Table A.1. The pipe sizes chosen were based on using either the pre-existing geometry or the commercially available pipe size that most closely matched both the fluid velocities and the pressure losses.

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

Space limitations required that some of the RD-14M pipe sections be shorter than scaling dictated. There were no reasonable cost effective ways of avoiding this distortion.

A.3 HEADERS

The flow patterns within the headers are highly three-dimensional in nature, thus the scaling laws developed for the other piping components in RD-14M could not be applied.

There are basically two types of transients that are of interest: natural circulation (thermosiphoning, core-cooling in the absence of forced flow (CCAFF)) transients, and blowdown and refill transients. The relative importance of each scaling parameter depends on the type of flow expected.

Under certain low-inventory transients, such as blowdown and refill; the flow in the headers may be stratified. Thus, to ensure that, for a given void fraction, the feeder nozzles in both RD-14M and the reactor are exposed to the same conditions (i.e., steam only, water only, or a combination), the ratio of header to feeder diameter must be maintained. This then determines the diameter of the headers since the diameter of the feeders has already been specified by the loop scaling laws.

Header refilling times are important during certain blowdown and refill transients. To ensure reasonable simulation of such transients the fluid volumes in the headers must be properly scaled. This requirement, along with the diameter considerations detailed above, dictated the length of the header.

The above scaling criteria were selected in order to capture the phase separation and feeder-nozzle uncovering phenomena in the headers. Using these criteria, however, it is impossible to design headers that maintain the full range of fluid flow-path lengths within them. The range of flow-path lengths in the scaled headers is 0 to 0.5 m versus 0 to 2 m in the reactor.

The fluid transit times in the header are preserved since the moving fluid volume is properly scaled. However, this results in lower fluid velocities in the RD-14M headers, which enhances any flow separation that occurs. The latter is conservative in terms of feeder-connection uncovering during certain transients.

It is desirable to scale the metal mass of the headers in order to obtain the correct stored heat and wall temperatures. This is important in certain blowdown and refill transients. Unfortunately, scaling of this parameter using the dimensions specified by the above criteria yields piping walls that are too thin. To maintain structural integrity and satisfy pressure vessel code requirements, much thicker piping walls were necessary.

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

Since there are only five channels and the proximity of the feeder nozzles is limited because of welding and stress limitations, not all combinations of channel interactions can be investigated. At each axial plane there are, at most, only two feeders connected, instead of five (or six) as in the full-scale reactors. Each of the different nozzle orientations (angles), however, are represented (see Figures 2.22 to 2.25).

A comparison of the scaled and "as designed" parameters for the RD-14M headers is given in Table A.2. The headers are scaled to Darlington NGS. As shown, the actual design is reasonably close to the scaled values in most cases.

Some of the features of the RD-14M header design are as follows:

- all feeder nozzle orientations are represented,
- the investigation of channel-to-channel interaction is possible,
- the header diameter is properly scaled to allow investigation of the effect of feeder nozzle location under stratified flow conditions, and
- the header fluid volume is correctly scaled.

The design does have some limitations that may affect the fluid behaviour in the header:

- the header metal mass is too high (this is conservative from the point of header refill),
- the fluid flow paths are short, and
- only five channels are connected to the headers, with a maximum of two at any one header cross section.

These limitations are a direct result of the scaling criteria used in the design of the headers. It is impossible to avoid these limitations and satisfy the scaling criteria.

A.4 FEEDERS

The feeders are first scaled using the scaling criteria developed in Reference [A.1]. The dimensions obtained are given in Tables A.3 and A.4. Unfortunately, the manufacture of piping sections with the exact scaled dimensions would have required spending enormous amounts of money. Practically, one must utilize the pipe sizes that are commercially available. This resulted in some distortions in the scaling of the feeders, as noted below and in the tables.

For feeder refill behaviour, the proper scaling of the piping heat capacity is important. The pressure vessel code for the facility design pressure, however, requires thicker pipe sections than specified by the scaling laws. Thus, the piping heat capacity scaling must be relaxed somewhat.

Another consideration is the potential for flooding in the pipe sections during feeder refill. As noted in Reference [A.1], the mass flows at similar flooding conditions are related by the ratio

$(D_R)^{5/2}$, whereas the mass of the feeders is scaled according to $(D_R)^2$. Thus the feeder refill times, assuming that the process is flooding-limited, are related by $(D_R)^{1/2}$. For similar conditions, the scaled feeder diameters would result in approximately 50% longer feeder refill times than in the reactor.

Based on a flooding analysis, the larger pipe sizes used in the actual design result in more representative, yet still conservative, refill times. It should be noted, however, that flooding in elbows is also a function of the length of the horizontal runs. Since the RD-14M facility piping lengths are scaled 1:1, the horizontal runs, relative to their diameter, are much longer than in the reactor. This can result in conservative (longer) refill times.

A.4.1 Feeder Pipework Heat Losses

To minimize heat losses it was originally proposed to place "guard" heaters, between layers of insulation, on all below-header pipework. Inspection of this design revealed potential heater maintenance problems. To eliminate these problems, the trace heating design discussed in Section 5.500 was used.

Electrical heating tapes are wrapped directly onto the metal pipework and then covered with insulation. Feeders and end-fittings are all trace-heated in this way. With this trace heating design the total heat loss below the headers in each pass can effectively be limited to a few percent of total core power. This is comparable to the heat losses expected in full-scale reactors.

A.5 END-FITTING

During certain accident transients, separated flow will occur in the end-fittings. For such transients, the scaling laws developed in Reference [A.1] and applied to the rest of the RD-14M loop cannot be applied to the end-fittings. They require special consideration as outlined below.

The end-fittings do not behave as simple pipe sections in many of the accident transients. For example, experiments in the Cold Water Injection Test (CWIT) facility have shown that the end-fittings play a major role in the re-establishment of thermosiphoning following stagnation conditions. Analysis of this transient has shown that the heat capacity (metal mass) and the geometry of the end-fitting are very important. Under blowdown/refill transients, the fluid volumes (both stagnant and moving) and the pressure drops in the end-fitting are also important.

Direct application of the scaling laws based on homogeneous flow yields full-length reduced-diameter end-fittings. While such a design is adequate when the flow can be considered to be one-dimensional (homogeneous), it will severely distort any two-dimensional (separated flow) effects that occur. The latter will occur in the end-fittings under most two-phase low-flow conditions. To capture the phenomena expected and to reduce distortions, the end-fitting was designed to include those aspects deemed to be important.

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

In blowdown and refill transients, the delay of ECI penetration into a channel is related to the fluid volume and stored heat of the end-fitting. The thermal mass (heat storage capacity) also determines the timing of the re-establishment of natural circulation following a flow stagnation. In order to provide a reasonable simulation of end-fitting behaviour during these transients, both the fluid volumes and thermal masses of end-fittings must be scaled. Included as part of both is the so called "stagnant" fluid (i.e., the fluid in the liner tube between the closure and shield plugs). It acts as an additional source of channel coolant during blowdown and refill.

Under intermittent buoyancy-induced flow, recirculation flow patterns may be set up in the region of the end-fittings during the end-fitting heat-up periods. That is, steam produced in the channel and condensed in the end-fittings can flow back into the channel, driven by the gravity head within the end-fitting. To ensure a reasonable simulation of the flow patterns, it therefore was desirable to preserve the l/D ratio in this component.

The RD-14M end-fitting design requirements are summarized as follows:

- scaled moving and stagnant fluid volumes,
- scaled end-fitting metal masses (i.e., heat capacities), and
- conservation of the l/D ratio in the moving fluid annulus.

The scaled and "as designed" values obtained from these requirements are given in Table A.5.

The RD-14M end-fitting is designed/scaled starting with the outer fluid annulus. The scaled ID of this space is approximately 58 mm. This corresponds closely to the outside diameter of 2-inch (nominal) schedule-10 stainless steel pipe (60.3 mm). The scaled stagnant fluid volume contained within this pipe is 3 L. This requires a length of 1.4 m. Approximately 25% of the volume is located outboard of the feeder connection as in the reactor end-fitting.

The scaled moving fluid volume is 2 L. This, along with the requirement to maintain the l/D ratio of the annulus, yields a 1.18-m long, 74.3-mm (OD) annulus space.

REFERENCE

[A.1] Ingham, P.J., Krishnan, V.S., Sergejewich, P., and Ardron, K.H., "Scaling Laws for Simulating the CANDU Heat Transport System," Proceedings of the Second International Conference on Simulation Methods in Nuclear Engineering," Montreal, Canada, 1986 October 14-16 (reprinted at the end of this appendix).

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

NOMENCLATURE

A	Area (m^2)
C_W	Specific heat [J/(kg·°C)]
D	Hydraulic diameter (m)
l	Pipe length (m)
M	Mass (kg)
M‴	Mass per unit flow volume (kg/m^3)
N_{fi}	Friction number = $\left(\frac{\eta}{A^*}\right) i^2 \left(\frac{f\,l}{D} = K\right)_i$
N_C	Number of channels/pass
Q‴	Heat loss or gain per unit time per unit flow volume for pipe (W/m^3)
η	Factor (=1 for pipes below header, = N_c for pipes above header)

Subscripts

o	Reference property (defined in Section 2.2.1)
i	property of i'th pipe section
R	Ratio between model and reactor value, i.e., $A_R = A_{model}/A_{reactor}$
w	Property of pipe wall

Superscript

*	Dimensionless quantity

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

TABLE A.1

SCALING RATIOS OF PIPEWORK ABOVE HEADERS

Section	RD-14M Pipe Size (mm) ID	OD	Scaling Ratios([1]) $(A_l^*/N_c)_R$	$(l_l^*)_R$	$(N_{fi})_R$	$(M_w'''C_w)_R$
S/G Inlet	92.1	114.3	4.3	0.9	0.34	1.7
Pump Suction	92.1	114.3	4.3	0.8	0.3	1.7
Pump Discharge	66.7	88.9	3.6	1.6	0.99	2.4

[1] See "NOMENCLATURE" for definitions

TABLE A.2

RD-14M HEADER SCALING

Parameter	Scaled Inlet	Scaled Outlet	As Designed Inlet	As Designed Outlet
Inside Diameter (mm)	199	221	194	194
Header ID/Feeder ID	6.12	5.8	5.86	5.08
Fluid Volume (L)	12	15	15	17
Metal Mass (kg)	56	60	107	145

TABLE A.3

FEEDER SCALING

Reactor Pipe Nominal Size (inches)	Pipe ID (mm)	RD-14M Feeder Pipe: Scaled Values[1] Pipe ID (mm)	Scaled Values[1] Thickness (mm)	Actual Design Pipe ID (mm)	Actual Design Thickness (mm)
1½	38.1	16.6	2.2	21.0	2.9
2	49.2	21.4	2.4	26.6	3.4
2½	59.0	25.7	3.0	35.1	3.6
3	73.7	32.1	3.3	35.1	3.6
3½	85.4	37.1	3.5	40.9	3.7

[1] $(A_l^*)_R = 1$

TABLE A.4

SCALING RATIOS FOR THE FEEDERS

	Reactor	RD-14M	Scaling Ratios (c)					
Feeder	Pipe Nominal Size (a) (inches)	Pipe Nominal Size (b) (inches)	$(A_i^*)_R$	$(l_i^*)_R$	$(\sin_i)_R$	$(N_{fi})_R$ (d)	$(M_w'''C_w)_R$ (e)	$(Q_i''')_R$
INLET								
B10	2	1	1.55	0.90	1	0.72	1.14	1
L2	2	1	1.55	0.86	1	0.78	1.14	1
M11	2.5	1.25	1.86	0.97	1	0.54	0.85	1
	3	1.25	1.19	0.96		1.74	0.98	
O5	2.5	1.25	1.86	0.96	1	0.53	0.85	1
	3	1.25	1.19	0.96		1.72	0.98	
X12	2	1	1.55	0.88	1	0.80	0.98	1
OUTLET								
B10	2.5	1.25	1.86	0.65	1	0.36	0.85	1
L2	2.5	1.25	1.86	0.79	1	0.44	0.85	1
M11	2.5	1.25	1.86	0.95	1	0.53	0.86	1
	3.5	1.5	1.19	0.92		1.65	0.96	
O5	2.5	1.25	1.86	0.94	1	0.52	0.85	1
	3.5	1.5	1.19	0.93		1.67	0.96	
X12	2.5	1.25	1.86	0.80	1	0.45	0.85	1
	3	1.25	1.19	0.80		1.44	0.98	

Notes:
(a) Schedule 80
(b) Schedule 40
(c) See Nomenclature for definitions
(d) K factors neglected
(e) $Q_i \sim 0$ in both reactor and RD-14M

TABLE A.5

END-FITTING SCALING

Parameter	Scaled Value	Design Value
Moving Volume (L)	2.0	2.0
Stagnant Volume (L)	3.0	3.0
Metal Mass (kg)	50.0	49.9
Annulus l/D_h Ratio	72.4	70.0

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

The following was reprinted from the "Proceedings of the Second International Conference on Simulation Methods in Nuclear Engineering," held in Montreal, Canada, 1986 October 14-16.

SCALING LAWS FOR SIMULATING THE CANDU HEAT TRANSPORT SYSTEM

by

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ABSTRACT

The RD-14 test facility at Whiteshell Nuclear Research Establishment is a full-elevation model of a typical CANDU™ primary heat transport loop. It consists of two full-scale, full-power electrically heated channels, full-scale feeders and two full-height steam generators. The loop is designed so that fluid mass flux, transit times, and pressure and enthalpy distributions in the primary system are the same as in a typical power reactor in both forced and natural circulation.

To study the interaction between parallel channels in thermosiphoning and blowdown/emergency coolant injection transients, it is proposed to modify RD-14 to a multiple-channel configuration. A scaling rationale has been developed from a consideration of the one-dimensional, homogeneous, two-phase-flow conservation equations. The scaling laws show that to represent the CANDU™ system correctly, particularly under thermosiphoning conditions, the model loop must possess the full linear dimensions and elevation changes of the reactor.

The paper will describe the development of the scaling laws and their application in defining the sizes of the major loop components of the proposed multiple-channel RD-14 loop.

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NOMENCLATURE

A	Area (m^2)
C_w	Specific heat (J/(kg.°C))
d	Diameter (m)
e	Internal energy (J/kg)
f	D'Arcy friction factor = $\frac{\Delta p}{\rho u^2} \frac{2d}{l}$
g	Acceleration due to gravity (m/s^2)
G	Mass flux (kg/(m^2•s))
h	Enthalpy (J/kg)
K	Pressure loss coefficient
l	Pipe length (m)
m	Mass (kg)
m	Mass per unit flow volume (kg/m^3)
N_{fi}	Friction number = $\left(\frac{\eta}{A^*}\right)_i^2 \left(\frac{fl}{d} + K\right)_i$
N_c	Number of channels per pass
p	Pressure (N/m^2)
q_L	Pin power rating (W/m)
Re	Reynolds number
Q	Heat loss or gain per unit flow volume for pipe (W/m^3)
$\dot{Q}_f$	Heat entering fluid from wall/unit time (J/s)
Q_{LS}	Heat loss per unit time (J/s)
t	Time (s)
T	Temperature (°C)
u	Velocity (m/s)
V_f	Fluid volume (m^3)
W	Mass flow rate (kg/s)
X	Quality
z	Length coordinate (m)

Greek

α Void fraction

β Function defined by Equation (13) (kg/m^3)

Δh_{SUB} Subcooling (J/kg)

η Factor (for pipes below header = 1, for pipes above header = N_c)

Φ^2_{fo} Two phase multiplier = $(\frac{dp}{dz})_{TP}$ / $(\frac{dp}{dz})_{fo}$

ρ Density (kg/m^3)

θ_i Upward inclination from horizontal

Subscripts

g Steam property

f Water property

fo Value if two-phase mixture flowed as liquid at same mass flow rate

gf Difference between fluid and gas properties (e.g., $h_{gf} = h_f - h_g$)

o Reference property

i Property of i'th pipe section

$( )_R$ Ratio between model and reactor values. $(Re)_R = \frac{Re_{model}}{Re_{reactor}}$

SAT Saturation property

W Property of pipewall

EF Property of end fitting

TP Property of two-phase flow

Superscript

* Dimensionless quantity

- Steady state variable

INTRODUCTION

The RD-14 test facility (Figure 1) is a full elevation-model of a typical CANDU™ primary heat transport loop. It consists of two full-scale, full-power electrically heated channels, full-scale headers and two full-height steam generators in a figure-of-eight configuration. The number of U tubes in the steam generators is reduced in direct proportion to the heated channels to give the correctly scaled heat transfer area. The loop is designed so that fluid mass flux, transit times and pressure and enthalpy distribution terms in the primary system of the loop are the same as those in a typical reactor under both forced and natural circulation.

To study the interaction between parallel channels in thermosiphoning and blowdown/emergency coolant injection (ECI) transients the loop will be modified to a multichannel geometry. This paper describes the scaling rationale developed for this modification. Scaling requirements for the new configuration are identified. The scaling laws are used to define the sizes of major loop components in the multichannel RD-14 loop.

SCALING REQUIREMENTS

The primary requirement of the modified loop is that it must represent reasonably well the behaviour that occurs in a reactor during thermosiphoning and blowdown/ECI transients. Ideally, dynamic similarity should exist between the reactor and its model. If this is true, known scaling laws can be applied to experimental data, and reactor behaviour can be deduced.

In constructing a scale model of single-phase flow in a reactor, the necessary scaling requirements to achieve dynamic similarity can be derived by expressing the governing thermo-fluid equations in dimensionless form. Dynamic similarity between the model and the actual reactor is assured by matching the dimensionless parameters that appear in these equations. For example, Reynolds numbers in both model and reactor must be the same. Unfortunately, the application of this method to two-phase flow is not so simple is because the governing equations for two-phase flow depend on a large number of dimensionless groups. Simultaneous matching of all dimensionless groups in a scale model is usually impossible.

However, by using a simple set of conservation equations, like those of the homogeneous equilibrium model or drift-flux model, to represent the two-phase-flow, scaling criteria can be developed. Using this assumption, Ishii and Kataoka [1] developed a scaling rationale to model a Light Water Reactor (LWR) natural circulation loop. If the void/quality equation for the two phase mixture is of the form

$$\alpha = \alpha\ (X,\ \text{gas properties, liquid properties}) \qquad (1)$$

their scaling rules are valid. Equation (1) is obviously true for homogeneous two-phase flow, although Ishii and Kataoka suggest it may also apply to certain types of churn-turbulent flow.

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

In this paper the approach of Ishii and Kataoka [1] is used to develop scaling criteria for multichannel RD-14 loop. The importance of certain dimensionless groups in CANDU reactor geometries (identified by Ishii and Kataoka for LWR's) will be highlighted. Model development is described below.

DEVELOPMENT OF SCALING LAWS

Characteristic Parameters

The multichannel RD-14 test loop is assumed to consist of N_c channels per pass (Figure 2). At steady thermosiphoning conditions, with the loop operating at reactor typical temperatures and pressures, the mass flow in all channels is assumed equal.

Most of the loop can be described as several pipe lengths of uniform area connected in series and parallel. These pipe lengths can represent sections of a feeder, a riser, a heated channel, or a bank of parallel boiler tubes. Channel end fittings, and headers, cannot be represented as simple pipes and are considered separately.

If the steady thermosiphoning flow rate in the feeders and heated channels is W_o, then the flow rate in pipe sections above the headers is $N_c W_o$. If ρ_o is the saturated liquid density and A_o the flow area of the channel, then the characteristic velocity $\bar{u}_o$ can be defined as

$$\bar{u}_o = \frac{W_o}{\rho_o A_o} \tag{2}$$

Analysis

To simplify development we will neglect interphase slip, and momentum flux terms, which are small at the low mass velocities encountered in thermosiphoning. The headers will be considered as a point source with no volume, and hence no mass energy.

Assuming one-dimensional flow, the transient conservation equations in pipe section i can be written as follows:

Mass Conservation

$$\frac{\partial \rho_i}{\partial t} + \frac{\partial(\rho_i u_i)}{\partial z} = 0 \tag{3}$$

Momentum Balance

$$\rho_i \left(\frac{\partial u_i}{\partial t} + \frac{u_i \partial u_i}{\partial z}\right) = \frac{-\partial p_i}{\partial z} - 1_i \rho_i g \sin\theta_i + \tfrac{1}{2} \rho_i u_i^2 \; \Phi^2_{foi} \left(\frac{fl}{d} + K\right)_i \tag{4}$$

APPENDIX A: SCALING: RD-14M DESIGN RATIONALE

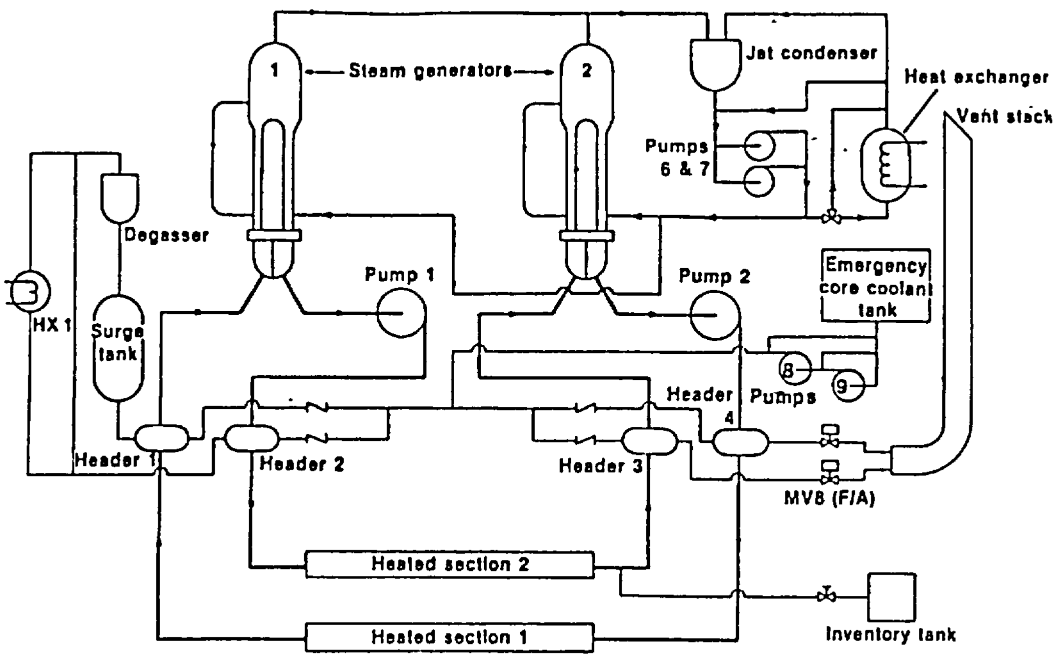

FIGURE 1: RD-14 Loop Schematic

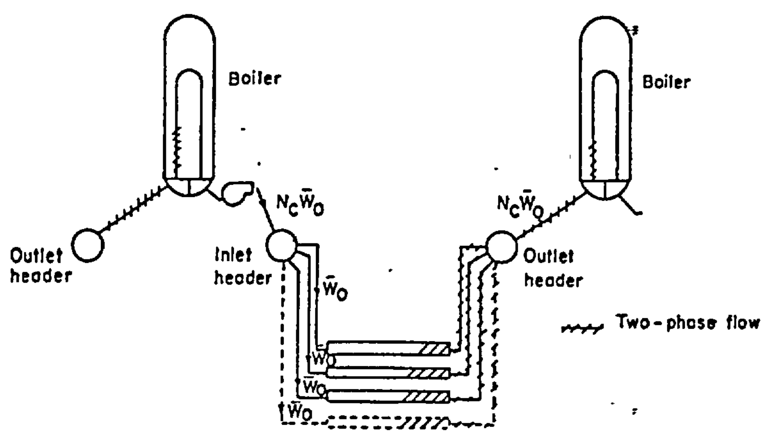

FIGURE 2: Schematic of Multichannel Facility in Steady Thermosiphoning (Single Pass Only Shown)

Energy Balance

$$\rho_i \frac{Dh_i}{dt} - \frac{Dp}{dt} = Q_i \qquad (5)$$

The mean volumetric heat source, Q_i, consists of components due to a heat source, Q_{iHS}, within the pipe section, heat loss through the pipe wall, Q_{iHL}, and the accumulated heat term Q_{iA}:

$$Q_i = Q_{iHS} - Q_{iHL} + Q_{iA} \qquad (6)$$

In a transient, an important component of the volumetric heat source is due to the release of thermal energy stored in the pipe walls and fuel [1,2]. This can be written as

$$Q_{iA} = - M_{wi} C_{wi} \frac{\partial T_{wi}}{\partial t} \qquad (7)$$

where M_{wi} is the wall mass per unit flow volume for pipe section i. In slow transients, the wall temperature, Tw,can be assumed as equal to the fluid temperature, T, Equation (7) becomes

$$Q_{iA} = M_{wi} C_{wi} \left(\frac{dT}{dp}\right)_{SAT} \frac{\partial p_i}{\partial t} \qquad (8)$$

Substituting Equation (7) into (5), we get

$$\rho_i \frac{Dh_i}{dt} - \frac{Dp}{dt} = Q_i - M_{wi} C_{wi} \left(\frac{dT}{dp}\right)_{SAT} \frac{\partial p_i}{\partial t} \qquad (9)$$

If we define the following dimensionless parameters:

$$l^* = \frac{l}{l_o},\ t^* = \frac{t\bar{u}_o}{l_o},\ A^* = \frac{A}{A_o},\ u^* = \frac{u}{\bar{u}_o},$$

$$p^* = \frac{p}{p_o},\ \rho^* = \frac{\rho}{\rho_o},\ h^* = \frac{h}{h_{gf}},\ T^* = \frac{T}{T_o}$$

Where l_o, is the reference length, p_o is the reference pressure, T_o the reference temperature and h_{gf} the latent heat of vaporization at pressure p_o, we can rewrite equations (3), (4) and (9) in dimensionless form.

Mass

$$\frac{\partial \rho_i^*}{\partial t^*} + \frac{\partial}{dz^*} (\rho_i^* u_i^*) = 0 \qquad (10)$$

Momentum

$$\rho_i^* \frac{Du_i^*}{Dt^*} + \left(\frac{p_o}{\rho_o \bar{u}_o^2}\right) \frac{\partial p_i^*}{dz^*} + \rho_i^* l_i^* \left(\frac{l_o g}{\bar{u}_o^2}\right) \sin\theta_i = \frac{1}{2} \rho_i^* N_{fi} \Phi^2_{foi} \qquad (11)$$

Energy

$$\rho_i \frac{DX_i}{Dt^*} + \left(\rho_i^* \beta^* - \frac{P_o}{\rho_o h_{gf}}\right) \frac{Dp_i^*}{DT^*} + \left[M_{wi} \; C_{wi} \; \frac{dT}{dp}_{SAT} \; \frac{P_o}{h_{gf}\rho_o}\right] \frac{\partial p_i^*}{\partial t^*} = \frac{Q_i l_o}{h_{gf}\rho_o u_o} \qquad (12)$$

Where B* is defined as follows:

$$\beta^* = \left[\left(\frac{dh_g}{dp}\right)_{SAT} X + \left(\frac{dh_f}{dp}\right)_{SAT} (1-X)\right] \frac{P_o}{h_{gf}} \qquad (13)$$

Auxiliary Equations

Density ρ_i is related to X_i, the quality, by the following relationship:

$$\rho_i = \rho_i \; (X_i, G_i, \text{gas properties, fluid properties}) \qquad (14)$$

The two-phase friction factor can be expressed in various ways. We will assume the following form:

$$\Phi_{foi} = \Phi_{foi} \; (X_i, G_i, \text{gas properties, liquid properties}) \qquad (15)$$

The equations of Dukler et al. [3], Baroczy [4] and Thom [5] are all expressed in this empirical form.

Scaling Laws

For the loop model to have the same transient response as the reactor, the nondimensional paramenters appearing as coefficients in Equations (10), (11), and (12) must be equal in both model and reactor. For example, the ratio of Reynolds number in the model to the Reynolds numbers in the reactor $(Re)_R$ must equal unity.

Therefore for dynamic similarly between the model and reactor the following scaling laws must be obeyed.

$$(\rho_i^*)_R = 1 \qquad (16)$$

$$(u_i^*)_R = 1 \qquad (17)$$

$$(l_i^*)_R = 1 \qquad (18)$$

$$\left(\frac{A_i^*}{\eta_i}\right)_R = 1 \qquad (19)$$

$$(\Phi^2_{foi})_R = 1 \qquad (20)$$

$$(\sin\theta_i)_R = 1$$

$$(N_{fi})_R = 1 \qquad (22)$$

$$(M_{wi}C_{wi})_R = 1 \qquad (23)$$

$$\left(\frac{Q_i l_o}{h_{gf}\,\rho_o u_o}\right)_R = 1 \qquad (24)$$

$$\left(\frac{g l_o}{\overline{u}_o^{\,2}}\right)_R = 1 \qquad (25)$$

$$(\beta_i^*)_R = 1 \qquad (26)$$

Some of the dimensionless group are automatically satisfied because of equations (10), (11), (12), (14) and (15), and the fact that the model operates at the same pressure as the reactor. If we remove the redundant equations, seven fundamental scaling laws are apparent.

$$(A_i^*)_R = \begin{cases} 1 & \text{pipe sections below headers} \\ N_c & \text{pipe sections above headers} \end{cases} \qquad (27)$$

$$(l_i^*)_R = 1 \qquad (28)$$

$$(\sin\theta_i)_R = 1 \qquad (29)$$

$$(N_{fi})_R = 1 \qquad (30)$$

$$(Q_i)_R = 1 \qquad (31)$$

$$(M_{wi}C_{wi})_R = 1 \qquad (32)$$

$$(l_o)_R = 1 \qquad (33)$$

Equations (27) to (29) imply similarity of pipe length and areas between model and reactor. The most suprising scaling requirement is Equation (33). This implies that the model must have full-scale pipe lengths and be of full height. Ishii and Kataoka [1] identified their requirement in their scaling analysis for an LWR type system, but did not stress its importance. The full-length requirement arises because of a component in the pressure gradient term, $\frac{\partial p_i^*}{\partial z^*}$, in Equations (11) and (12). An important parameter in characterising this gradient is the gravitational group that appears in Equation (11), $\left(\frac{l_o g}{\overline{u}_o^{\,2}}\right)$, which contains the full length requirement term, l_o. If it is not met quality changes around the loop caused by elevation changes will not be reproduced. Boiling as a result of elevation change is important in determining the void distribution in a CANDU system during two-phase thermosiphoning [6,7]. Partial length scaling will reduce the importance of this effect and will generate distortions in the transient response of the system.

Equations (27) to (33) form the complete set of scaling laws. When obeyed, transient and steady-state thermosiphoning behaviour will be the same in both reactor and model. These scaling laws only apply if the homogeneous flow model, used to describe the system, is valid.

LOOP SPECIFICATIONS

Heated Sections

A CANDU reactor has up to 120 parallel channels per pass per loop. The coolant flow in each channel is approximately one hundredth of the system flow per loop. To simulate the parallel-channel behaviour of CANDU reactor it is desirable to have as many channels as possible. However, the size and number of channels in the RD-14 test facility is limited by the design of the existing loop.

Steam generators and pumps in RD-14 were scaled for a single 37-element, 5.5 MW channel per pass. Loop flow areas were similarily scaled. Thus for a multichannel geometry, the sum of the individual channel flow areas must correspond to that of a single 37-element channel. Other criteria must also be satisfied.

To maintain the same element heat flux at a given power, the total number of elements in a multichannel pass should equal the original single channel design. The heaters should also have a ring geometry as in a CANDU reactor. Three parallel channel geometries will satisfy these requirements: (a) two 18-element channels (b) three 12-element channels and (c) five 7-element channels per pair.

Very strong interactions between channels are expected to occur with the two and three channel geometries. This would not be representative of a typical CANDU reactor. The five-channel geometry was chosen for two reasons. It has weaker channel to channel interactions, and seven element channels were used in earlier RD-12 experiments.

Each channel will have the full heated length of 6 m, satisfying Equation (33). Seven electrically heated fuel element simulators (FES), as per current RD-14 design, will be used in each channel. The geometry of the FES will correspond to the seven central elements of a typical CANDU fuel bundle. Since a typical CANDU bundle contains 37 fuel elements, the flow in a seven-element channel will be reduced proportionately. Major characteristics of the heated channels are listed in Table 1. Based on this heated channel design, the scaling ratios given in Equations (27) to (32) are listed in Table 2. Certain nominal operating conditions for thermosiphoning flow have been assumed for both loop and reactor. These conditions, based on available RD-14 data, are an average pin power rating q_L = 0.9 kW/m, p_o = 4 MPa and $\bar{u}_o$ = 0.36 m/s. These values correspond to a reactor channel decay power of 200 kW and a channel flow of 1 kg/s. It should also be noted that with the proposed channel design, Equation (31) requires that the average pin power rating, q_L, be the same in both loop and reactor.

Channel End Fittings

It is obvious that these end fittings cannot be represented as uniform area pipes. The previously developed scaling rules are therefore not applicable. Pressure and heat losses, plus heat capacity requirements for the end fittings can, however, be developed. To obtain approximate scaling rules for the end fitting geometry, we write integral momentum and energy balances, as shown below.

TABLE 1

HEATED CHANNEL CHARACTERISTICS

	RD-14	Reactor
Flow Tube Diameter (mm)	44.8	103
Flow Area (mm^2)	647.2	3421
Flow Tube Thickness (mm)	6.1	4.3
Hydraulic Diameter (mm)	6.07	7.5
Pin Outside Diameter (mm)	13	13
Pin Number	7	37
Pin Heat Capacity (at 250°C) (kJ/(m.°C))	0.38	0.37

TABLE 2

VALUES OF SCALING RATIOS FOR HEATED SECTION

$(A_i^*)_R$	$(l_i^*)_R$	$(\sin\theta_i)_R$	$(N_{fi})_R$	$(Q_i)_R$	$(M_wC_w)_R$
1	1	1	1.29[a]	1.01[b]	1.03[c]

Notes:
(a) K factors are neglected.
(b) Assumes heat loss for multichannel loop is 550 W and reactor channel heat loss is 8 kW
(c) Assume heat capacity of reactor fuel and FES are 0.37 kJ/(m.°C)[10] and 0.38 kJ/(m.°C), respectively.

The frictional pressure loss in the end fitting when steady two-phase flow occurs is

$$\Delta p = \Phi_{fo}^2 \, K_{EF} \, \frac{1}{2} \, \rho_o u_o^2 \qquad (34)$$

Written in dimensionless form, Equation (34) becomes

$$\Delta p^* = \Phi_{fo}^2 \, K_{EF} \, (\rho_o u_o^2 / 2 p_o) \qquad (35)$$

But p_o, ρ_o and Φ_{fo}^2 are the same in both model and reactor. The scaling requirement becomes

$$(K_{EF})_R = 1 \qquad (36)$$

The frictional pressure loss coefficient K_{EF} is expressed in terms of the velocity head of the heated channel.

The integral energy balance for the fluid inside the end fitting is

$$V_f \frac{\partial}{\partial t}(e\rho) = -W\Delta h + \dot{Q}_w \qquad (37)$$

where $\dot{Q}_w$, is the energy in the form of heat entering the wall per unit time, V_f, is the fluid volume and e, the fluid internal energy.

For the end-fitting metal work the energy balance can be written as

$$-M_c C_w \left(\frac{\partial T_w}{\partial t}\right) = \dot{Q}_w + Q_{HL} \qquad (38)$$

Eliminating $\dot{Q}_w$ and transforming the dimensionless variables we get

$$\Delta h = -\left(\frac{V_f}{l_o A_o}\right)\frac{\partial}{\partial t^*}(e^* \rho^*) - \frac{M_w C_w T_o}{l_o A_o \rho_o h g_f}\left(\frac{\partial T_w^*}{\partial t^*}\right) - \left(\frac{Q_{HL}}{\rho_o u_o A_o h_{gf}}\right) \qquad (39)$$

For similarity the following scaling laws must be satisfied.

$$(V_f / A_o l_o)_R = 1 \qquad (40)$$

$$(M_w C_w / A_o l_o)_R = 1 \qquad (41)$$

$$(Q_{HL} / A_o)_R = 1 \qquad (42)$$

Equations (40) to (42) show that fluid volume and heat capacity of the end fittings should be scaled in direct proportion to channel volume. End-fitting heat losses must be reduced in direct proportion to channel flow area.

For similarity, Equations (36) and (40) to (42) should be satisfied. End fitting scaling ratios are given in Table 3.

TABLE 3

SCALING RATIOS FOR END FITTING

$(K_{EF})_R$	$(V_f/A_o l_o)_R$	$(M_w C_w/A_o l_o)_R$	$(Q_{LS}/A_o)_R$
1	1	1	0.9[a]

Notes: (a) Reactor-end fitting heat loss was taken as 3 kW. Model end-fitting heat loss was estimated from RD-14 measurements. A value approximating to 7/37 of the RD-14 37-element channel end fitting heat loss was used.

Feeders

Five reactor-channel/feeder geometries have been selected to represent CANDU feeders; three middle channels, one top channel and one bottom channel. Channels were chosen as follows:

(1) The channels should cover the full range of elevation differences.
(2) The five-channel average powers should equal the core average power.
(3) The five-channel average flows should equal the core average flow.
(4) Feeder geometries should cover the range of pipe diameters, horizontal lengths, and flow restricting orifices present in the reactor.
(5) Nozzle angles, at header connections, should cover the range found in a reactor.

Table 4 lists relevant data for selected channel/feeder geometries or a typical CANDU reactor. Figure 3 shows the feeder geometry for reactor channel X 12.

Model feeders, where possible, will have the same lengths and geometries as reactor feeders. Diameters and wall thicknesses should be reduced according to the scaling requirements of Equations (27) and (32). To manufacture piping sections with the exact diameters and wall thicknesses specified by the scaling laws would be costly. For practical purposes, commercially available pipe sizes will be used. This will result in some scaling distortions (see Table 5).

Data from the existing RD-14 loop indicates that, at a 4 MPa operating pressure, heat losses from lagged feeders in the multichannel loop will be 5-10 kW/channel. At thermosiphoning conditions, where power levels are at decay levels, with an average pin power rating of 0.9 kW/m, 12-25% of the channel input power could be dissipated through heat losses. This is a significant heat loss when compared with reactor feeder losses.

In a reactor, feeder lines are enclosed in cabinets. At 4 MPa, and typical reactor decay power levels, heat losses are expected to be less than one percent of the channel power.

This discrepancy between the multichannel loop and the reactor will lead to a significant distortion in $(Q_i)_R$ ratios. A more serious problem is that with such high heat losses in the multichannel loop the void distribution around the loop will not be reactor typical. To avoid this problem feed pipework in the multichannel loop will be trace heated to eliminate heat losses.

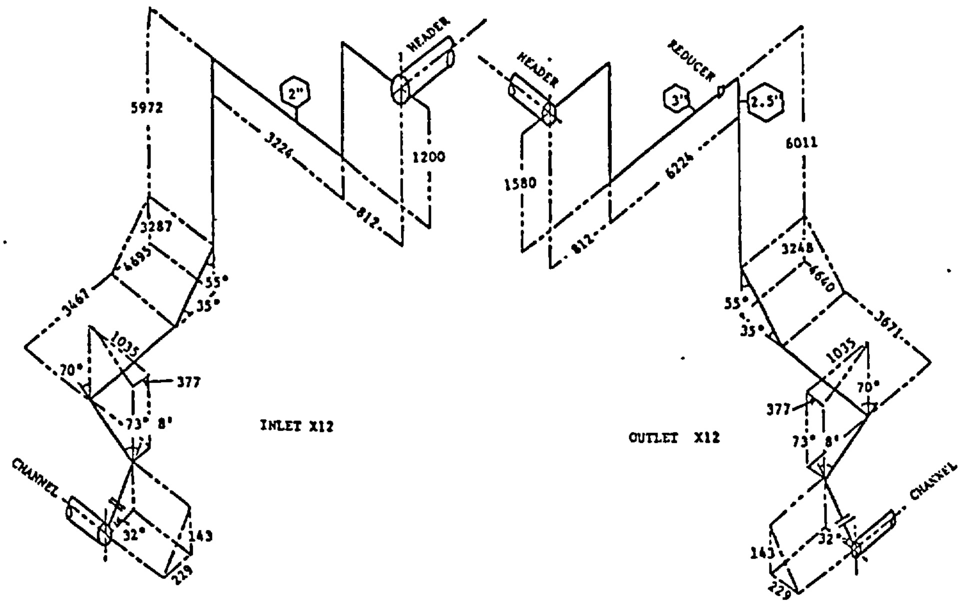

FIGURE 3: Reactor Feeder Geometry for Channel (X 12)

Pipework Above Headers

Existing RD-14 pipework will be used above the headers. Scaling ratios with respect to a CANDU 600 reactor are given in Table 6.

Significant distortions from ideality are apparent. However, the deviations are not considered critical since they will not have a major effect on loop behaviour. Primarily this is because the above header pipe lengths in both reactor and the multichannel facility are small when compared to the rest of the primary circuit. Pressure drops for the above header pipework in both the RD-14 facility and a typical reactor are comparable. (≈20% of the total loop pressure drop.)

Boilers

The RD-14 boilers are recirculating U-tube steam generators. They closely resemble reactor boilers and have a reduced number of tubes. Boiler characteristics are summarized in Table 7.

Scaling ratios are listed in Table 8. All values are close to unity.

TABLE 4
DATA ON REACTOR FEEDER/CHANNEL GEOMETRIES

Channel	Power (MW)	Flow (kg/s)	Elevation Difference[a] (m)	Header Connection (deg)	Notes
H10	4.9	19.07	+3.003	54	Outer core, upper elevation channel. No horizontal pipe sections near channel. Close to minimum restricting orifice size
L2	5.1	20.97	+0.429	54	Outer core mid-elevation channel. No horizontal pipe sections near channel. Large restricting orifice.
M11	6.5	23.6	+0.143	90	Inner core, mid-elevation high power channel. Long horizontal section near channel. No orifice.
O5	6.4	24.25	-0.429	18	Inner core, mid-elevation high power channel. Representative geometry.
X12	4.8	20.20	-3.003	90	Outer core, low-elevation channel. Long horizontal section near channel. No orifice.

Notes:

(a) Measured with respect to core centre.

TABLE 5

SCALING RATIOS FOR FEEDER X 12

REACTOR PIPE NOMINAL SIZE (a)	MULTICHANNEL LOOP PIPE NOMINAL SIZE (b)	$(A_i)_R$	$(N_{fi})_R$ (c)	$(Q_i)_R$ (d)	$(M_wC_w)_R$
2	1	1.55	0.74	1	1.14
2½	1¼	1.86	0.53	1	0.85
3	1½	1.19	1.7	1	0.98

Notes:
(a) Schedule 80 pipe
(b) Schedule 40 pipe
(c) K factor's neglected
(d) Assume Q_i=0 in reactor and multichannel loop.

TABLE 6

SCALING RATIOS FOR PIPES ABOVE HEADERS
(CANDU 600 REACTOR GEOMETRY)

DESCRIPTION	$(A_i^*/N_c)_R$	$(l_i^*)_R$	$(\sin\theta_i)_R$	$(N_{fi})_R$	$(Q_i)_R$	$(M_wC_w)_R$
Steam Generator Inlet	4.3	0.9	-	0.34	1[a]	1.7
Pump Suction	4.3	0.8	-	0.3	1[a]	1.7
Pump Discharge	3.6	1.6	-	0.99	1[a]	2.4

Notes: (a) Assume Q = 0 in multichannel loop and reactor.

TABLE 7

RD-14 BOILER CHARACTERISTICS

	RD-14	Reactor
Number of tubes	44	3550
Tube I.D. (mm)	13.6	13.8
Tube O.D. (mm)	15.8	16.0
Tube wall thickness (mm)	1.1	1.1
Tube material	Incaloy-800	Incaloy-800
Average tube length (m)	18.8[(a)]	17.5[(a)]

Notes: (a) Average based on total heat transfer area.

TABLE 8

SCALING RATIOS FOR BOILER TUBE BANK

$(A_i^*/N_c)_R$	$(l_i^*)_R$	$(\sin\theta_i)_R$	$(N_{fi})_R$	$(Q_i)_R$	$(M_wC_w)_R$
1.2	1.1	1.0	0.7	1.0	1.0

Headers

Flow patterns in the headers will be highly three dimensional. This means that scaling laws developed for pipe components cannot be applied.

In certain two-phase thermosiphoning transients, and during blowdown and refill in a reactor loop, the flow in the headers will most likely stratify. Stratified flow will affect the quality of fluid supplied to the channels connected to the headers.

To simulate the correct quality distribution in the multichannel loop, headers will be constructed with the same feeder to header-diameter ratio as in a typical reactor. Feeders in the multichannel loop will be positioned at angles typical of a reactor. These requirements will effectively simulate phase separation and feeder nozzle uncovering phenomena in the modified loop. However, with this geometry, scaling of fluid flow path lengths is not possible, although transit times will be maintained since volumes will be scaled.

To obtain the desired wall temperatures and stored heat terms in the modified loop, the metal mass of the headers should be correctly scaled. Given that the previous scaling rationale for the headers is followed, the headers would have to be constructed from thin piping. To satisfy pressure vessel code requirements, and to maintain structural integrity, piping of a much larger thickness must be used. The header design is shown in Figure 4.

DISCUSSION

The scaling laws developed are applicable to two-phase flows that occur in thermosiphoning and in blowdown/emergency-coolant injection transients. The scaling rationale only applies if the flow is well mixed and the void/quality relationship for homogeneous flow can be applied (Equation (14)). For separated flow behaviour, like horizontal stratified flow or horizontal/vertical annular flow, Equation (14) is not usually valid. If these flow regimes occur, departures from similarity between reactor and loop behaviour are expected. A brief discussion of some of the expected departures from homogeneous flow in horizontal and vertical loop pipework is included below.

Horizontal Channel Behaviour

The onset of stratified flow in horizontal channels is expected to be important in determining the behaviour of the test facility in thermosiphoning. Flow stratification will uncover the upper elements of fuel assemblies, leading to reduced channel to coolant heat transfer. With perfect scaling, flow stratification in the loop and reactor would occur at identical conditions.

Kowalski and Krishnan [8] made detailed studies of the transition to stratified flow in a seven-rod channel. The channel geometry used was almost identical to that proposed for heated sections in the modified multichannel loop. In their study they developed a correlation for the transition to stratified flow. The correlation agreed well with both their own experimental data and that of Aly [9] and Sawamura et al. [10]. The latter workers used a 37 rod CANDU channel geometry.

Using dimensionless variables defined previously, Kowalski and Krishnan's correlation can be written

$$\rho^{*}.u^{*} = f(X,\ \text{fluid and gas properties}) \sqrt{\frac{gA_o}{d_o \bar{u}_o^2}} \qquad (43)$$

Stratified flow will occur if the left hand side of Equation (43) is less than the right hand side.

Since ρ^*, u^*, X, $\bar{u}_o$, gas and fluid properties will be equal when scaling laws are obeyed, if $\sqrt{(A_o/d_o)_R}$ is unity, stratification will occur under similar conditions in both the loop and the reactor. The actual scaling ratio is in fact given by $\sqrt{(A_o/d_o)_R} = 0.66$. This implies that stratified flow will occur at a loop mass flux, which is approximately 30% lower than in a typical reactor. This is well within uncertainties normally associated with predictions of flow regime transitions.

Figure 5 shows the transition to stratified flow for 7- and 37-rod geometries as predicted by the Kowalski-Krishnan model. Sawamura's data [10] is also shown. There is reasonable agreement between the two curves.

Feeder Geometries

Under some conditions the penetration of water downwards into the feeders may be limited by flooding caused by steam upflow [11]. This phenomenon is expected during loop blowdown and refill. In a feeder, the minimum steam upflow, to prevent water downflow, is expected to follow an equation of the form:

$$\frac{j_g}{(gd\rho_{fg/\rho})}^{\frac{1}{2}} = K \qquad (44)$$

where K is a constant fixed by feeder geometry. Transforming Equation (44) to a dimensionless form, we get

$$(\rho^* u^*)\text{min} = f\ (x,\ \text{gas properties, fluid properties}) \left(gd/\bar{u}_o^2\right)^{\frac{1}{2}} \qquad (45)$$

The model feeders have approximately one quarter the cross sectional area of reactor feeders. Therefore liquid downflow in the modified loop will be prevented at a steam mass flux, which is 70% of that in a typical reactor. As a consequence, channel refilling in the loop may take longer than in a reactor.

SUMMARY AND CONCLUSIONS

Scaling laws have been developed and applied to the design of a multichannel loop. Consideration has been given to themosiphoning, blow down and ECI transients. The scaling laws are consistent with those derived by Ishii and Kataoka [1].

The importance of maintaining full linear dimensions and elevation changes present in a typical CANDU reactor has been stressed. If this requirement is not met, simulation of the reactor void distribution, caused by elevation induced flashing, will not be possible in the multichannel loop.

The main features of the multichannel loop design are summarized in Table 9.

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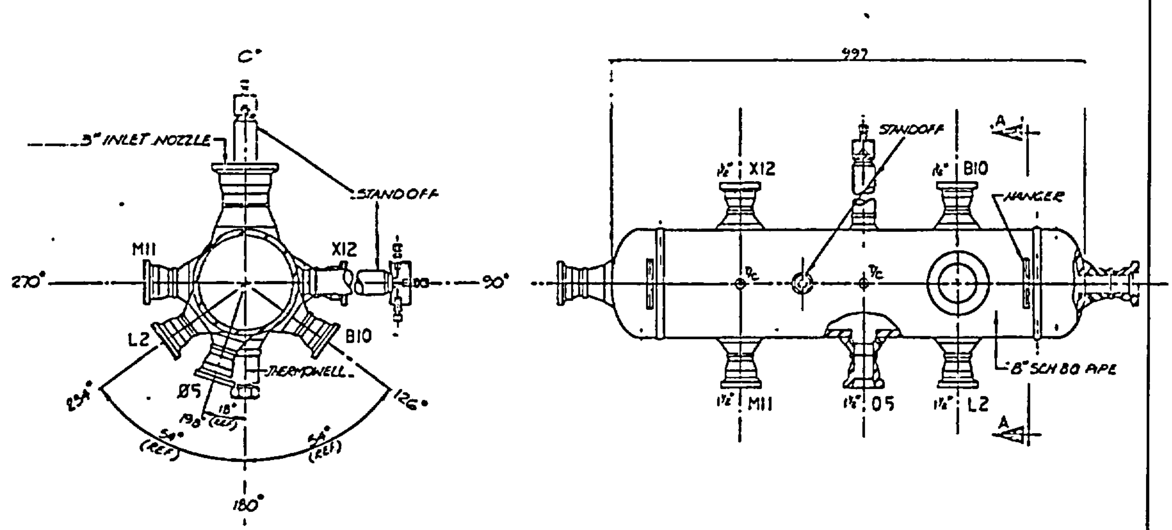

Section
'A-A'
Inlet Header

Plan
Inlet Header

FIGURE 4: Typical RD-14 Inlet Header Design

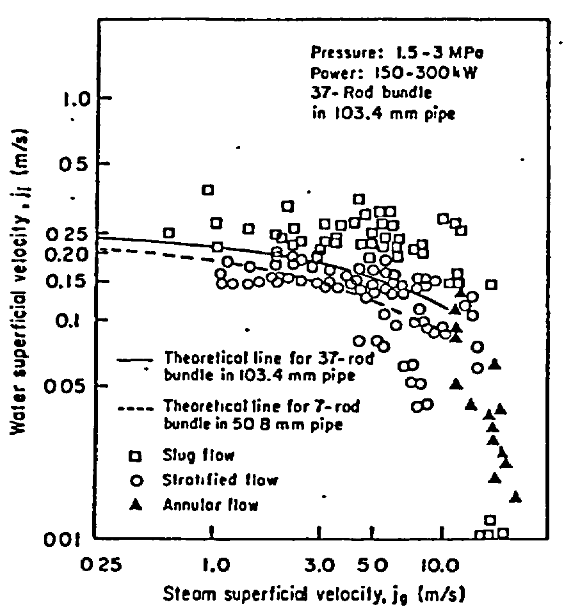

FIGURE 5: Predicted Transition to Stratified Flow for 37-Rod and 7-Rod Channel Geometries. Data of Sawamura et al. [10]

TABLE 9

DESIGN FEATURES OF PROPOSED FACILITY

Heated Channels	5 channels/pass. 7 full-heated length FES/ channel. (Model channel flow area)/(Reactor channel flow area = 7/37
End Fittings	(Model fitting metalwork mass)/(Reactor end-fitting metalwork mass) = 7/37 Model end-fitting fluid Vol.)/(Reactor end-fitting vol.) = 7/37 Model end-fitting K factor) = (Reactor end-fitting K factor)
Feeders	Model feeders = full-length scale, height scale models of typical reator feeders for one top, one bottom and three middle channels (Model feeder flow area)/(Reactor feeder flow area) = 0.2 - 0.3
Headers	Feeder nozzles at reactor-typical angles (Header to feeder diameter) R = 1
Components Above Headers	Unchanged from present build of RD-14
Heat Losses	Feeders, headers, SG inlet, exit pipework surrounded by guard heaters to reduce heat losses to reactor levels

REFERENCES

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3. A.E. Dukler, M. Wicks and B. Cleveland, "Frictional Pressure Drop in Two-Phase Flow: An Approach Through Similarity Analysis", AIChE J. 10, 44-51 (1984).

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5. J.R.S. Thom, "Prediction of Pressure Drop During Forced Circulation Boiling of Water", Int. J. Ht. Mass Transfer 7, 709-724 (1964).

6. K.H. Ardron and V.S. Krishnan, "Stability of Two-Phase Natural Circulation in a Natural Circulation Loop with Figure-of-Eight Geometry", Proc. 3rd Multiphase Flow and Heat Transfer Symposium Workshop, Miami Beach, Fla, USA, 1983 April 18-20.

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8. J.E. Kowalski and V.S. Krishnan, "Flow Regime Transitions in Horizontal Pipes Containing Rod Bundles", International Symposium on Fundamental Aspects of Gas-Liquid Flows", ASME Winter Meeting, Miami, USA, Nov. 17-21, 1985.

9. A.M.M. Aly, "Flow Regime Boundaries for an Interior Subchannel of a Horizontal 37-Element Bundle", Can. J. Chem. Eng. 59, 158-163 (1981).

10. O. Sawamura, M. Wakayama, A. Hosokawa, H. Kusuroki, J. Nagashima and A. Inoue, "Experimental and Analytical Study of Flow Stratification in a Horizontal Fuel Channel", Proc. 3rd CNS Annual Conf., Toronto, 1982.

11. K.H. Ardron, V.S. Krishnan, J.P. Mallory and D.A. Scarth, "Studies of Hot-Wall Delay Effects Pertinent to CANDU LOCA Analysis", paper presented at ANS/ENS Meeting on Thermal Reactor Safety, Karlsruhe, FRG, 1984 Sept.

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

The following schematics and engineering drawings are given in this appendix:

Title	Drawing Number
RD-14M Loop Flow Diagram	A0-30W54-F1
RD14M Channel Geometry Flow Diagram: Test Sections TS5-TS9	A0-45W05-F1
RD14M Channel Geometry Flow Diagram: Test Sections TS10-TS14	A0-45W05-F1
RD14M Channel Geometry Isometric Arrangement: Below Header Piping to/from HDR6 and HDR7	A2-45W05-58
RD14M Channel Geometry Isometric Arrangement: Below Header Piping to/from HDR5 and HDR8	A2-45W05-59
RD-14M Channel Geometry Assembly and Details: Inlet Header HDR5	A0-45W05-A1
RD-14M Channel Geometry Assembly and Details: Inlet Header HDR6	A0-45W05-A2
RD-14M Channel Geometry Assembly and Details: Inlet Header HDR7	A0-45W05-A3
RD-14M Channel Geometry Assembly and Details: Inlet Header HDR8	A0-45W05-A4

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

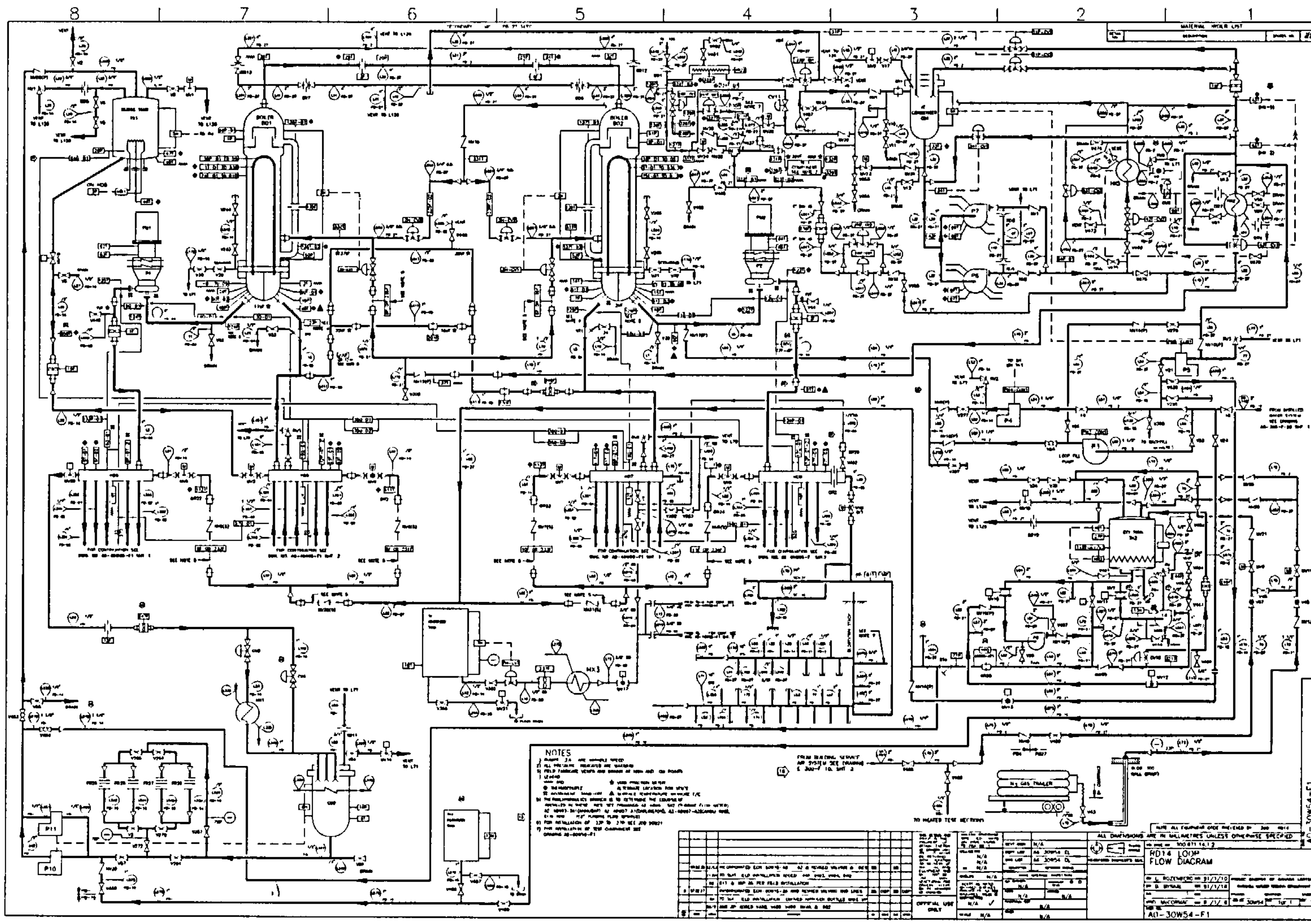


FIGURE B.1: RD-14M Loop Flow Diagram (Drawing A0-30W54-F1)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

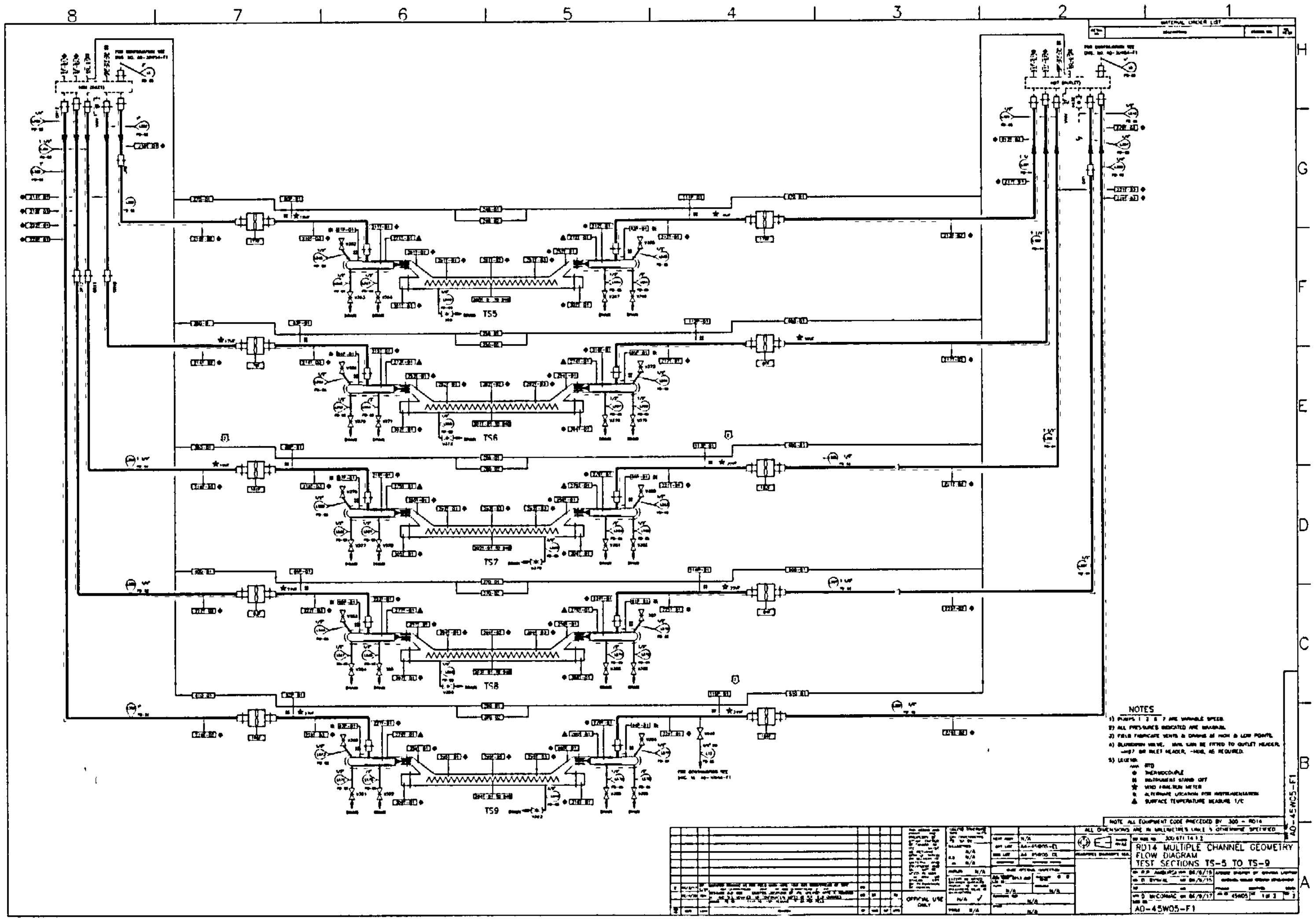


FIGURE B.2: RD-14M Channel Geometry Flow Diagram: Test Sections TS5-TS9 (Drawing A0-45W05-F1)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

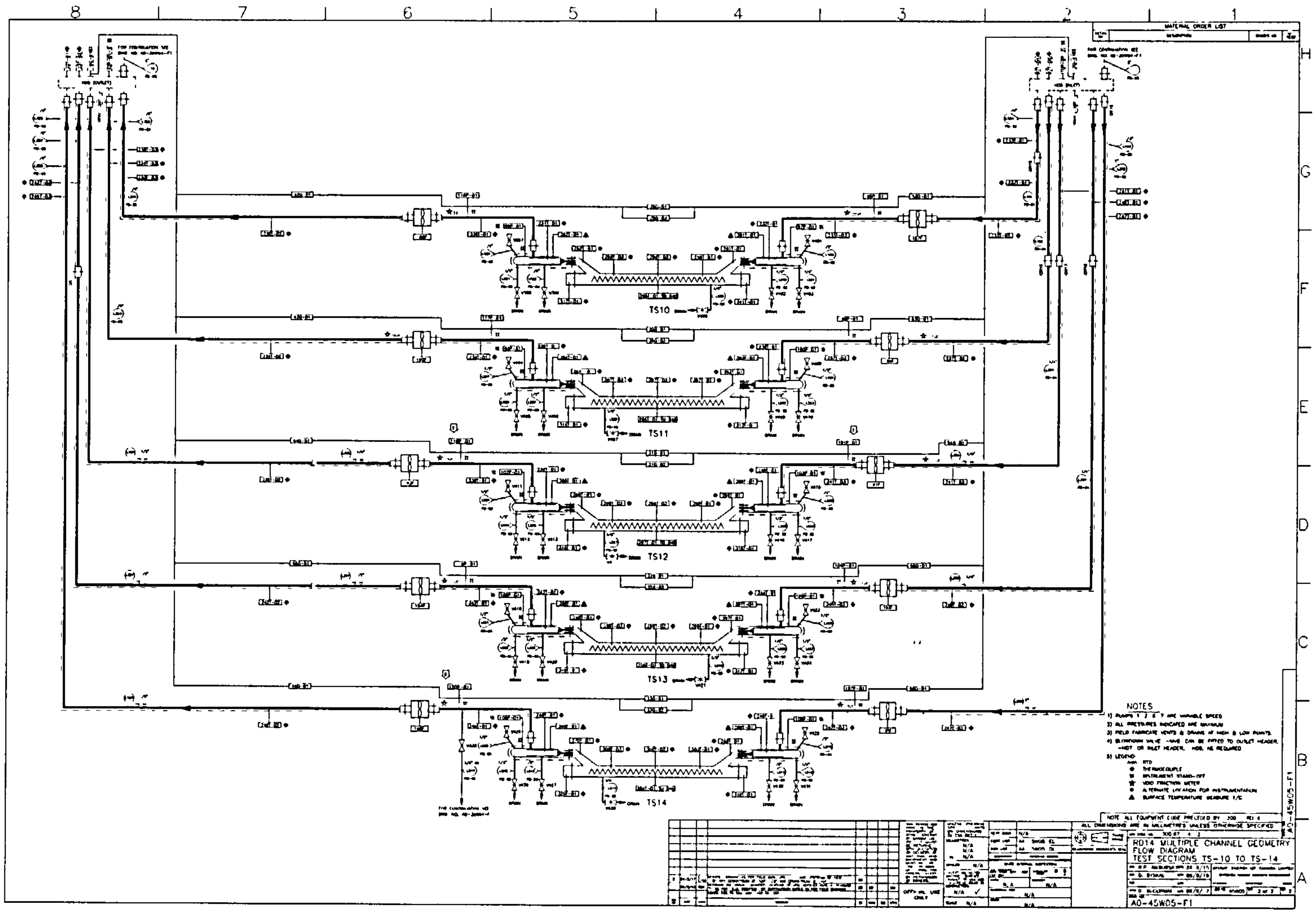


FIGURE B.3: RD-14M Channel Geometry Flow Diagram: Test Sections TS10-TS14 (Drawing A0-45W05-F1)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

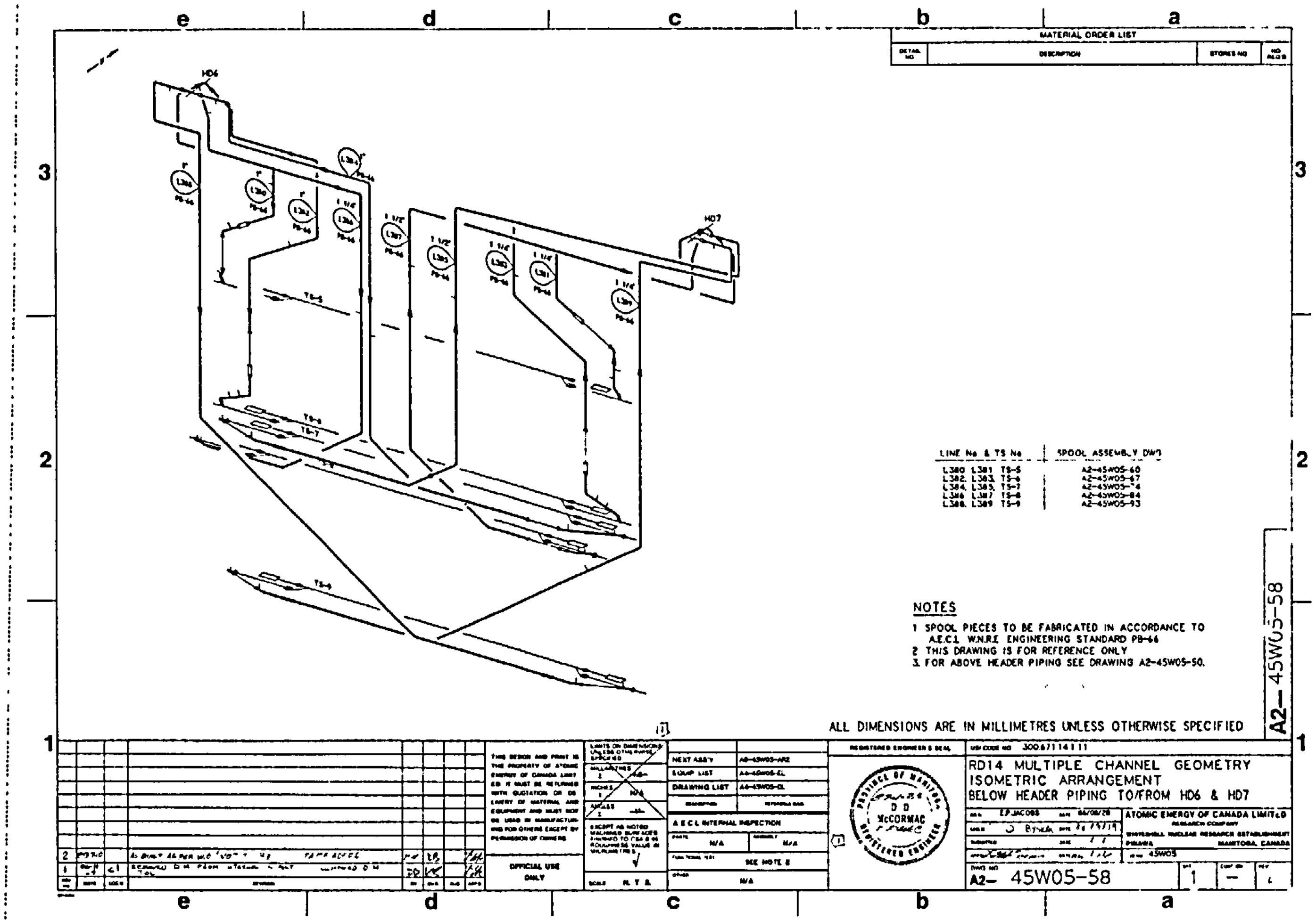


FIGURE B.4: RD-14M Channel Geometry Isometric Arrangement: Below Header Piping to/from HDR6 and HDR7 (Drawing A2-45W05-58)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

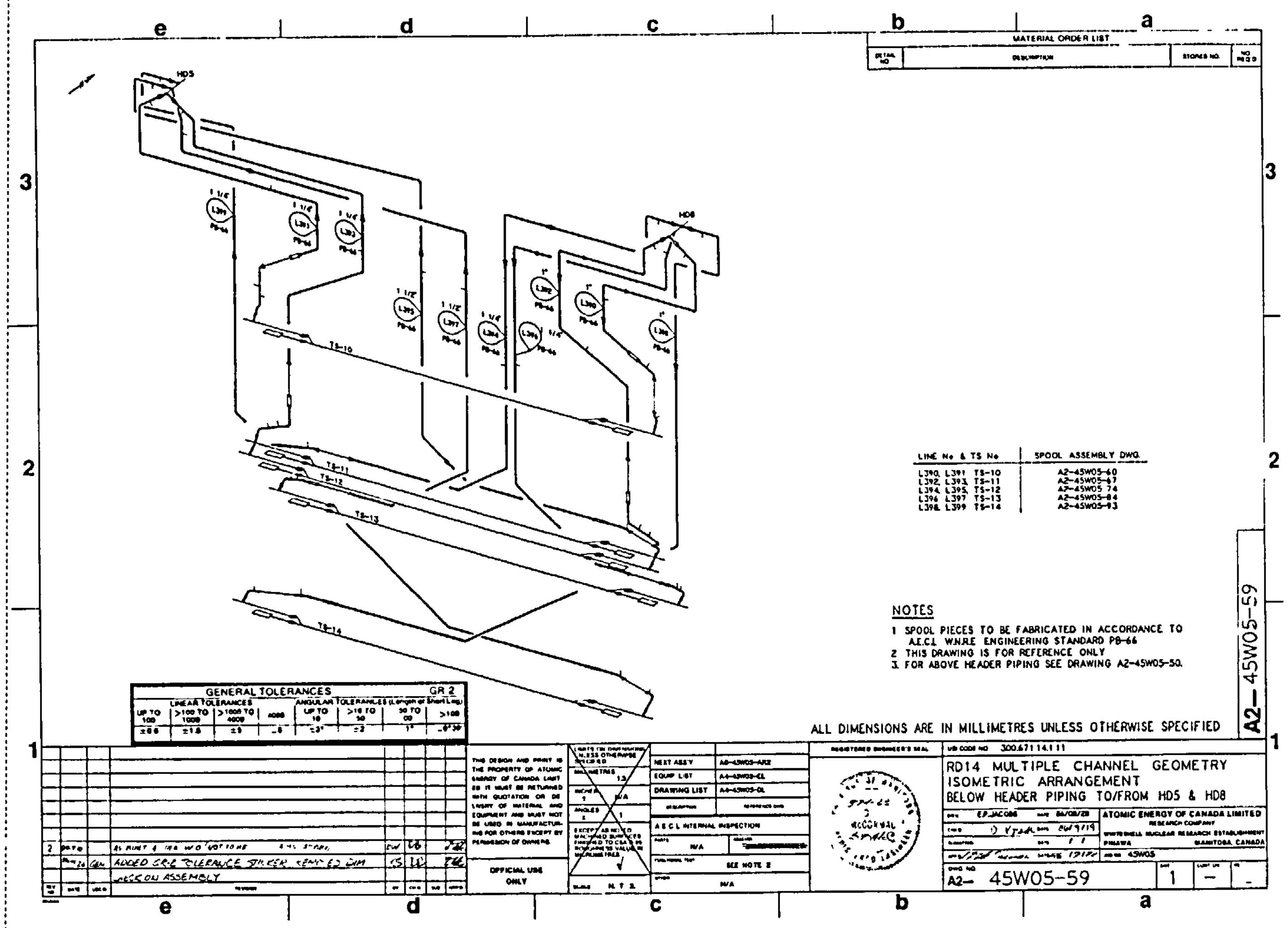


FIGURE B.5: RD-14M Channel Geometry Isometric Arrangement: Below Header Piping to/from HDR5 and HDR8 (Drawing A2-45W05-59)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

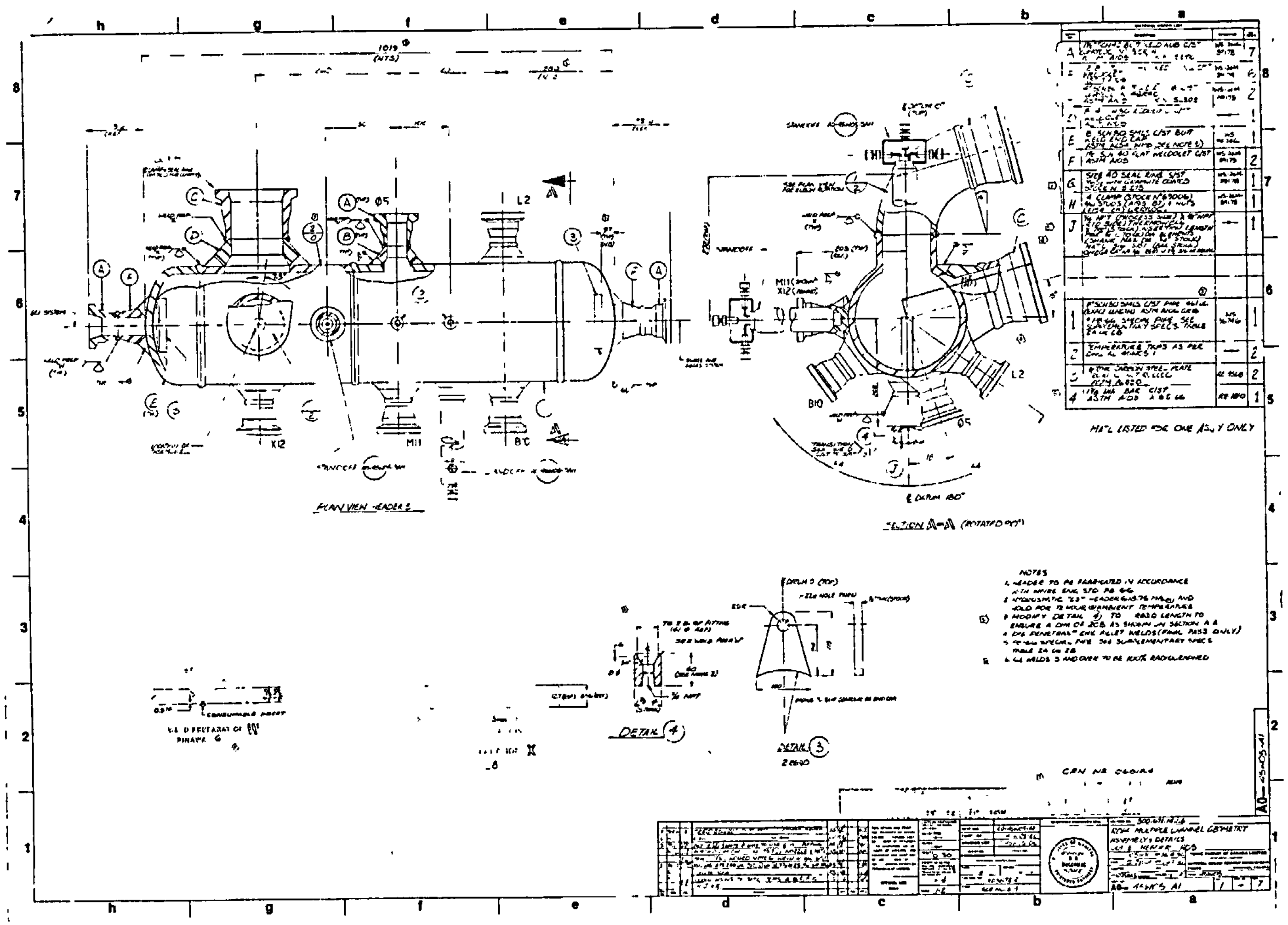


FIGURE B.6: RD-14M Channel Geometry Assembly and Details: Inlet Header HDR5 (Drawing A0-45W05-A1)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

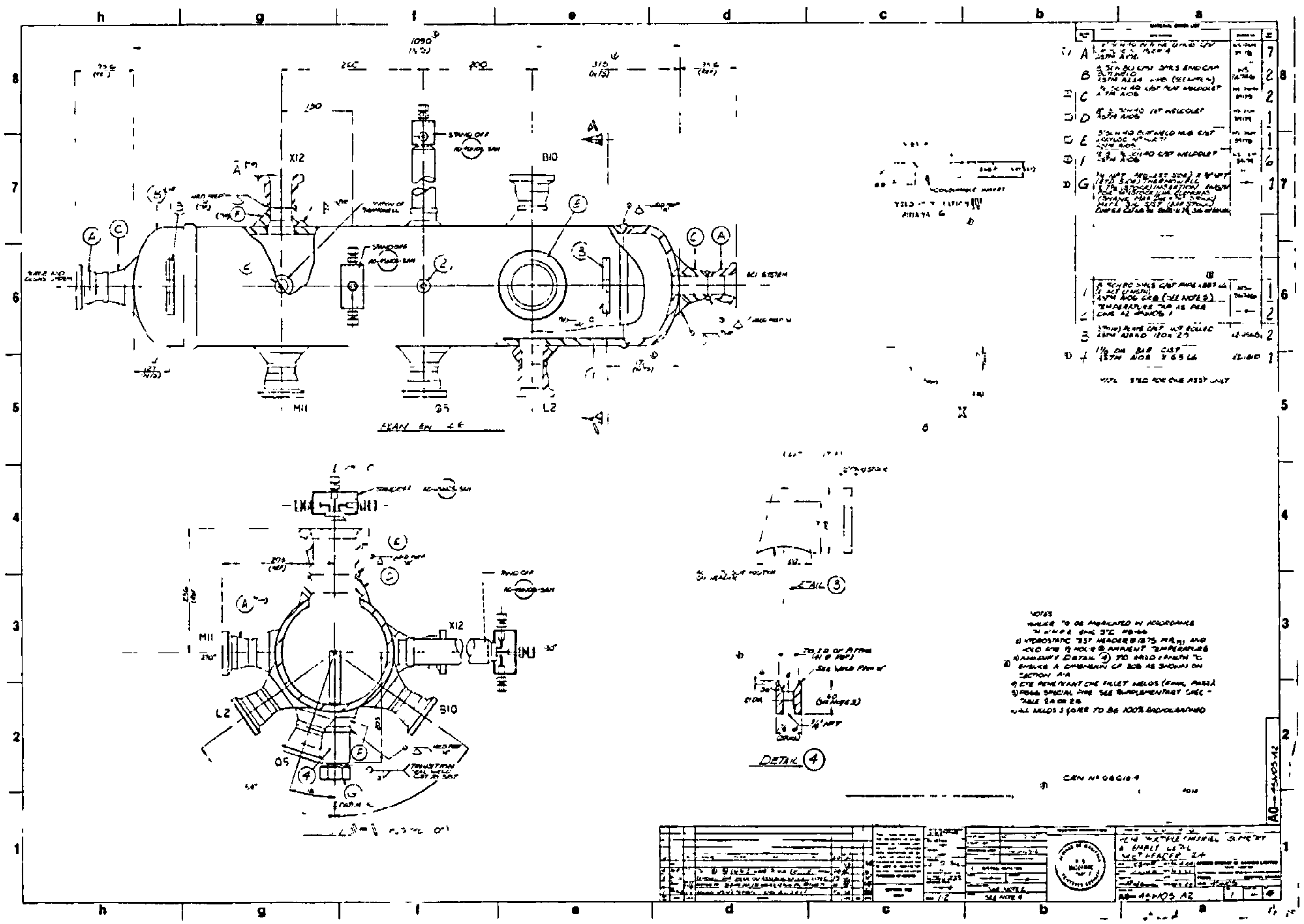


FIGURE B.7: RD-14M Channel Geometry Assembly and Details: Inlet Header HDR6 (Drawing A0-45W05-A2)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

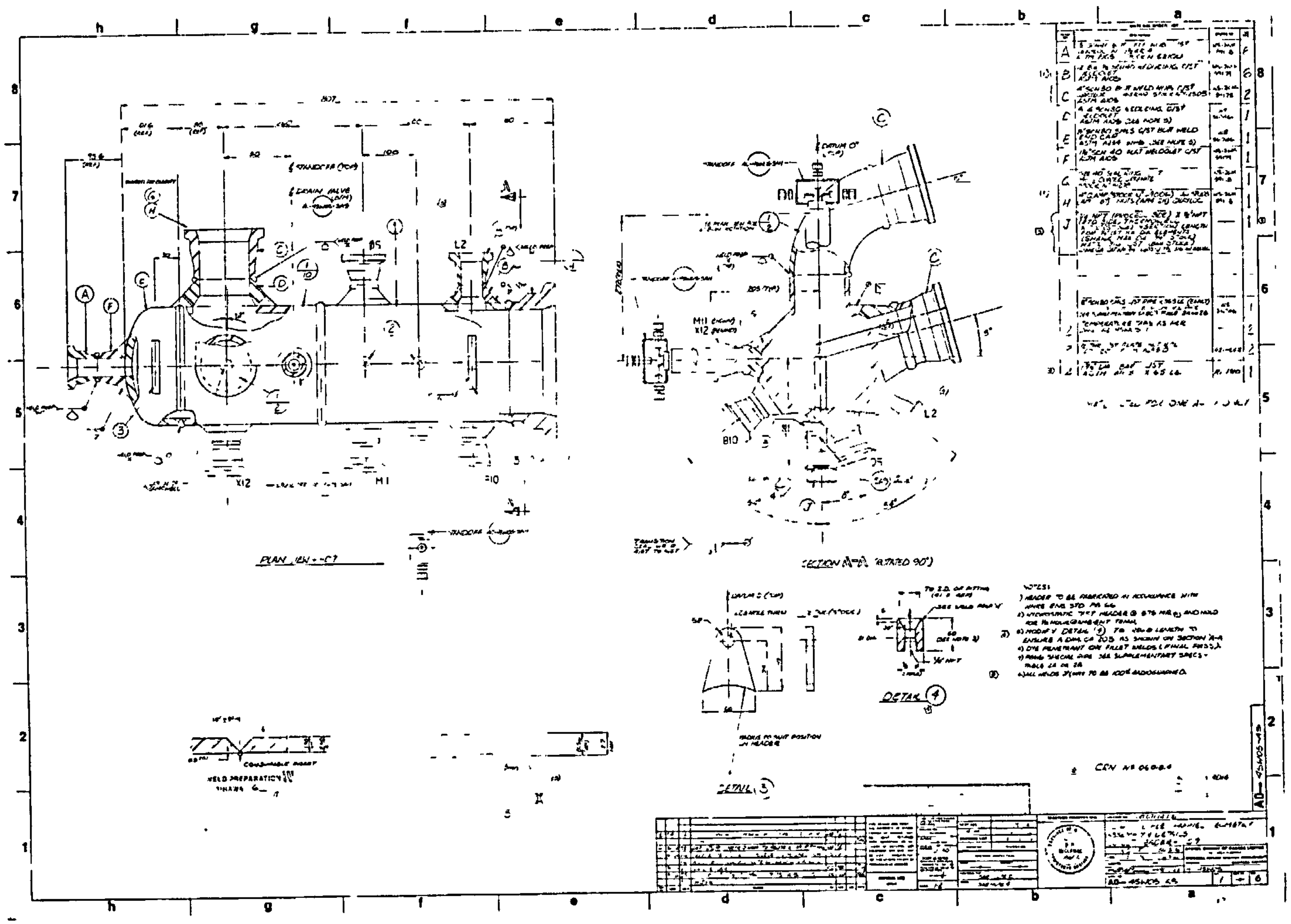


FIGURE B.8: RD-14M Channel Geometry Assembly and Details: Inlet Header HDR7 (Drawing A0-45W05-A3)

APPENDIX B: SCHEMATICS AND ENGINEERING DRAWINGS

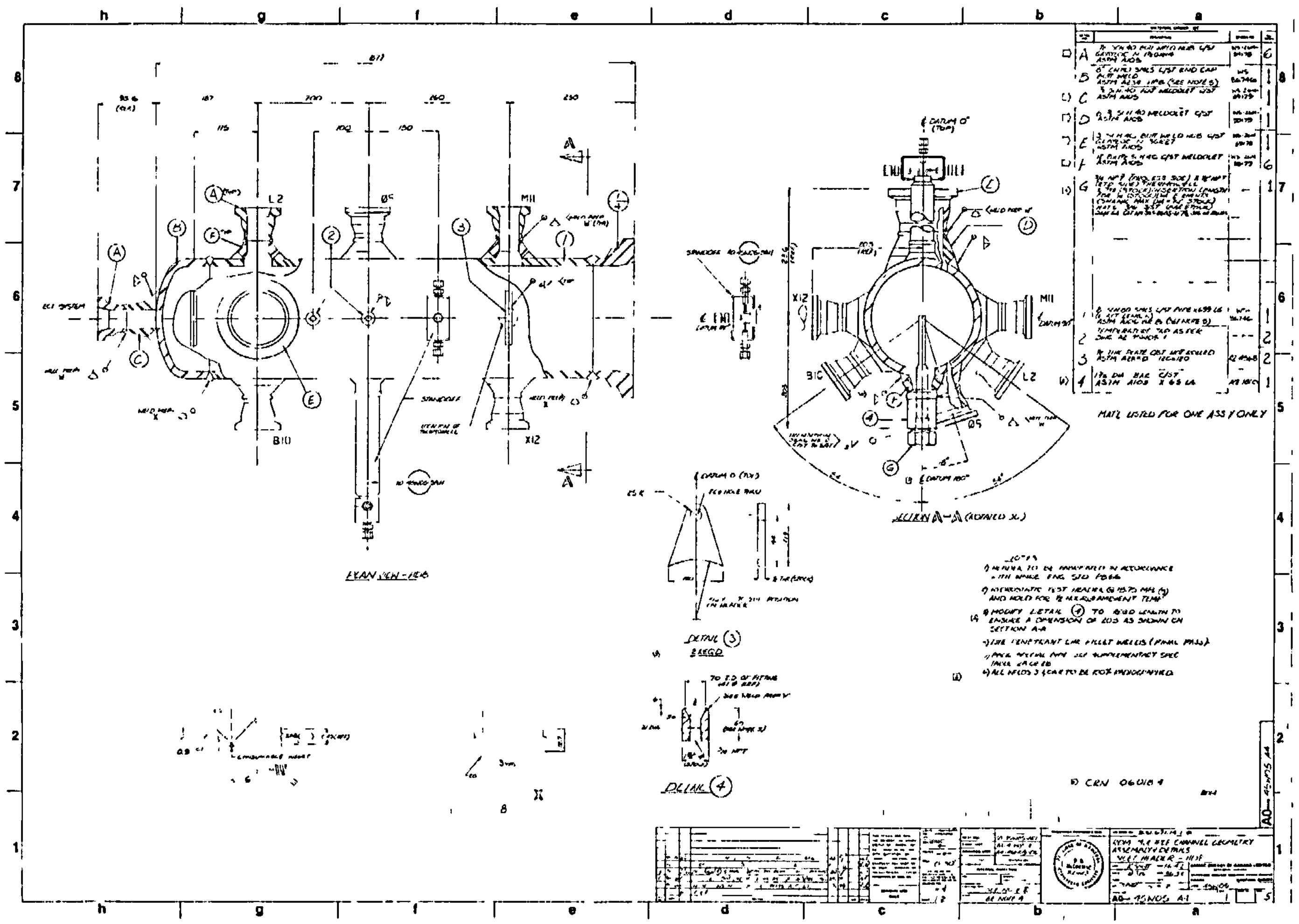


FIGURE B.9: RD-14M Channel Geometry Assembly and Details: Inlet Header HDR8 (Drawing A0-45W05-A4)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

In Section 2.210, the nominal position of each FES thermocouple was given. This appendix gives the exact radial and axial location of each FES thermocouple that has been installed. When an FES (or one or more elements in an FES) fails and is replaced, the location of the thermocouples change. What is presented here is a running history of all thermocouple locations to date. As this facility description is a living document, updates to this appendix will be issued as necessary.

Tables C.1 to C.10 give the FES thermocouple locations for heated section HS5 to HS14, respectively. Notes to the tables are as follows:

- multiple tables are given for an FES (or elements in an FES) that were replaced, as the thermocouple locations change;
- see Figure 2.15 for the arranging and numbering of the elements;
- see Figure 2.16 for a diagram showing the segmentation of the FES and the location name configuration;
- radial locations of the thermocouples are given with the top centre of the element being 0°, then rotate clockwise;
- axial distances are referenced from the inlet hydraulic boundary to the thermocouple location;
- thermocouples are placed on the inside walls of the elements, as shown in Figure 2.17;
- C/L refers to the centreline (see core thermocouple in Figure 2.17); and
- U/S refers to the thermocouple as being unserviceable as of the date given (due to failure). If the date given is "Rec'd", then this means that the thermocouple was failed when the FES was received from the manufacturer (i.e., it was failed prior to use in RD-14M).

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.1

HEATED SECTION 5 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS5 1-2J-2	1	2	0	971		
HS5 1-4L-2	1	4	304	1921		
HS5 1-6M-2	1	6	288	3043		
HS5 1-7N-2	1	7	72	3464		
HS5 1-9O-2	1	9	50	4388	U/S	10 APR 92
HS5 1-11P-2	1	11	62	5322		
HS5 1-2KC-2	1	2	C/L	972		
HS5 1-11RC-2	1	11	C/L	5324		
HS5 4-2J-2	4	2	0	960		
HS5 4-4L-2	4	4	294	1913		
HS5 4-6M-2	4	6	285	2812		
HS5 4-7N-2	4	7	91	3461		
HS5 4-9O-2	4	9	195	4398		
HS5 4-11P-2	4	11	40	5409		
HS5 4-2KC-2	4	2	C/L	961		
HS5 4-11RC-2	4	11	C/L	5311		
HS5 5-1A-1	5	1	0	404		
HS5 5-3B-1	5	3	207	1415		
HS5 5-5C-1	5	5	44	2407		
HS5 5-8E-1	5	8	199	3883	U/S	Rec'd
HS5 5-10G-1	5	10	20	4895		
HS5 5-12H-1	5	12	222	5889		
HS5 5-5DC-1	5	5	C/L	2407		
HS5 5-8FC-1	5	8	C/L	3882		
HS5 6-1A-1	6	1	0	422		
HS5 6-3B-1	6	3	259	1406		
HS5 6-5C-1	6	5	124	2446		
HS5 6-8E-1	6	8	284	3898		
HS5 6-10G-1	6	10	35	4878		
HS5 6-12H-1	6	12	293	5928	U/S	19 JUN 89
HS5 6-5DC-1	6	5	C/L	2447		
HS5 6-8FC-1	6	8	C/L	3898		
HS5 7-2J-2	7	2	0	967	U/S	22 JUL 92
HS5 7-4L-2	7	4	353	1920		
HS5 7-6M-2	7	6	108	2836		
HS5 7-7N-2	7	7	256	3424	U/S	Rec'd
HS5 7-9O-2	7	9	35	4378		
HS5 7-11P-2	7	11	171	5296		
HS5 7-2KC-2	7	2	C/L	977		
HS5 7-11RC-2	7	11	C/L	5299		

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.2

HEATED SECTION 6 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS6 1-2J-2	1	2	0	954.00		
HS6 1-4L-2	1	4	265	1912.00		
HS6 1-6M-2	1	6	161	2855.00		
HS6 1-7N-2	1	7	277	3420.00		
HS6 1-9O-2	1	9	353	4398.00		
HS6 1-11P-2	1	11	228	5336.00		
HS6 1-2KC-2	1	2	C/L	955.00		
HS6 1-11RC-2	1	11	C/L	5336.00		
HS6 4-2J-2	4	2	0	991.00		
HS6 4-4L-2	4	4	221	1926.00		
HS6 4-6M-2	4	6	184	2868.00		
HS6 4-7N-2	4	7	299	3483.00		
HS6 4-9O-2	4	9	300	4383.00		
HS6 4-11P-2	4	11	254	5341.50		
HS6 4-2KC-2	4	2	C/L	991.00		
HS6 4-11RC-2	4	11	C/L	5341.00		
HS6 5-1A-1	5	1	0	381.00		
HS6 5-3B-1	5	3	285	1410.00		
HS6 5-5C-1	5	5	40	2407.00		
HS6 5-8E-1	5	8	238	3856.00	U/S	17 FEB 92
HS6 5-10G-1	5	10	350	4897.00		
HS6 5-12H-1	5	12	325	5883.00		
HS6 5-5DC-1	5	5	C/L	2407.00		
HS6 5-8FC-1	5	8	C/L	3856 00		
HS6 6-1A-1	6	1	0	433.00		
HS6 6-3B-1	6	3	266	1416.00	U/S	Rec'd
HS6 6-5C-1	6	5	218	2459.00	U/S	02 MAR 95
HS6 6-8E-1	6	8	14	3908.00	U/S	15 MAR 93
HS6 6-10G-1	6	10	120	4891.00		
HS6 6-12H-1	6	12	333	5929.00		
HS6 6-5DC-1	6	5	C/L	2460.00		
HS6 6-8FC-1	6	8	C/L	3908.00		
HS6 7-2J-2	7	2	0	986.00		
HS6 7-4L-2	7	4	123	1921.00		
HS6 7-6M-2	7	6	251	2908.00		
HS6 7-7N-2	7	7	37	3472.00		
HS6 7-9O-2	7	9	167	4397.00		
HS6 7-11P-2	7	11	298	5395.00		
HS6 7-2KC-2	7	2	C/L	981.00		
HS6 7-11RC-2	7	11	C/L	5375.00		

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.3A

HEATED SECTION 7 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS7 1-2J-2	1	2	0	974.00	U/S	29 MAY 89
HS7 1-4L-2	1	4	193	1913 00		
HS7 1-6M-2	1	6	10	2844.50	U/S	25 JAN 93
HS7 1-7N-2	1	7	178	3467 00		
HS7 1-9O-2	1	9	276	4403 50		
HS7 1-11P-2	1	11	110	5339 00		
HS7 1-2KC-2	1	2	C/L	976.00		
HS7 1-11RC-2	1	11	C/L	5338.00		
HS7 4-2J-2	4	2	0	932 00		
HS7 4-4L-2	4	4	301	1901.00		
HS7 4-6M-2	4	6	193	2877.00		
HS7 4-7N-2	4	7	2	3428.00		
HS7 4-9O-2	4	9	54	4407.00		
HS7 4-11P-2	4	11	244	5381.00		
HS7 4-2KC-2	4	2	C/L	931.00		
HS7 4-11RC-2	4	11	C/L	5378.00		
HS7 5-1A-1	5	1	0	386.00		
HS7 5-3B-1	5	3	172	1418.00		
HS7 5-5C-1	5	5	299	2402.00	U/S	08 MAR 90
HS7 5-8E-1	5	8	130	3858.00		
HS7 5-10G-1	5	10	276	4888.00		
HS7 5-12H-1	5	12	141	5873.00		
HS7 5-5DC-1	5	5	C/L	2402.00		
HS7 5-8FC-1	5	8	C/L	3856.00		
HS7 6-1A-1	6	1	0	444.00	U/S	22 MAR 89
HS7 6-3B-1	6	3	276	1422.00		
HS7 6-5C-1	6	5	119	2458.00	U/S	24 FEB 89
HS7 6-8E-1	6	8	266	3910.00		
HS7 6-10G-1	6	10	53	4886.00		
HS7 6-12H-1	6	12	313	5929.00		
HS7 6-5DC-1	6	5	C/L	2459.00		
HS7 6-8FC-1	6	8	C/L	3911.00		
HS7 7-2J-2	7	2	0	947.00		
HS7 7-4L-2	7	4	125	1924 00		
HS7 7-6M-2	7	6	229	2880.50		
HS7 7-7N-2	7	7	335	3420 00		
HS7 7-9O-2	7	9	96	4395.00		
HS7 7-11P-2	7	11	222	5370 00		
HS7 7-2KC-2	7	2	C/L	959.00		
HS7 7-11RC-2	7	11	C/L	5364.00		

Notes: Element 5 disconnected for balance on 04 June 1991 (arc damage on element 7, HS12)
Elements 1, 4 and 5 were replaced on 28 August 1998 due to severe damage (see Table C.3B)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.3B

HEATED SECTION 7 FES (1st REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS7 1-2J-2	1	2	0	988.50		
HS7 1-4L-2	1	4	121	1915.50		
HS7 1-6M-2	1	6	269	2860.00		
HS7 1-7N-2	1	7	358	3462.00		
HS7 1-9O-2	1	9	102	4289.50		
HS7 1-11P-2	1	11	148	5335.50		
HS7 1-2KC-2	1	2	C/L	990.00		
HS7 1-11RC-2	1	11	C/L	5335.00		
HS7 4-2J-2	4	2	0	947.00		
HS7 4-4L-2	4	4	58	1920.00		
HS7 4-6M-2	4	6	276	2829.00		
HS7 4-7N-2	4	7	52	3421.00		
HS7 4-9O-2	4	9	20	4392.00		
HS7 4-11P-2	4	11	125	5303.00		
HS7 4-2KC-2	4	2	C/L	947.50		
HS7 4-11RC-2	4	11	C/L	5301.00		
HS7 5-1A-1	5	1	0	380.00		
HS7 5-3B-1	5	3	78	1420.00		
HS7 5-5C-1	5	5	235	2407.00		
HS7 5-8E-1	5	8	255	3855.00		
HS7 5-10G-1	5	10	261	4886.00		
HS7 5-12H-1	5	12	255	5875.00		
HS7 5-5DC-1	5	5	C/L	2407.00		
HS7 5-8FC-1	5	8	C/L	3856.00		
HS7 6-1A-1	6	1	0	444.00	U/S	22 MAR 89
HS7 6-3B-1	6	3	276	1422.00		
HS7 6-5C-1	6	5	119	2458 00		
HS7 6-8E-1	6	8	266	3910.00		
HS7 6-10G-1	6	10	53	4886 00		
HS7 6-12H-1	6	12	313	5929.00		
HS7 6-5DC-1	6	5	C/L	2459.00		
HS7 6-8FC-1	6	8	C/L	3911.00		
HS7 7-2J-2	7	2	0	947.00	U/S	06 NOV 98
HS7 7-4L-2	7	4	125	1924.00	U/S	06 NOV 98
HS7 7-6M-2	7	6	229	2880.50	U/S	06 NOV 98
HS7 7-7N-2	7	7	335	3420.00	U/S	06 NOV 98
HS7 7-9O-2	7	9	96	4395.00	U/S	06 NOV 98
HS7 7-11P-2	7	11	222	5370.00	U/S	06 NOV 98
HS7 7-2KC-2	7	2	C/L	959.00	U/S	06 NOV 98
HS7 7-11RC-2	7	11	C/L	5364.00	U/S	28 AUG 98

Notes: Replacement elements 1, 4 and 5 were installed on 28 August 1998
Element 7 disconnected due to failure on 06 November 1998 (element 7, HS12 disconnected for balance)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.4A

HEATED SECTION 8 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS8 1-2J-2	1	2	0	949.00	U/S	Rec'd
HS8 1-4L-2	1	4	290	1921 00		
HS8 1-6M-2	1	6	192	2818 00		
HS8 1-7N-2	1	7	337	3450 00	U/S	24 FEB 89
HS8 1-9O-2	1	9	7	4387.00	U/S	19 JAN 89
HS8 1-11P-2	1	11	224	5299.00	U/S	03 MAR 89
HS8 1-2KC-2	1	2	C/L	948.00		
HS8 1-11RC-2	1	11	C/L	5298 00		
HS8 4-2J-2	4	2	0	975.00		
HS8 4-4L-2	4	4	288	1915.00		
HS8 4-6M-2	4	6	228	2841.00		
HS8 4-7N-2	4	7	27	3450.00		
HS8 4-9O-2	4	9	34	4400 00		
HS8 4-11P-2	4	11	235	5332.00		
HS8 4-2KC-2	4	2	C/L	975 00		
HS8 4-11RC-2	4	11	C/L	5334.00		
HS8 5-1A-1	5	1	0	443 00		
HS8 5-3B-1	5	3	133	1419.00		
HS8 5-5C-1	5	5	313	2441.00		
HS8 5-8E-1	5	8	125	3901.00		
HS8 5-10G-1	5	10	285	4891.00		
HS8 5-12H-1	5	12	343	5913.00		
HS8 5-5DC-1	5	5	C/L	2442.00		
HS8 5-8FC-1	5	8	C/L	3901.00		
HS8 6-1A-1	6	1	0	399.50		
HS8 6-3B-1	6	3	257	1421.00		
HS8 6-5C-1	6	5	213	2419.00		
HS8 6-8E-1	6	8	34	3869 00		
HS8 6-10G-1	6	10	251	4886 00		
HS8 6-12H-1	6	12	37	5887.00		
HS8 6-5DC-1	6	5	C/L	2419.00		
HS8 6-8FC-1	6	8	C/L	3869.00		
HS8 7-2J-2	7	2	0	994.00		
HS8 7-4L-2	7	4	130	1912.00		
HS8 7-6M-2	7	6	238	2839.00		
HS8 7-7N-2	7	7	33	3472.00		
HS8 7-9O-2	7	9	145	4392.00		
HS8 7-11P-2	7	11	255	5329.00		
HS8 7-2KC-2	7	2	C/L	1007.00		
HS8 7-11RC-2	7	11	C/L	5329.00		

Note: FES was replaced on 18 December 1989 due to severe damage (see Table C.4B)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.4B

HEATED SECTION 8 FES (1st REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS8 1-2J-2	1	2	191	971.00		
HS8 1-4L-2	1	4	274	1910.00		
HS8 1-6M-2	1	6	79	2836.00		
HS8 1-7N-2	1	7	249	3456.00		
HS8 1-9O-2	1	9	120	4396.00		
HS8 1-11P-2	1	11	0	5322.00		
HS8 1-2KC-2	1	2	C/L	973.00		
HS8 1-11RC-2	1	11	C/L	5324.00		
HS8 4-2J-2	4	2	358	969.00		
HS8 4-4L-2	4	4	253	1913.00		
HS8 4-6M-2	4	6	304	2839.00		
HS8 4-7N-2	4	7	104.5	3465.00		
HS8 4-9O-2	4	9	65	4394.00		
HS8 4-11P-2	4	11	0	5328.00		
HS8 4-2KC-2	4	2	C/L	972.00	U/S	Rec'd
HS8 4-11RC-2	4	11	C/L	5325.00		
HS8 5-1A-1	5	1	169	407.00		
HS8 5-3B-1	5	3	352	1429.00		
HS8 5-5C-1	5	5	123	2429.00		
HS8 5-8E-1	5	8	284	3884.00		
HS8 5-10G-1	5	10	159	4894.00		
HS8 5-12H-1	5	12	0	5901.00	U/S	Rec'd
HS8 5-5DC-1	5	5	C/L	N/A	U/S	Rec'd
HS8 5-8FC-1	5	8	C/L	3881.00		
HS8 6-1A-1	6	1	244	423.50		
HS8 6-3B-1	6	3	50	1423.50		
HS8 6-5C-1	6	5	186	2417.50		
HS8 6-8E-1	6	8	134	3895.50		
HS8 6-10G-1	6	10	89	4904.50		
HS8 6-12H-1	6	12	0	5889.50	U/S	12 MAR 90
HS8 6-5DC-1	6	5	C/L	2416.50	U/S	Rec'd
HS8 6-8FC-1	6	8	C/L	3895.50		
HS8 7-2J-2	7	2	358	953.00		
HS8 7-4L-2	7	4	56	1910.00		
HS8 7-6M-2	7	6	80	2815.00		
HS8 7-7N-2	7	7	133	3437.00		
HS8 7-9O-2	7	9	205	4392.00		
HS8 7-11P-2	7	11	0	5312.00		
HS8 7-2KC-2	7	2	C/L	960.00		
HS8 7-11RC-2	7	11	C/L	2836.00		

Notes: Replacement FES installed on 18 December 1989
FES was replaced on 14 February 1996 due to severe damage (see Table C.4C)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.4C

HEATED SECTION 8 FES (2nd REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS8 1-2J-2	1	2	0	992.00		
HS8 1-4L-2	1	4	251	1933.00		
HS8 1-6M-2	1	6	182	2859.00		
HS8 1-7N-2	1	7	338	3483.00		
HS8 1-9O-2	1	9	74	4415.00		
HS8 1-11P-2	1	11	212	5349.00		
HS8 1-2KC-2	1	2	C/L	999.00		
HS8 1-11RC-2	1	11	C/L	5351.50		
HS8 4-2J-2	4	2	0	948.00		
HS8 4-4L-2	4	4	214	1907.50		
HS8 4-6M-2	4	6	41	2840.50		
HS8 4-7N-2	4	7	171	3438.00		
HS8 4-9O-2	4	9	254	4391.00		
HS8 4-11P-2	4	11	131	5330.00		
HS8 4-2KC-2	4	2	C/L	948.50		
HS8 4-11RC-2	4	11	C/L	5330.50		
HS8 5-1A-1	5	1	0	443.00		
HS8 5-3B-1	5	3	133	1419 00		
HS8 5-5C-1	5	5	313	2441 00	U/S	15 OCT 99
HS8 5-8E-1	5	8	125	3901.00	U/S	26 JAN 98
HS8 5-10G-1	5	10	285	4891.00		
HS8 5-12H-1	5	12	343	5913.00	U/S	08 MAY 98
HS8 5-5DC-1	5	5	C/L	2442.00		
HS8 5-8FC-1	5	8	C/L	3901.00		
HS8 6-1A-1	6	1	0	399.50		
HS8 6-3B-1	6	3	257	1421.00		
HS8 6-5C-1	6	5	213	2419.00		
HS8 6-8E-1	6	8	34	3869.00		
HS8 6-10G-1	6	10	251	4886.00		
HS8 6-12H-1	6	12	37	5887.00		
HS8 6-5DC-1	6	5	C/L	2419.00		
HS8 6-8FC-1	6	8	C/L	3869.00		
HS8 7-2J-2	7	2	0	976 50		
HS8 7-4L-2	7	4	130	1921.00		
HS8 7-6M-2	7	6	236	2789 00		
HS8 7-7N-2	7	7	27	3465 00		
HS8 7-9O-2	7	9	168	4294.00		
HS8 7-11P-2	7	11	246	5382.00		
HS8 7-2KC-2	7	2	C/L	977.00		
HS8 7-11RC-2	7	11	C/L	5367.00		

Note: Replacement FES installed on 14 February 1996

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.5

HEATED SECTION 9 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS9 1-2J-2	1	2	0	897.00		
HS9 1-4L-2	1	4	158	1915.00		
HS9 1-6M-2	1	6	4	2843.00		
HS9 1-7N-2	1	7	157	3389.00		
HS9 1-9O-2	1	9	274	4392.00		
HS9 1-11P-2	1	11	102	5343.00		
HS9 1-2KC-2	1	2	C/L	897.00		
HS9 1-11RC-2	1	11	C/L	5343.00		
HS9 4-2J-2	4	2	0	935.00		
HS9 4-4L-2	4	4	168	1912.00		
HS9 4-6M-2	4	6	23	2871.00		
HS9 4-7N-2	4	7	157	3432.00		
HS9 4-9O-2	4	9	282	4397.00		
HS9 4-11P-2	4	11	118	5367.00		
HS9 4-2KC-2	4	2	C/L	936 00		
HS9 4-11RC-2	4	11	C/L	5368.00		
HS9 5-1A-1	5	1	0	415.00		
HS9 5-3B-1	5	3	8	1414.00	U/S	25 MAY 94
HS9 5-5C-1	5	5	51	2437.00		
HS9 5-8E-1	5	8	79	3891.00	U/S	02 APR 92
HS9 5-10G-1	5	10	358	4892.00	U/S	15 JUL 93
HS9 5-12H-1	5	12	341	5908.00	U/S	07 MAY 90
HS9 5-5DC-1	5	5	C/L	2436.00		
HS9 5-8FC-1	5	8	C/L	3893.00		
HS9 6-1A-1	6	1	0	437.00		
HS9 6-3B-1	6	3	202	1417.00		
HS9 6-5C-1	6	5	180	2444.00	U/S	26 MAY 95
HS9 6-8E-1	6	8	350	3903.00		
HS9 6-10G-1	6	10	112	4885.00		
HS9 6-12H-1	6	12	16	5912.00		
HS9 6-5DC-1	6	5	C/L	2446.00		
HS9 6-8FC-1	6	8	C/L	3903.00		
HS9 7-2J-2	7	2	0	976.00		
HS9 7-4L-2	7	4	69	1925.00	U/S	27 APR 95
HS9 7-6M-2	7	6	206	2851.00		
HS9 7-7N-2	7	7	332	3453.00	U/S	16 SEP 94
HS9 7-9O-2	7	9	39	4383.00		
HS9 7-11P-2	7	11	115	5313.00	U/S	14 AUG 91
HS9 7-2KC-2	7	2	C/L	984.50		
HS9 7-11RC-2	7	11	C/L	5313.00		

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.6

HEATED SECTION 10 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS10 1-2J-2	1	2	0	989.00		
HS10 1-4L-2	1	4	290	1923.00		
HS10 1-6M-2	1	6	276	2865.00		
HS10 1-7N-2	1	7	81	3466.00		
HS10 1-9O-2	1	9	259	4383.00		
HS10 1-11P-2	1	11	32	5349.00		
HS10 1-2KC-2	1	2	C/L	993.00		
HS10 1-11RC-2	1	11	C/L	5348.00		
HS10 4-2J-2	4	2	0	996.00	U/S	04 DEC 96
HS10 4-4L-2	4	4	251	1917.50		
HS10 4-6M-2	4	6	154	2867.00		
HS10 4-7N-2	4	7	327	3482.00		
HS10 4-9O-2	4	9	99	4388.00		
HS10 4-11P-2	4	11	286	5348.00	U/S	Rec'd
HS10 4-2KC-2	4	2	C/L	996 00		
HS10 4-11RC-2	4	11	C/L	5349 00		
HS10 5-1A-1	5	1	0	428 00		
HS10 5-3B-1	5	3	128	1419.00		
HS10 5-5C-1	5	5	233	2446.50		
HS10 5-8E-1	5	8	107	3903.00	U/S	Rec'd
HS10 5-10G-1	5	10	293	4891 00	U/S	02 DEC 91
HS10 5-12H-1	5	12	111	5916 00		
HS10 5-5DC-1	5	5	C/L	2448.00		
HS10 5-8FC-1	5	8	C/L	3901.00		
HS10 6-1A-1	6	1	0	373.00	U/S	17 FEB 92
HS10 6-3B-1	6	3	289	1410 00		
HS10 6-5C-1	6	5	53	2406.00		
HS10 6-8E-1	6	8	261	3858.00		
HS10 6-10G-1	6	10	69	4896.00	U/S	26 JAN 98
HS10 6-12H-1	6	12	244	5875.00		
HS10 6-5DC-1	6	5	C/L	2406.00		
HS10 6-8FC-1	6	8	C/L	3858.00		
HS10 7-2J-2	7	2	0	1008.00	U/S	08 JUL 94
HS10 7-4L-2	7	4	32	1884.00		
HS10 7-6M-2	7	6	129	2867.00		
HS10 7-7N-2	7	7	246	3452.00		
HS10 7-9O-2	7	9	355	4373.00	U/S	16 OCT 90
HS10 7-11P-2	7	11	171	5353 00	U/S	Rec'd
HS10 7-2KC-2	7	2	C/L	1022.00		
HS10 7-11RC-2	7	11	C/L	5346 00		

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.7

HEATED SECTION 11 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS11 1-2J-2	1	2	0	968.00	U/S	26 JAN 98
HS11 1-4L-2	1	4	302	1918.00	U/S	26 JAN 98
HS11 1-6M-2	1	6	289	2830.00		
HS11 1-7N-2	1	7	75	3447.00		
HS11 1-9O-2	1	9	70	4390.00	U/S	Rec'd
HS11 1-11P-2	1	11	353	5320 00	U/S	Rec'd
HS11 1-2KC-2	1	2	C/L	966.00		
HS11 1-11RC-2	1	11	C/L	5319.00		
HS11 4-2J-2	4	2	0	968.00		
HS11 4-4L-2	4	4	148	1918.00	U/S	17 MAR 99
HS11 4-6M-2	4	6	16	2842.00		
HS11 4-7N-2	4	7	110	3468.00		
HS11 4-9O-2	4	9	169	4288.00		
HS11 4-11P-2	4	11	84	5317.00		
HS11 4-2KC-2	4	2	C/L	969.00		
HS11 4-11RC-2	4	11	C/L	5315.00		
HS11 5-1A-1	5	1	0	428.00		
HS11 5-3B-1	5	3	226	1406 00		
HS11 5-5C-1	5	5	210	2449.00		
HS11 5-8E-1	5	8	324	3904.00	U/S	26 JAN 98
HS11 5-10G-1	5	10	122	4883.00	U/S	18 AUG 89
HS11 5-12H-1	5	12	314	5939.00		
HS11 5-5DC-1	5	5	C/L	2450.00		
HS11 5-8FC-1	5	8	C/L	3904.00		
HS11 6-1A-1	6	1	0	441.00	U/S	07 NOV 89
HS11 6-3B-1	6	3	280	1426.00		
HS11 6-5C-1	6	5	263	2454.00		
HS11 6-8E-1	6	8	51	3908.00		
HS11 6-10G-1	6	10	272	4879.00		
HS11 6-12H-1	6	12	184	5924.00		
HS11 6-5DC-1	6	5	C/L	2453.00		
HS11 6-8FC-1	6	8	C/L	3908.00		
HS11 7-2J-2	7	2	0	930.00	U/S	08 FEB 91
HS11 7-4L-2	7	4	7	1907.00		
HS11 7-6M-2	7	6	35	2819.00		
HS11 7-7N-2	7	7	138	3385.00		
HS11 7-9O-2	7	9	267	4378.00		
HS11 7-11P-2	7	11	127	5297.00		
HS11 7-2KC-2	7	2	C/L	945.00		
HS11 7-11RC-2	7	11	C/L	5299.00		

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.8A

HEATED SECTION 12 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS12 1-2J-2	1	2	0	959.00		
HS12 1-4L-2	1	4	199	1908.50		
HS12 1-6M-2	1	6	4	2847.00		
HS12 1-7N-2	1	7	119	3454.00		
HS12 1-9O-2	1	9	248	4395.50		
HS12 1-11P-2	1	11	116	5337.00		
HS12 1-2KC-2	1	2	C/L	960.00		
HS12 1-11RC-2	1	11	C/L	5338.00		
HS12 4-2J-2	4	2	0	977.00	U/S	Rec'd
HS12 4-4L-2	4	4	244	1909.00		
HS12 4-6M-2	4	6	140	2849.00		
HS12 4-7N-2	4	7	285	3423.00		
HS12 4-9O-2	4	9	344	4389.00		
HS12 4-11P-2	4	11	144	5334.00		
HS12 4-2KC-2	4	2	C/L	976.00		
HS12 4-11RC-2	4	11	C/L	5335.00		
HS12 5-1A-1	5	1	0	414 00	U/S	13 JUL 94
HS12 5-3B-1	5	3	236	1418.00		
HS12 5-5C-1	5	5	171	2432 00		
HS12 5-8E-1	5	8	356	3886.00		
HS12 5-10G-1	5	10	180	4887 00		
HS12 5-12H-1	5	12	9	5918.00		
HS12 5-5DC-1	5	5	C/L	2432.00		
HS12 5-8FC-1	5	8	C/L	3886 00		
HS12 6-1A-1	6	1	0	414.50		
HS12 6-3B-1	6	3	172	1423 00	U/S	18 DEC 91
HS12 6-5C-1	6	5	284	2426.00		
HS12 6-8E-1	6	8	151	3882.00	U/S	27 APR 95
HS12 6-10G-1	6	10	279	4891.00		
HS12 6-12H-1	6	12	114	5895.00		
HS12 6-5DC-1	6	5	C/L	2425.00		
HS12 6-8FC-1	6	8	C/L	3879.00		
HS12 7-2J-2	7	2	0	987.00		
HS12 7-4L-2	7	4	47	1905.00		
HS12 7-6M-2	7	6	146	2878.00	U/S	04 JUN 91
HS12 7-7N-2	7	7	268	3468.00		
HS12 7-9O-2	7	9	35	4378.00		
HS12 7-11P-2	7	11	161	5359.00	U/S	Rec'd
HS12 7-2KC-2	7	2	C/L	1006.00		
HS12 7-11KC-2	7	11	C/L	5366 00		

Notes: Element 7 disconnected due to arc damage on 04 June 1991 (element 5, HS7 disconnected for balance)
Element 7 was replaced on 21 July 1998 due to severe damage (see Table C.8B)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.8B

HEATED SECTION 12 FES (1st REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS12 1-2J-2	1	2	0	959.00		
HS12 1-4L-2	1	4	199	1908.50		
HS12 1-6M-2	1	6	4	2847.00		
HS12 1-7N-2	1	7	119	3454.00		
HS12 1-9O-2	1	9	248	4395.50		
HS12 1-11P-2	1	11	116	5337.00		
HS12 1-2KC-2	1	2	C/L	960.00		
HS12 1-11RC-2	1	11	C/L	5338 00		
HS12 4-2J-2	4	2	0	977.00	U/S	Rec'd
HS12 4-4L-2	4	4	244	1909.00		
HS12 4-6M-2	4	6	140	2849.00		
HS12 4-7N-2	4	7	285	3423.00		
HS12 4-9O-2	4	9	344	4389.00		
HS12 4-11P-2	4	11	144	5334.00		
HS12 4-2KC-2	4	2	C/L	976.00		
HS12 4-11RC-2	4	11	C/L	5335 00		
HS12 5-1A-1	5	1	0	414.00	U/S	10 DEC 98
HS12 5-3B-1	5	3	236	1418.00		
HS12 5-5C-1	5	5	171	2432 00		
HS12 5-8E-1	5	8	356	3886.00		
HS12 5-10G-1	5	10	180	4887.00		
HS12 5-12H-1	5	12	9	5918 00		
HS12 5-5DC-1	5	5	C/L	2432.00		
HS12 5-8FC-1	5	8	C/L	3886.00		
HS12 6-1A-1	6	1	0	414.50		
HS12 6-3B-1	6	3	172	1423.00	U/S	16 OCT 98
HS12 6-5C-1	6	5	284	2426 00	U/S	Rec'd
HS12 6-8E-1	6	8	151	3882.00	U/S	27 APR 95
HS12 6-10G-1	6	10	279	4891.00		
HS12 6-12H-1	6	12	114	5895.00		
HS12 6-5DC-1	6	5	C/L	2425.00		
HS12 6-8FC-1	6	8	C/L	3879.00		
HS12 7-2J-2	7	2	0	974.50		
HS12 7-4L-2	7	4	132.5	1930.00		
HS12 7-6M-2	7	6	1	2850.50		
HS12 7-7N-2	7	7	322	3443.00		
HS12 7-9O-2	7	9	355	4392.00		
HS12 7-11P-2	7	11	348.5	5315.00		
HS12 7-2KC-2	7	2	C/L	975.00		
HS12 7-11KC-2	7	11	C/L	5298.00		

Notes: Replacement element 7 was installed on 21 July 1998
Element 7 was disconnected on 06 November 1998 for balance (failure of element 7, HS7)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.9A

HEATED SECTION 13 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS13 1-2J-2	1	2	0	950.00		
HS13 1-4L-2	1	4	204	1909.00		
HS13 1-6M-2	1	6	41	2877.00	U/S	03 MAY 95
HS13 1-7N-2	1	7	168	3453.00		
HS13 1-9O-2	1	9	251	4403 00		
HS13 1-11P-2	1	11	332	5381.00		
HS13 1-2KC-2	1	2	C/L	951.00		
HS13 1-11RC-2	1	11	C/L	5380.00		
HS13 4-2J-2	4	2	0	969.00	U/S	12 AUG 91
HS13 4-4L-2	4	4	286	1915.00		
HS13 4-6M-2	4	6	243	2899.00		
HS13 4-7N-2	4	7	30	3465.00		
HS13 4-9O-2	4	9	151	4388 00		
HS13 4-11P-2	4	11	358	5394.00		
HS13 4-2KC-2	4	2	C/L	970.50		
HS13 4-11RC-2	4	11	C/L	5393 00		
HS13 5-1A-1	5	1	0	421.00	U/S	12 NOV 96
HS13 5-3B-1	5	3	155	1421 00		
HS13 5-5C-1	5	5	266	2445 00		
HS13 5-8E-1	5	8	57	3900 00		
HS13 5-10G-1	5	10	292	4889 00		
HS13 5-12H-1	5	12	139	5916 00		
HS13 5-5DC-1	5	5	C/L	2444.00		
HS13 5-8FC-1	5	8	C/L	3897.00		
HS13 6-1A-1	6	1	0	399.00	U/S	25 OCT 96
HS13 6-3B-1	6	3	245	1423 00		
HS13 6-5C-1	6	5	92	2420.00		
HS13 6-8E-1	6	8	278	3869.00		
HS13 6-10G-1	6	10	166	4886 00		
HS13 6-12H-1	6	12	279	5886.00		
HS13 6-5DC-1	6	5	C/L	2419.00		
HS13 6-8FC-1	6	8	C/L	3868.00		
HS13 7-2J-2	7	2	0	985 00	U/S	25 OCT 96
HS13 7-4L-2	7	4	51	1885.00	U/S	26 JAN 98
HS13 7-6M-2	7	6	98	2860.00	U/S	26 JAN 98
HS13 7-7N-2	7	7	217	3445.00	U/S	26 JAN 98
HS13 7-9O-2	7	9	320	4363 00	U/S	26 JAN 98
HS13 7-11P-2	7	11	182	5317.00	U/S	26 JAN 98
HS13 7-2KC-2	7	2	C/L	1000 00	U/S	26 JAN 98
HS13 7-11RC-2	7	11	C/L	5321.00	U/S	26 JAN 98

Note: Elements 6 and 7 were replaced on 15 April 1998 due to severe damage (see Table C.9B)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.9B

HEATED SECTION 13 FES (1st REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS13 1-2J-2	1	2	0	950.00		
HS13 1-4L-2	1	4	204	1909.00		
HS13 1-6M-2	1	6	41	2877.00	U/S	03 MAY 95
HS13 1-7N-2	1	7	168	3453.00		
HS13 1-9O-2	1	9	251	4403.00		
HS13 1-11P-2	1	11	332	5381.00		
HS13 1-2KC-2	1	2	C/L	951.00		
HS13 1-11RC-2	1	11	C/L	5380.00		
HS13 4-2J-2	4	2	0	969.00	U/S	12 AUG 91
HS13 4-4L-2	4	4	286	1915.00		
HS13 4-6M-2	4	6	243	2899.00		
HS13 4-7N-2	4	7	30	3465.00		
HS13 4-9O-2	4	9	151	4388.00		
HS13 4-11P-2	4	11	358	5394.00		
HS13 4-2KC-2	4	2	C/L	970.50		
HS13 4-11RC-2	4	11	C/L	5393.00		
HS13 5-1A-1	5	1	0	421.00	U/S	12 NOV 96
HS13 5-3B-1	5	3	155	1421.00	U/S	26 NOV 99
HS13 5-5C-1	5	5	266	2445.00		
HS13 5-8E-1	5	8	57	3900.00		
HS13 5-10G-1	5	10	292	4889.00		
HS13 5-12H-1	5	12	139	5916.00	U/S	Rec'd
HS13 5-5DC-1	5	5	C/L	2444.00		
HS13 5-8FC-1	5	8	C/L	3897.00		
HS13 6-1A-1	6	1	0	391.50		
HS13 6-3B-1	6	3	306	1419.50		
HS13 6-5C-1	6	5	279	2423.50		
HS13 6-8E-1	6	8	78	3873.50		
HS13 6-10G-1	6	10	307	4889.00	U/S	02 DEC 98
HS13 6-12H-1	6	12	178	5890.00	U/S	Rec'd
HS13 6-5DC-1	6	5	C/L	2423.50		
HS13 6-8FC-1	6	8	C/L	3872.50		
HS13 7-2J-2	7	2	0	981.00		
HS13 7-4L-2	7	4	293	1936.00		
HS13 7-6M-2	7	6	16	2857.00		
HS13 7-7N-2	7	7	63	3448.00		
HS13 7-9O-2	7	9	12	4400.00		
HS13 7-11P-2	7	11	7	5321.00		
HS13 7-2KC-2	7	2	C/L	974.00		
HS13 7-11RC-2	7	11	C/L	5297.00		

Notes: Replacement elements 6 and 7 were installed on 15 April 1998
Element 7 was replaced on 09 December 1999 due to severe damage (see Table C.9C)

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.9C

HEATED SECTION 13 FES (2nd REPLACEMENT) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS13 1-2J-2	1	2	0	950.00		
HS13 1-4L-2	1	4	204	1909.00		
HS13 1-6M-2	1	6	41	2877.00	U/S	03 MAY 95
HS13 1-7N-2	1	7	168	3453.00		
HS13 1-9O-2	1	9	251	4403.00		
HS13 1-11P-2	1	11	332	5381.00		
HS13 1-2KC-2	1	2	C/L	951.00		
HS13 1-11RC-2	1	11	C/L	5380.00		
HS13 4-2J-2	4	2	0	969.00	U/S	12 AUG 91
HS13 4-4L-2	4	4	286	1915.00		
HS13 4-6M-2	4	6	243	2899.00		
HS13 4-7N-2	4	7	30	3465.00	U/S	07 DEC 99
HS13 4-9O-2	4	9	151	4388.00		
HS13 4-11P-2	4	11	358	5394.00		
HS13 4-2KC-2	4	2	C/L	970.50		
HS13 4-11RC-2	4	11	C/L	5393.00		
HS13 5-1A-1	5	1	0	421.00	U/S	12 NOV 96
HS13 5-3B-1	5	3	155	1421.00	U/S	26 NOV 99
HS13 5-5C-1	5	5	266	2445.00		
HS13 5-8E-1	5	8	57	3900.00		
HS13 5-10G-1	5	10	292	4889.00		
HS13 5-12H-1	5	12	139	5916 00	U/S	Rec'd
HS13 5-5DC-1	5	5	C/L	2444 00		
HS13 5-8FC-1	5	8	C/L	3897.00		
HS13 6-1A-1	6	1	0	391.50		
HS13 6-3B-1	6	3	306	1419.50		
HS13 6-5C-1	6	5	279	2423.50		
HS13 6-8E-1	6	8	78	3873.50		
HS13 6-10G-1	6	10	307	4889.00	U/S	02 DEC 98
HS13 6-12H-1	6	12	178	5890 00	U/S	Rec'd
HS13 6-5DC-1	6	5	C/L	2423.50		
HS13 6-8FC-1	6	8	C/L	3872.50		
HS13 7-1A-1	7	1	0	422.00		
HS13 7-3B-1	7	3	62	1435 00		
HS13 7-5C-1	7	5	131	2425 00		
HS13 7-8E-1	7	8	284	3851.00		
HS13 7-10G-1	7	10	56	4864 00		
HS13 7-12H-1	7	12	239	5840 00		
HS13 7-5DC-1	7	5	C/L	2425.00		
HS13 7-8FC-1	7	8	C/L	3863.00		

Note: Replacement element 7 was installed on 09 December 1999

APPENDIX C: FUEL ELEMENT SIMULATOR THERMOCOUPLE LOCATIONS

TABLE C.10

HEATED SECTION 14 FES (ORIGINAL) THERMOCOUPLE LOCATIONS

Location	Element Number	Segment Number	Radial Location (°)	Axial Distance (mm)	T/C Status	Date Failed
HS14 1-2J-2	1	2	0	966.00	U/S	Rec'd
HS14 1-4L-2	1	4	296	1916.00	U/S	24 MAR 92
HS14 1-6M-2	1	6	271	2813.00		
HS14 1-7N-2	1	7	66	3457.00		
HS14 1-9O-2	1	9	189	4392.00		
HS14 1-11P-2	1	11	289	5317.00		
HS14 1-2KC-2	1	2	C/L	964.50		
HS14 1-11RC-2	1	11	C/L	5316.00		
HS14 4-2J-2	4	2	0	986.00		
HS14 4-4L-2	4	4	108	1910.00		
HS14 4-6M-2	4	6	17	2869.00		
HS14 4-7N-2	4	7	127	3429.00		
HS14 4-9O-2	4	9	238	4399.00		
HS14 4-11P-2	4	11	303	5336.00		
HS14 4-2KC-2	4	2	C/L	985.00		
HS14 4-11RC-2	4	11	C/L	5335 00		
HS14 5-1A-1	5	1	0	378 00		
HS14 5-3B-1	5	3	249	1421.00		
HS14 5-5C-1	5	5	184	2401 00		
HS14 5-8E-1	5	8	280	3850 00	U/S	15 JAN 98
HS14 5-10G-1	5	10	48	4890 00	U/S	22 OCT 96
HS14 5-12H-1	5	12	243	5873.00		
HS14 5-5DC-1	5	5	C/L	2400.00		
HS14 5-8FC-1	5	8	C/L	3850.00		
HS14 6-1A-1	6	1	0	378.00		
HS14 6-3B-1	6	3	253	1422.00		
HS14 6-5C-1	6	5	219	2401.00	U/S	04 FEB 92
HS14 6-8E-1	6	8	85	3850.00	U/S	19 JUL 88
HS14 6-10G-1	6	10	287	4889.00		
HS14 6-12H-1	6	12	97	5880.00	U/S	15 JAN 98
HS14 6-5DC-1	6	5	C/L	2401.00		
HS14 6-8FC-1	6	8	C/L	3849.00		
HS14 7-2J-2	7	2	0	965.00		
HS14 7-4L-2	7	4	16	1923.00	U/S	04 FEB 92
HS14 7-6M-2	7	6	165	2804.00	U/S	03 JUN 94
HS14 7-7N-2	7	7	269	3451.00		
HS14 7-9O-2	7	9	72	4376.00		
HS14 7-11P-2	7	11	210	5289.00	U/S	Rec'd
HS14 7-2KC-2	7	2	C/L	967.00		
HS14 7-11RC-2	7	11	C/L	5300.00		

APPENDIX D: FAST-FILL WATER SYSTEM

The fast-fill water system is required to fill the primary, secondary, and the ECI systems with fresh distilled water. The water is supplied to the loop via a 3-inch line, from the distilled water system.

The fast-fill water system schematic is shown in Figure D.1.

D.1 PRIMARY AND SECONDARY SYSTEMS

A low head centrifugal pump, P3, is used to fill the primary and secondary systems. Using P3, fast-fill water is injected into the primary system upstream of P2, and into the secondary system piping downstream of HX2.

D.2 ECI SYSTEM

The ECI tank, TK2, is filled with water using pump P8.

D.3 BACK-FILL SYSTEM

Instrumentation requiring full impulse lines, such as pressure or differential pressure transmitters, are filled using an air-driven pump and tubing lines connected to the impulse lines. This pump automatically turns on when the transmitters isolation valves are opened and shuts off when the valves are closed.

APPENDIX D: FAST-FILL WATER SYSTEM

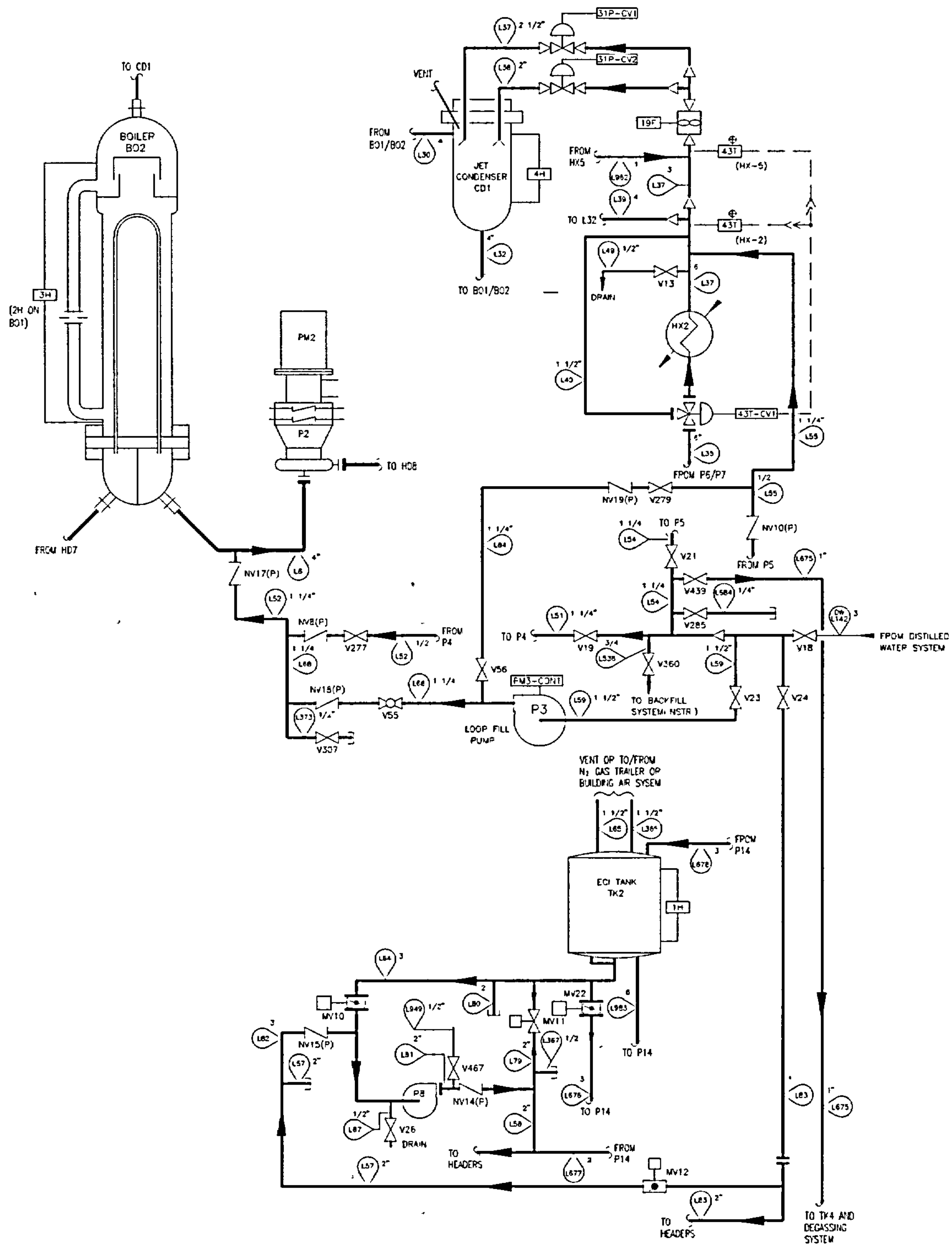


FIGURE D.1: Fast-Fill Water System Schematic

APPENDIX E: DEGAS SYSTEM

The degas system is used to remove noncondensible gases from the loop prior to an experiment.

Since the RD-14M loop is frequently drained, either for loop reconfiguration or during an experiment, an effective system for removing noncondensible gases from the loop is required.

Before filling the RD-14M loop with water, noncondensible gases are usually removed using a vacuum pump. If further degassing is required, the RD-14M degas system is used.

During degassing, some primary fluid is diverted from header HDR6 to the vapour side of the degas tank. Noncondensible gases then accumulate in the degas tank and are periodically vented. The condensate side of the degas tank is connected via high-pressure, positive displacement pumps to the surge tank, where the fluid returns to the primary loop via header HDR5.

During an experiment, the degas tank is isolated from the main loop. A ball valve, MV20, located in the line connecting the degas tank to HDR6, is normally closed to isolate the degassing system prior to any transient experiments.

The major components are described below. The piping schematic and pipe sizes for the RD-14M degas system are shown in Figure E.1, the degas tank is shown in Figure E.2, the heat exchanger, HX1, is shown in Figure E.3, and pumps P10 and P11 are shown in Figure E.4.

A distilled water line is connected upstream of P10 and P11. This line can be used to fill the system.

E.1 DEGAS SYSTEM PIPING

All degas system piping is ASTM A106, Grade-B carbon-steel pipe. Pipe sizes vary from 0.5-inch (nominal) schedule-80 to 1.5-inch (nominal) schedule-80. All degas system piping is pressure rated to 16.5 MPa (g) at 343°C. Socket-welded joints are used for nominal piping up to 2 inches.

E.2 DEGAS TANK

The degas tank (CD2), shown in Figure E.2, is a vertical carbon-steel vessel (ASME SA106 Grade-B) with a 10-inch Grayloc type closure on the top. The top closure has an array of piping and tubing connections. There are three pipe connections (2 inch, 1¼ inch, and 1 inch) that hold fulljet nozzles. The nozzles are used to separate the vapour from the liquid. There are also two connections for a 3/8-inch (OD) tube-cooling coil. This coil is used to condense vapours. The non-condensable gases are vented through a ½-inch line via motorized valve MV14. The line is also connected to a safety relieving device (burst disc BD11) for the tank.

The degas tank has a design pressure of 16.5 MPa (g) at 343°C. The working pressure for the vessel is 14 MPa (g) at 337°C.

The empty vessel mass is 1227 kg, and the capacity is 0.264 m^3.

The tank's liquid level is regulated using feedback from differential pressure cell 6H. The liquid level in the degas tank is determined by measuring the pressure difference between two taps provided near the top and bottom of the vessel, as shown in Figure E.2. The tank's fluid temperature (thermocouple 4T) and pressure (14P) can be measured near the bottom of the tank, as shown in Figure E.2.

A bursting disc, BD11, is used to protect the degas tank from over pressure. The burst disc is set at 16.5 MPa (g).

E.3 DEGAS COOLER

A bleed-flow cooler (heat exchanger), shown in Figure E.3, is used to cool the primary system operating fluid temperature to 100°C. This prevents the fluid from flashing in CD2. The unit is a shell and tube type heat exchanger designed and fabricated by ISKO Limited. The shell is 16-inch (OD) × 3/8-inch nominal wall and made from carbon steel. The tube is ¾ inch (OD) by 16 BWG wall, made from 304 stainless steel, and is coiled to the required heat transfer length. The rated capacity of the cooler is 300 kW. The capacity is based on a primary fluid flow of 0.2 kg/s with a temperature change of the primary fluid from 310 to 100°C. The tube side of the vessel is rated for 16.5 MPa (g) at 343°C and the shell side is rated for 1.035 MPa (g) at 343°C.

E.4 PUMPS

Two positive displacement pumps, P10 and P11, shown in Figure E.4, return the condenser's condensate to the surge tank. The pumps are a packed plunger size C positive-displacement duplex-type pump manufactured by Milton Roy, model MR2-128-140T, rated for 16.5 MPa (g), and has a total pumping capacity of 0.3 L/s at a discharge pressure of 16 MPa (g). A 7.5 kW, 3-phase, 60 Hz, 575 VAC, 1750 rpm electric motor drives the pumps (one motor drives both pumps simultaneously).

E.5 DEGAS FILTERS

Two sets of filters (FR26-FR29 in Figure E.1) are used to clean the water before the water is returned to TK1. The filter housings are rated for 16.5 MPa (g) at 350°C. Each filter housing holds 1 - 100 micron cartridge. The filters are designed and fabricated by Peacock (model number 1-H-2).

APPENDIX E: DEGAS SYSTEM

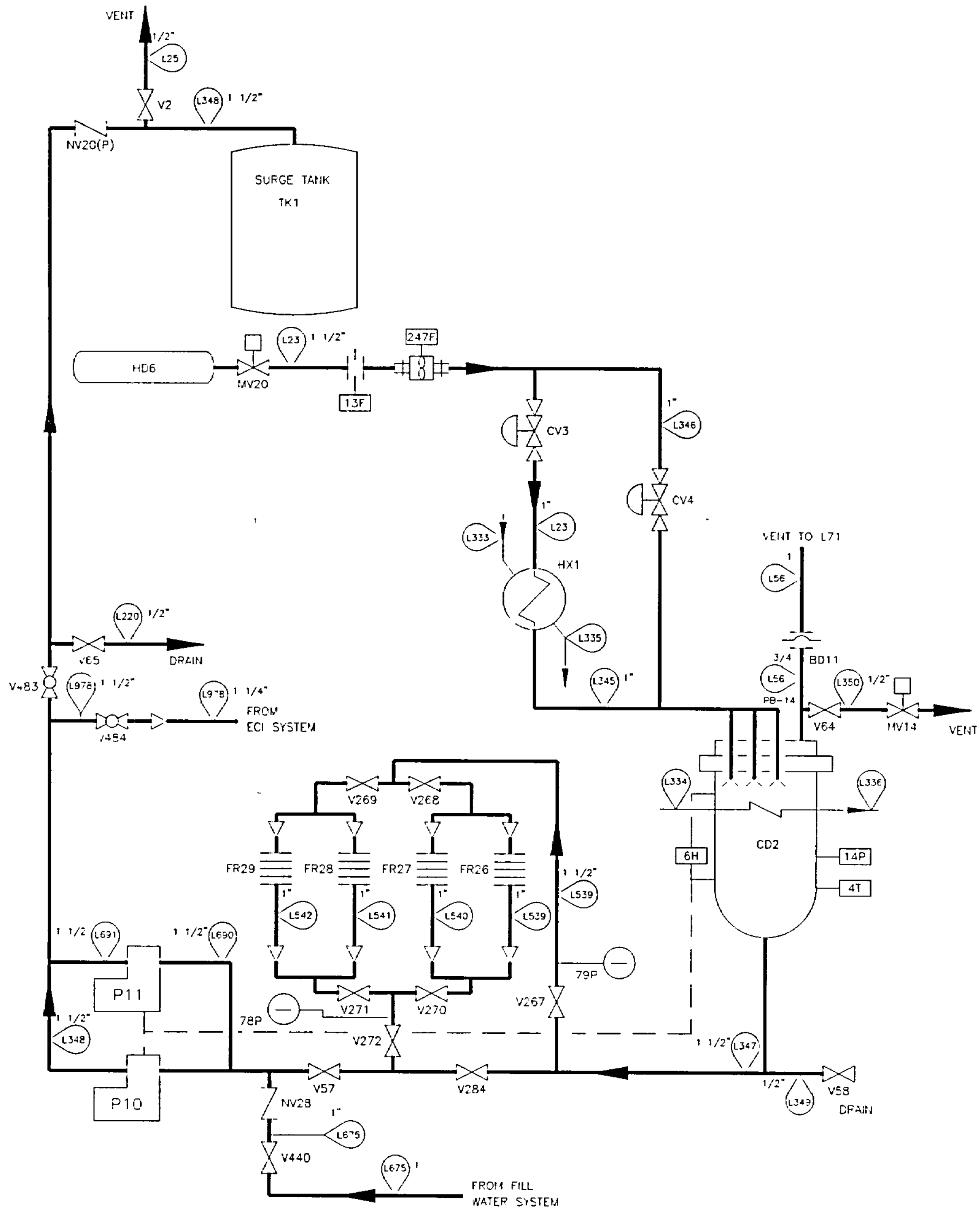


FIGURE E.1: Degas System Schematic

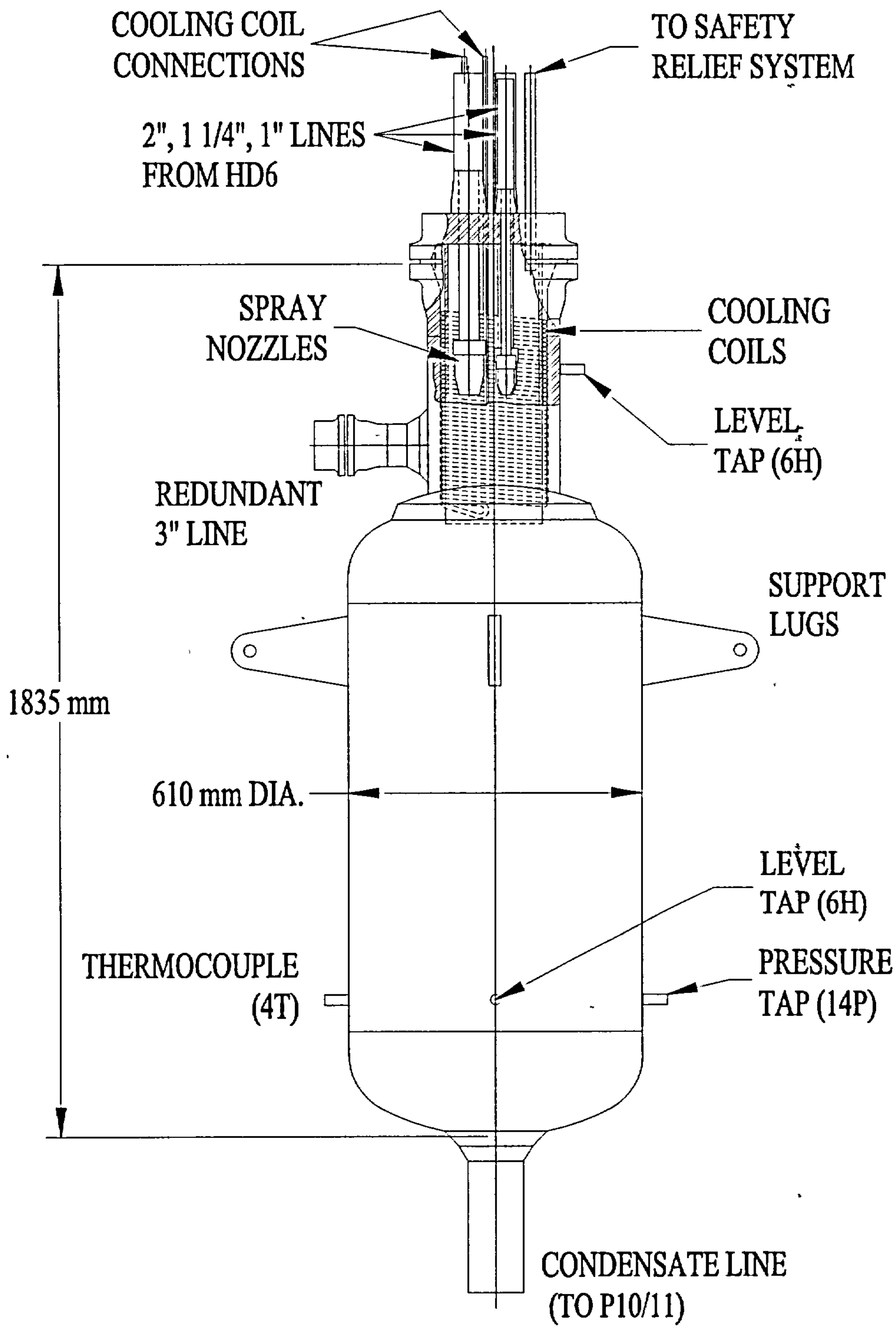


FIGURE E.2: Degas Tank (CD2) Schematic

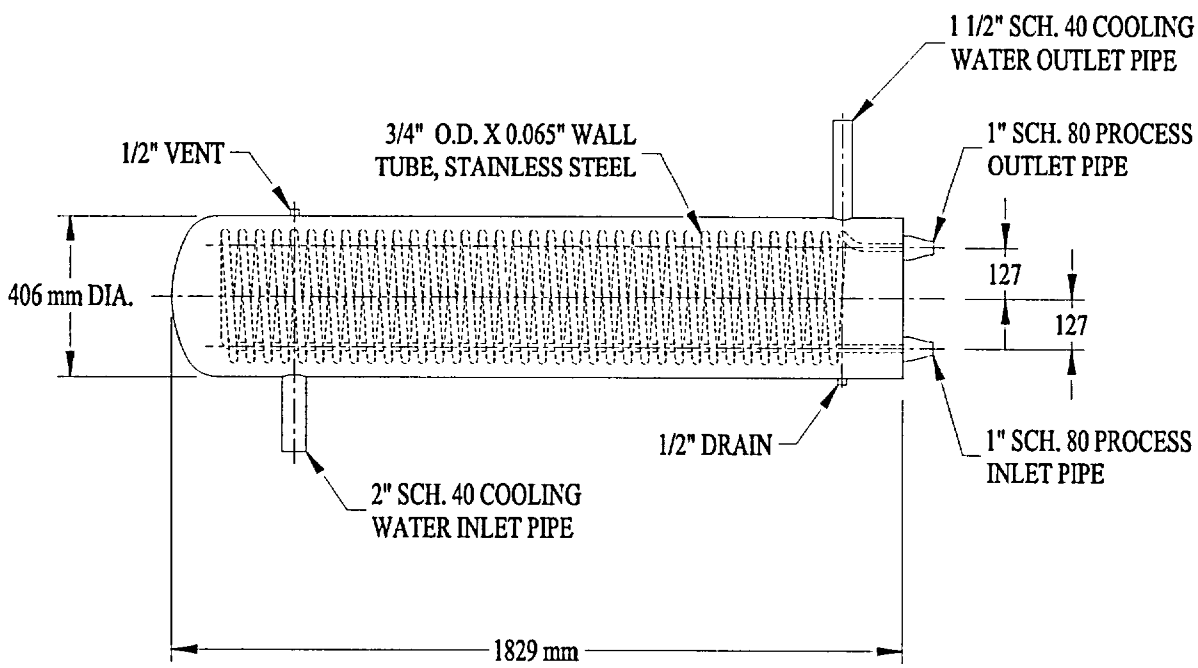
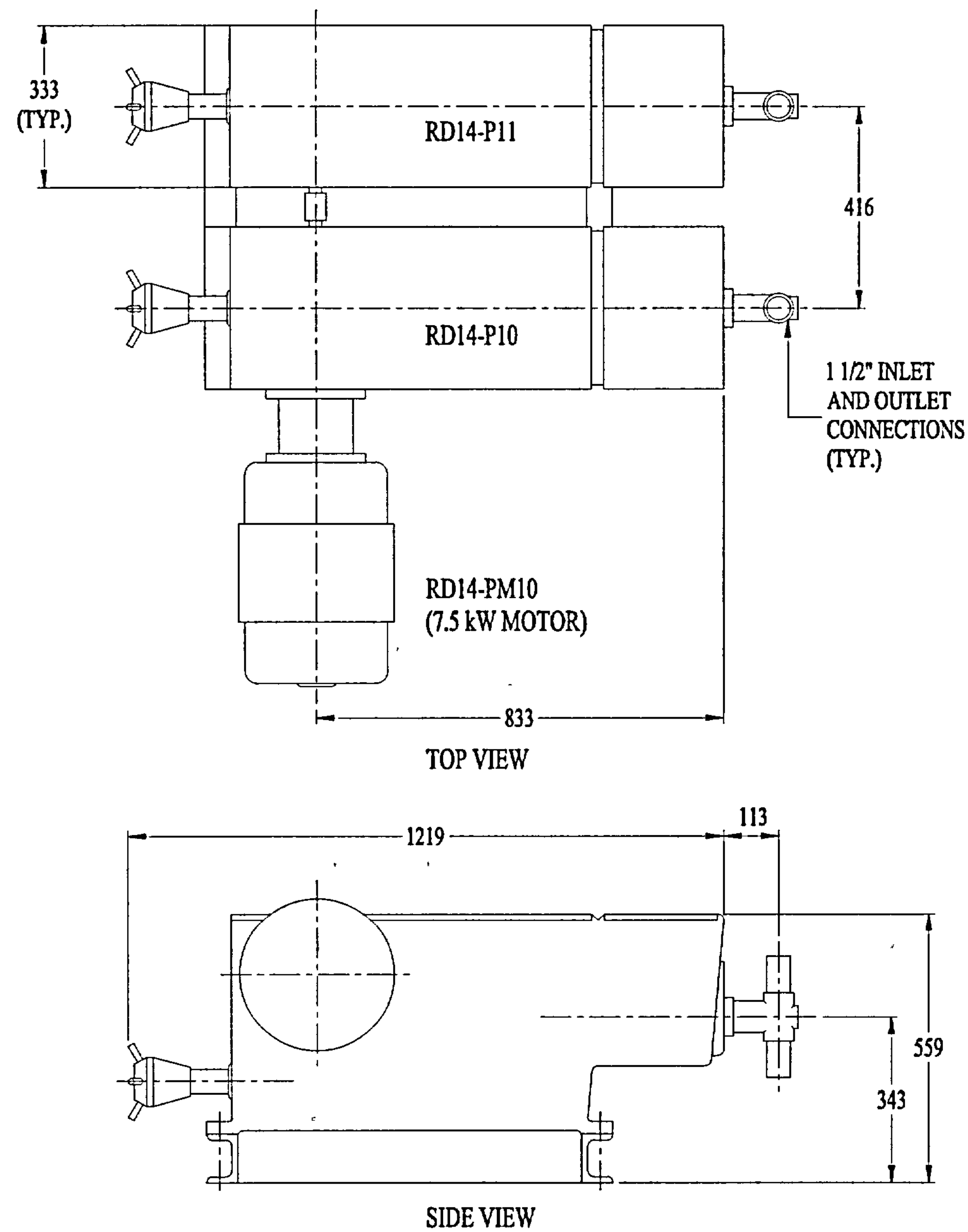


FIGURE E.3: Degas Heat Exchanger (HX1) Schematic



Note: Dimensions in mm

FIGURE E.4: Pumps P10/P11

APPENDIX F: ELECTRICAL SYSTEM

F.1 GENERAL

The RD-14M facility's electrical system is supplied from the WL site's main plant substation at the 4160 volt AC level. The main requirement was obtaining an 11 MW block of controllable D.C. power at the heated sections. The total RD-14M load required is approximately 16000 kVA. This includes the conversion and auxiliary power.

A general overview of the electrical system is shown in Figure F.1. Two indoor unit substations (DE-PL76 and DE-PL78) are connected to feeder breakers 9 and 10 (CCT # 9 and CCT # 10, respectively) at the main plant substation via two main 5 kV feeders. These indoor substations feed the two main rectifier transformers (RD14-T1 and RD14-T2) for the D.C. power supplies and the distribution transformers (RD14-T15 and RD14-T16) for the 600 volt auxiliary equipment.

F.2 MAIN 5 kV FEEDERS

Two 5 kV feeders connect the main plant substation to the indoor RD-14M substations. The main feeders are buried in common code-approved trenches.

Each main 5 kV feeder consists of 4 - 300 MCM shielded power cables, 3 conductor copper with ground wires, and 90°C XLPE insulation with PVC jacket suitable for direct earth burial. Each cable has a code current-carrying capacity of 300 A at 4160 V; each main feeder therefore has a 1200 A capacity or 8646 kVA.

F.3 UNIT SUBSTATIONS (DE-PL76 and DE-PL78)

The electrical distribution room, in the basement of the RD-14M building, houses the two indoor unit substations. The substations are metal-clad type, and are identical except for being a mirror image of each other. This was done to facilitate the high and low voltage cabling (see Figure F.2).

F.4 D.C. POWER SUPPLY SYSTEM

D.C. power is used for the fuel element simulators (FES). The D.C. power system consists of two indoor 7000 kVA double secondary rectifier transformers (T1 and T2), and four close coupled D.C. power supply units (PS1, PS2, PS3 and PS4).

The primary design output parameters were based on:

- a total loop load of 11 MW,
- size dictated by the FES resistance in each RD-14M heated section, and
- voltage drops due to the tubular bus runs and inductor coil lengths.

APPENDIX F: ELECTRICAL SYSTEM

The output specifications for each of the four power supplies are:

- Voltage 0 - 431 V D.C.
- Current: 0 - 6875 A
- Power: 0 - 2963 kW

The units can also supply 7248 A at 410 V.

Aluminum tubular water cooled bus bars run from the power supplies to the inductor coils and then to the aluminum power poles. The power poles are vertical and water cooled and are used to distribute the power to each of the fuel element simulators.

The D.C. power system can operate in one of three modes by switch selection. These modes are voltage, current and output kW. The power system is normally operated in the output kW mode.

The silicon controlled rectifiers, SCR's, are connected as a 3-phase, full-wave bridge, using parallel connected SCR's for the rectification. The SCR firing circuit is current limited.

The rectifier system includes the following protective circuits:

- Instantaneous Current Trip, ICT, which shuts down the output within 8 milliseconds;
- over-temperature thermostats on the SCR heat sinks for system shutdown;
- thermal switches in the transformer for alarm and system shutdown;
- water flow switches in the cooling water circuit to the SCR's;
- door interlock circuits (alarms only);
- automatic high voltage shutdown (sense trip on the breaker); and
- phase rotation indicator internally mounted to indicate proper phase rotation.

In RD-14M there are five heated sections per pass, and two passes for a complete loop circuit. To simulate the reactor core power distribution, three heated sections per pass are connected to one set of power poles, and the other two heated sections per pass are connected to the other set of power poles. Under normal, full-power conditions, the power distribution is set to be a split of approximately 55% of total power to heated sections HS5, HS6, HS9, HS10, HS11, and HS14, and 45% to heated sections HS7, HS8, HS12, and HS13. The power distribution can be changed if desired.

Each end of the ten heated sections is connected to the power supplies' power poles. Each power pole-heated section connection has an aluminum bus bar at one end of the 4-350 MCM welding cables, and a copper bus bar at the other end. When all heated sections are used during an experiment, the heated sections are connected to the power supplies as follows:

- heated sections HS5, HS6, HS9 are fed from power supply PS1,
- heated sections HS7, HS8 are fed from power supply PS2,
- heated sections HS10, HS11, HS14 are fed from power supply PS3, and
- heated sections HS12, HS13 are fed from power supply PS4.

Each substation consists of the following sections:

- PANEL DE-PL 76

  - Section A - Low voltage distribution section 600 volts 3 phase 800 amp main containing:
    - metering section with 3-800/5 amp CTs, 2-600/120 volt VTs, 0-750 volt voltmeter (DE-12V-N1) with selector switch (DE-12V-H1), 0-800 amp ammeter (DE-12A-N1) with selector switch (DE-12A-H1), test blocks.
    - 3-200 amp QMBQ fusible disconnect units (RD14-PM1-S1, RD14-PM9-S1, and RD14-HR23-S1)
    - 1-400 amp QMBQ fusible disconnect unit (RD14-S43-S1)
    - 1-600 amp QMBQ fusible disconnect unit (RD14-PM14-S1)

  - Section B - 750 kVA indoor dry type transformer (RD14-T15) 150°C rise 4160 Δ - 600 grd Y with 4-2 ½% HVFC taps 2A and 2B normal temperature indicator with alarm contacts.

  - Section C - 5 kV 400 amp load break switch with 150 amp fuses (DE-S41).

  - Section D - 5 kV 1200 amp main disconnect switch (DE-S39)with 2-1500/5 amp CTs, 0-1500 amp ammeter (DE-10A-N1) with selector switch (DE-10A-H1), 2-4200/120 volt VTs with fused disconnects, 0-5000 volt voltmeter (DE-10V-N1) with selector switch (DE-10V-H1), connectors for 4-300 MCM cables per phase.

  - Section E - Manitoba Hydro Metering Compartment

  - Section F - 5 kV 1200 amp air circuit breaker (RD14-B1):
    - New protective relay settings
    - Target and seal in Tap: 2.0
    - Time Dial: 7
    - Short time tap: 4
    - Inst. Tap: 0

  - Section G - 5 kV 450 kVAR capacitor (RD14-CAP1)

- PANEL DE-PL 78

  - Section A - Low voltage distribution section 600 volts 3 phase 800 amp main containing:
    - metering section with 3-800/5 amp CTs, 2-600/120 volt VTs, 0-750 volt voltmeter (DE-13V-N1) with selector switch (DE-13V-H1), 0-800 amp ammeter (DE-13A-N1) with selector switch(DE-13A-H1), test blocks.
    - 3-200 amp QMBQ fusible disconnect units (RD14-PM8-S1, RD14-PM2-S1, and a spare)
    - 1-400 amp QMBQ fusible disconnect unit (RD14-S44-S1)

  - Section B - 750 kVA indoor dry type transformer (RD14-T16) 150°C rise 4160 Δ - 600 grd Y with 4-2 ½% HVFC taps 2A and 2B normal temperature indicator with alarm contacts.

  - Section C - 5 kV 400 amp load break switch with 150 amp fuses (DE-S42).

  - Section D - 5 kV 1200 amp main disconnect switch (DE-S40)with 2-1500/5 amp CTs, 0-1500 amp ammeter (DE-11A-N1) with selector switch (DE-11A-H1), 2-4200/120 volt VTs with fused disconnects, 0-5000 volt voltmeter (DE-11V-N1) with selector switch (DE-11V-H1), connectors for 4-300 MCM cables per phase.

  - Section E - Manitoba Hydro Metering Compartment

  - Section F - 5 kV 1200 amp air circuit (RD14-B2):
    - New protective relay settings
    - Target and seal in Tap: 2.0
    - Time Dial: 7
    - Short time tap: 4
    - Inst. Tap: 0

  - Section G - 5 kV 450 kVAR capacitor (RD14-CAP2)

F.5 TRACE HEATING SYSTEM

The electrical schematic for the trace heating system is given in Figure F.3. The trace heating system is discussed in Section 5.500.

APPENDIX F: ELECTRICAL SYSTEM

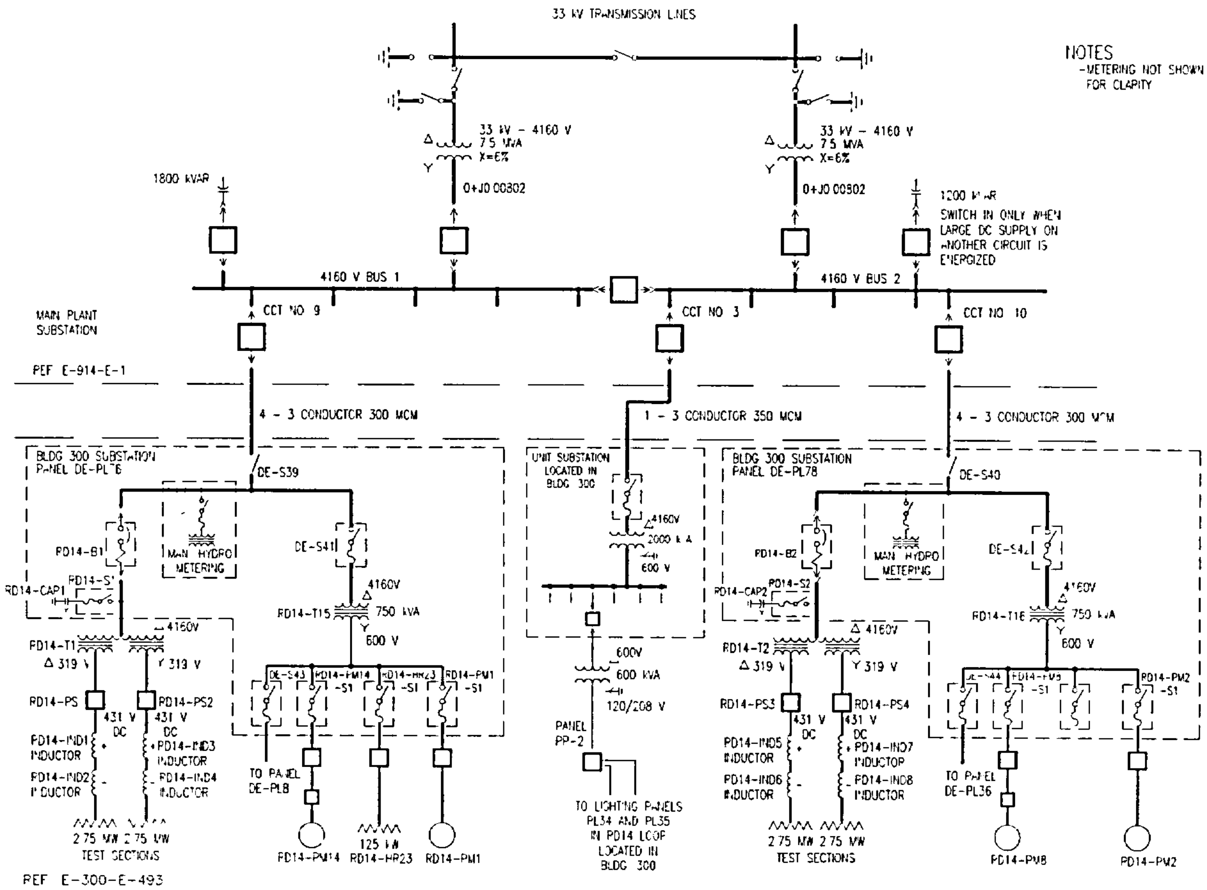


FIGURE F.1: Site's Electrical System Schematic for RD-14M

APPENDIX F: ELECTRICAL SYSTEM

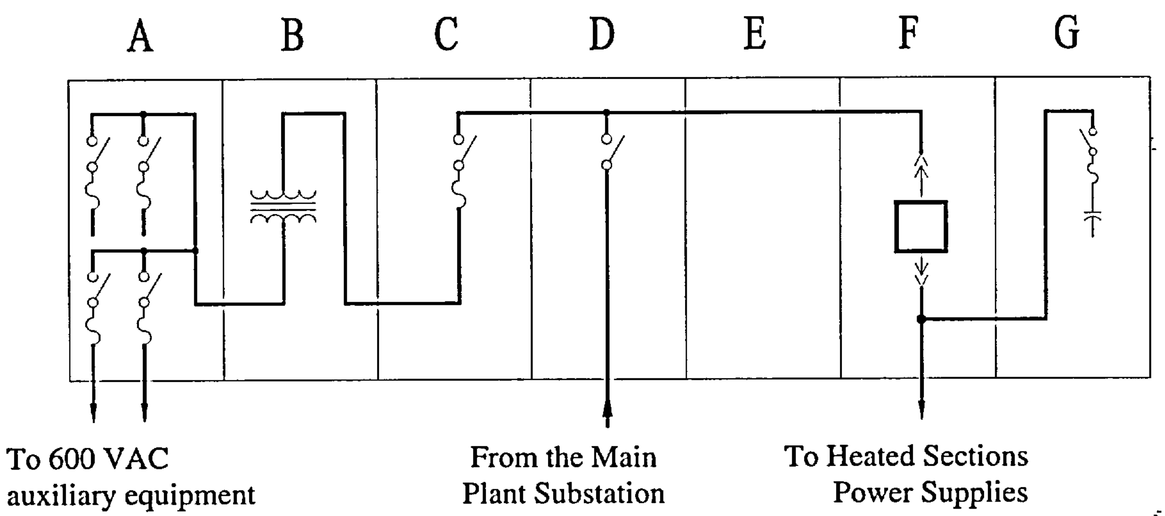


FIGURE F.2: Indoor Unit Substations

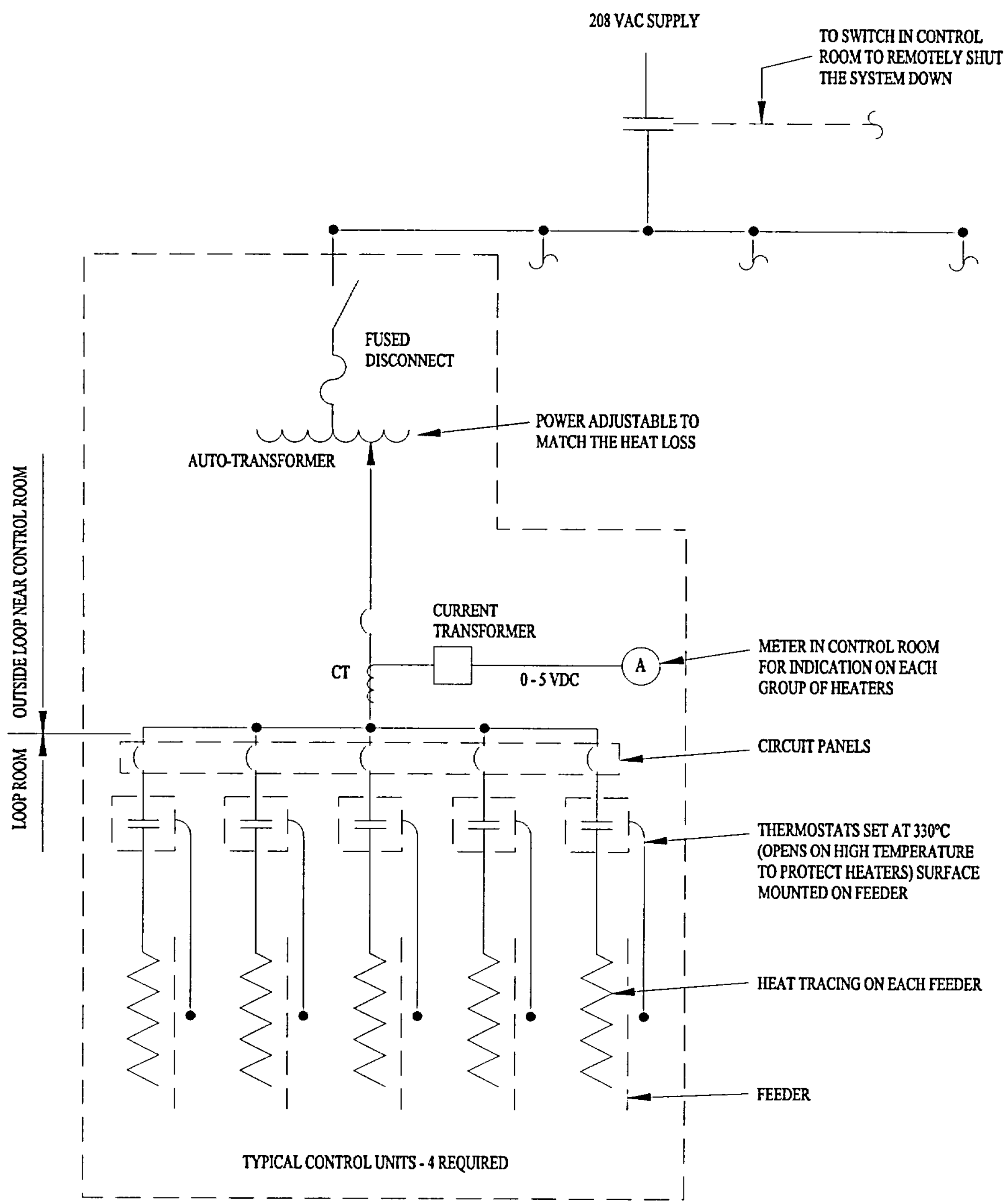


FIGURE F.3: Trace Heating Electrical Schematic

APPENDIX B

RD-14M TEST B9401 TEST DESCRIPTION

The following is a reproduction of stand-alone report giving specific, relevant information for test B9401.

AVAILABLE RC-2491

RD-14M TEST B9401 - 30 mm INLET HEADER BREAK EXPERIMENT WITH HIGH PRESSURE PUMPED EMERGENCY COOLANT INJECTION

by

T.V. Sanderson, A.J. Melnyk, P.J. Ingham
J.W. Findlay, J.E. Middleton and J.M. Wedgwood

ABSTRACT

A series of experiments to investigate the thermalhydraulic consequences of a critical break with Emergency Coolant Injection is in progress in the RD-14M Test Facility. This report briefly describes the experimental conditions, procedure and results from a 30 mm Inlet Header break with a high pressure pumped emergency coolant injection system.

OBJECTIVE

A series of experiments to investigate the thermalhydraulic behaviour of a critical break with emergency coolant injection is being conducted in the RD-14M Test Facility. A variety of conditions are examined, including break size, primary pump ramp, effect of surge tank isolation and high pressure pumped emergency coolant injection (ECI) systems. This report briefly describes the experimental conditions, procedure and results from a 30 mm Inlet Header break with a high pressure pumped emergency coolant injection system.

INITIAL CONDITIONS

The nominal initial conditions for the first experiment in this series, B9401, were as follows:

Primary System:	outlet header pressure	- 10.0 MPa(g)
	nominal input power	- 4.0 MW per pass
	(see Table 1)	
Secondary System:	steam drum pressure	- 4.4 MPa(g)
	steam separator level	- 55%
	feedwater temperature	- 186°C

PROCEDURE

Before the experiment, the loop was evacuated, filled and degassed, all instrument lines were vented, and instrument readings were checked and adjusted. The loop was warmed using low power and reduced pump speed. Input power and pump speed were then increased to bring the loop to the desired steady-state single phase starting conditions. The output from all instruments was then scanned and printed as a final check. Then, data gathering was started.

The sequence of events during the experiment was as follows:

t =	0 s,	data gathering started
t =	10 s,	open MV8, start pump 14
t =	12 s,	step power down to decay levels, start primary pump rampdown
t =	20.6 s,	ECI isolation valves open
t =	22.8 s,	Pressurizer (TK1) isolated
t =	116.2 s,	High pressure pumped ECI terminated, low pressure pumped ECI started
t =	213.2 s,	Primary pumps off
t =	229.2 s,	scans stopped
t =	231 s,	scans restarted
t =	350.7 s,	Low pressure pumped ECI terminated
t =	460 s,	scans stopped
t =	463 s,	scans restarted
t =	692 s,	scans stopped
t =	695 s,	scans restarted
t =	924 s,	scans stopped

Note: All times after t = 0 are approximate.

RESULTS

No analysis of the experimental results is presented here. The raw experimental data is attached in the following form:

Table 1 This table provides the measured power supplied to the heated sections.

Table 2 This table lists the instruments scanned during the experiment, but not included with the plots in this report. These instruments were not included because of off-scale, faulty, or inaccurate readings.

Table 3 This table lists the instruments plotted which failed during the course of the test. These instruments were included since they provide useful information for part of the test.

B.DAT This is a listing of all instruments scanned during the experiment. This listing has been rearranged to correspond with the master instrument list format used in the RD-14M data base. See note below for details of plot sequencing.

R.DAT This listing shows the average outputs of all instruments prior to data gathering. See note below for details of plot sequencing.

E.DAT This table gives the empty and full benchmark voltage for the gamma densitometers.

FLUKE This file shows heated section powers prior to the start of the experiment and the during the experiment.

Note: Instrument listings are arranged as follows: surge tank, primary circuit, FES, secondary circuit, ECI, and miscellaneous. In the primary circuit, the order is as follows: measurements at both outlet headers, measurements on piping connecting the outlet headers to the boiler inlets, primary boiler measurements, and pump and inlet header measurements. Inlet feeder measurements for both passes are grouped next, followed by test sections (excluding the FES) and outlet feeder measurements. FES measurements are listed according to test section. Measurements are sequenced from inlet to outlet location and from top to bottom FES at each location.

TABLE 1

INPUT POWER FOR B9401

HEATED SECTION	POWER (kW) Full	Decay
5	772 kW	28 kW
6	775 kW	29 kW
7	819 kW	36 kW
8	954 kW	42 kW
9	786 kW	29 kW
10	761 kW	29 kW
11	765 kW	30 kW
12	797 kW	33 kW
13	940 kW	40 kW
14	771 kW	29 kW

TABLE 2

INSTRUMENTS TO BE EXCLUDED FOR TEST B9401

CHANNEL NUMBER	DEVICE CODE	LOCATION
170	5F-M1	BO1 FW M FLOW
174	6F-M1	B02 FW M FLOW
468	209T-D2	HS14 7-6M-2

TABLE 3

INSTRUMENTS WHICH FAILED DURING THE TEST

CHANNEL NUMBER	DEVICE CODE	LOCATION
278	202T-D4	HS7 1-2KC-2
488	217T-D1	TS6 OUTLET
661	205T-D19	HS10 7-2J-2
79	2F	P2 OUT
366	178F-D1	HS5 OUTLET
370	182F-D1	HS7 OUTLET
374	186F-D1	HS9 OUTLET
375	187F-D1	HS10 INLET
377	189F-D1	HS11 INLET
379	191F-D1	HS12 INLET
381	193F-D1	HS13 INLET
383	195F-D1	HS14 INLET

Note: The turbine flow meters (TFMs) located at HS7 inlet (181F-D1), HS7 outlet (182F-D1), HS8 inlet (183F-D1), HS8 outlet (184F-D1), HS12 inlet (191F-D1), HS12 outlet (192F-D1), HS13 inlet (193F-D1) and HS13 outlet (194F-D1) were incorrectly calibrated to ± 6 L/s instead of ± 8 L/s. These TFMs were all off-scale at the start of the test. A pre-test mass balance, done at full loop flow of 22 L/s, indicates the total error introduced by these off-scale readings is 1.2 to 1.5% of total loop flow at the inlets and 4.7 to 5.3% at the outlets.

RD-14M Scanning File

Experiment B9401

Scanning file: B9401B.DAT
From file: SCNLST.DAT Created: 1-JUN-94 10:39:57

Total Channels 558

	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
1)	10	44	COND A	COND	5.00	VDC	2	BO2 INLET
2)	11	44	COND B	COND	5.00	VDC	2	BO2 OUTLET
3)	560	11	ECI DP1	DP-R	2000.00	KPA	3	77P-HDR5
4)	561	11	ECI DP2	DP-R	2000.00	KPA	3	77P-HDR6
5)	562	11	ECI DP3	DP-R	2000.00	KPA	3	77P-HDR7
6)	563	11	ECI DP4	DP-R	2000.00	KPA	3	77P-HDR8
7)	92	40	1H	DP-R	3556.00	MM	3	ECI TANK
8)	93	40	5H	DP-R	1828.80	MM	3	SRG TANK
9)	94	40	4H	DP-R	2184.40	MM	3	CD1
10)	169	40	2H-D1	DP-R	1535.00	MM	3	BO1 DRUM LEVEL
11)	172	40	3H-D1	DP-R	1528.00	MM	3	BO2 DRUM LEVEL
12)	334	40	8H-D1	DP-R	10579.00	MM	3	BO1 LEVEL
13)	335	40	9H-D1	DP-R	10581.00	MM	3	BO2 LEVEL
14)	7	39	12Q-D2	DP-R/S	100.00	KPA	5	P2 DELP
15)	72	39	135F	DP-R/S	15.00	KPA	5	BO1 DWNCMR
16)	198	39	57Q-D1	DP-R/S	2000.00	KPA	5	HDR5-HDR6
17)	322	39	5Q-D2	DP-R/S	100.00	KPA	5	P1 DELP
18)	326	39	136F	DP-R/S	15.00	KPA	5	BO2 DWNCMR
19)	330	39	58Q-D1	DP-R/S	2000.00	KPA	5	HDR7-HDR8
20)	331	39	35Q-D2	DP-R/S	1200.00	KPA	5	HDR8-HDR5
21)	336	39	35Q-D1	DP-R/S	2000.00	KPA	5	HDR8-HDR5
22)	337	39	36Q-D2	DP-R/S	1200.00	KPA	5	HDR6-HDR7
23)	338	39	36Q-D1	DP-R/S	2000.00	KPA	5	HDR6-HDR7
24)	339	39	3Q-D1	DP-R/S	300.00	KPA	5	BO1 DELP
25)	340	39	4Q-D1	DP-R/S	15.00	KPA	5	BO1-P1
26)	341	39	5Q-D1	DP-R/S	2500.00	KPA	5	P1 DELP
27)	342	39	6Q-D1	DP-R/S	75.00	KPA	5	P1-HDR6
28)	345	39	9Q-D1	DP-R/S	50.00	KPA	5	HDR7-BO2
29)	346	39	10Q-D1	DP-R/S	300.00	KPA	5	BO2 DELP
30)	347	39	11Q-D1	DP-R/S	15.00	KPA	5	BO2-P2
31)	348	39	12Q-D1	DP-R/S	2500.00	KPA	5	P2 DELP
32)	349	39	13Q-D1	DP-R/S	75.00	KPA	5	P2-HDR8
33)	352	39	16Q-D1	DP-R/S	50.00	KPA	5	HDR5-BO1
34)	530	39	24Q-D1	DP-R/S	1500.00	KPA	5	HS5
35)	531	39	24Q-D2	DP-R/S	175.00	KPA	5	HS5
36)	532	39	44Q-D1	DP-R/S	175.00	KPA	5	HS12-HDR5
37)	533	39	25Q-D1	DP-R/S	1500.00	KPA	5	HS6
38)	534	39	25Q-D2	DP-R/S	175.00	KPA	5	HS6
39)	535	39	39Q-D1	DP-R/S	300.00	KPA	5	HDR6-HS7
40)	536	39	26Q-D1	DP-R/S	1500.00	KPA	5	HS7
41)	537	39	26Q-D2	DP-R/S	575.00	KPA	5	HS7
42)	538	39	46Q-D1	DP-R/S	175.00	KPA	5	HS14-HDR5
43)	539	39	27Q-D1	DP-R/S	1500.00	KPA	5	HS8
44)	540	39	27Q-D2	DP-R/S	575.00	KPA	5	HS8
45)	541	39	41Q-D1	DP-R/S	1000.00	KPA	5	HDR6-HS9
46)	542	39	28Q-D1	DP-R/S	1500.00	KPA	5	HS9
47)	543	39	28Q-D2	DP-R/S	175.00	KPA	5	HS9

continued...

	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
48)	544	39	47Q-D1	DP-R/S	175.00	KPA	5	HS5-HDR7
49)	545	39	48Q-D1	DP-R/S	175.00	KPA	5	HS6-HDR7
50)	546	39	50Q-D1	DP-R/S	175.00	KPA	5	HS8-HDR7
51)	547	39	52Q-D1	DP-R/S	1000.00	KPA	5	HDR8-HS10
52)	548	39	53Q-D1	DP-R/S	1000.00	KPA	5	HDR8-HS11
53)	554	39	55Q-D1	DP-R/S	575.00	KPA	5	HDR8-HS13
54)	569	39	37Q-D1	DP-R/S	1000.00	KPA	5	HDR6-HS5
55)	570	39	29Q-D1	DP-R/S	1500.00	KPA	5	HS10
56)	571	39	29Q-D2	DP-R/S	175.00	KPA	5	HS10
57)	572	39	38Q-D1	DP-R/S	1000.00	KPA	5	HDR6-HS6
58)	573	39	30Q-D1	DP-R/S	1500.00	KPA	5	HS11
59)	574	39	30Q-D2	DP-R/S	175.00	KPA	5	HS11
60)	575	39	42Q-D1	DP-R/S	175.00	KPA	5	HS10-HDR5
61)	576	39	31Q-D1	DP-R/S	1500.00	KPA	5	HS12
62)	577	39	31Q-D2	DP-R/S	575.00	KPA	5	HS12
63)	578	39	40Q-D1	DP-R/S	575.00	KPA	5	HDR6-HS8
64)	579	39	32Q-D1	DP-R/S	1500.00	KPA	5	HS13
65)	580	39	32Q-D2	DP-R/S	575.00	KPA	5	HS13
66)	581	39	45Q-D1	DP-R/S	175.00	KPA	5	HS13-HDR5
67)	582	39	33Q-D1	DP-R/S	1500.00	KPA	5	HS14
68)	583	39	33Q-D2	DP-R/S	175.00	KPA	5	HS14
69)	584	39	43Q-D1	DP-R/S	175.00	KPA	5	HS11-HDR5
70)	585	39	49Q-D1	DP-R/S	175.00	KPA	5	HS7-HDR7
71)	586	39	51Q-D1	DP-R/S	175.00	KPA	5	HS9-HDR7
72)	587	39	54Q-D1	DP-R/S	575.00	KPA	5	HDR8-HS12
73)	588	39	56Q-D1	DP-R/S	1000.00	KPA	5	HDR8-HS14
74)	292	13	B11-DP	DP-TI	150.00	KPA	1	B2-TB11-DP
75)	293	13	B1-DP	DP-TI	150.00	KPA	1	B2-TB1-DP
76)	294	13	E4-DP	DP-TI	150.00	KPA	1	B2-TE4-DP
77)	170	26	5F-M1	FDW-F	3.00	KG/S	3	BO1 FW M FLOW
78)	174	26	6F-M1	FDW-F	3.00	KG/S	3	BO2 FW M FLOW
79)	100	7	12P-D1	GP-R	15000.00	KPA	3	HDR5
80)	102	7	31P-D1	GP-R	8000.00	KPA	3	CD1 PRESS
81)	103	7	27P	GP-R	7000.00	KPA	3	ECI TANK
82)	104	7	2P	GP-R	5000.00	KPA	3	BO2 DRUM
83)	105	7	1P	GP-R	5000.00	KPA	3	BO1 DRUM
84)	177	7	26P-D1	GP-R	16000.00	KPA	3	SRG TANK
85)	178	7	6P-D1	GP-R	15000.00	KPA	3	HDR7
86)	179	7	10P-D1	GP-R	15000.00	KPA	3	HDR8
87)	323	7	4P-D1	GP-R	15000.00	KPA	3	HDR6
88)	549	7	86P-D1	GP-R	15000.00	KPA	3	HS7 INLET
89)	550	7	95P-D1	GP-R	15000.00	KPA	3	HS10 INLET
90)	551	7	92P-D1	GP-R	15000.00	KPA	3	HS9 INLET
91)	552	7	98P-D1	GP-R	15000.00	KPA	3	HS11 INLET
92)	553	7	104P-D1	GP-R	15000.00	KPA	3	HS13 INLET
93)	555	7	111P-D1	GP-R	15000.00	KPA	3	HS5 OUTLET
94)	556	7	112P-D1	GP-R	15000.00	KPA	3	HS6 OUTLET
95)	557	7	114P-D1	GP-R	15000.00	KPA	3	HS8 OUTLET
96)	558	7	118P-D1	GP-R	15000.00	KPA	3	HS12 OUTLET
97)	559	7	120P-D1	GP-R	15000.00	KPA	3	HS14 OUTLET
98)	589	7	80P-D1	GP-R	15000.00	KPA	3	HS5 INLET
99)	590	7	101P-D1	GP-R	15000.00	KPA	3	HS12 INLET
100)	591	7	83P-D1	GP-R	15000.00	KPA	3	HS6 INLET
101)	592	7	107P-D1	GP-R	15000.00	KPA	3	HS14 INLET

continued...

	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
102)	593	7	89P-D1	GP-R	15000.00	KPA	3	HS8 INLET
103)	594	7	113P-D1	GP-R	15000.00	KPA	3	HS7 OUTLET
104)	595	7	115P-D1	GP-R	15000.00	KPA	3	HS9 OUTLET
105)	596	7	116P-D1	GP-R	15000.00	KPA	3	HS10 OUTLET
106)	597	7	117P-D1	GP-R	15000.00	KPA	3	HS11 OUTLET
107)	598	7	119P-D1	GP-R	15000.00	KPA	3	HS13 OUTLET
108)	297	9	77P	GP-TI	7000.00	KPA	2	ECI LINE PRESS
109)	299	9	36P-D1	GP-TI	350.00	KPA	2	BLWDWN LINE
110)	132	3	74T-D6	KTC-B	350.00	DEG C	3	BO1 PRE HTR
111)	133	3	225T-D3	KTC-B	350.00	DEG C	3	HS8 OUT FDR
112)	134	3	23T-D2	KTC-B	350.00	DEG C	3	HDR5
113)	135	3	5T-D2	KTC-B	350.00	DEG C	3	HDR6
114)	136	3	11T-D2	KTC-B	350.00	DEG C	3	HDR7
115)	137	3	17T-D2	KTC-B	350.00	DEG C	3	HDR8
116)	138	3	60T-D1	KTC-B	350.00	DEG C	3	BO1 INLET
117)	139	3	60T-D2	KTC-B	350.00	DEG C	3	BO1 OUTLET
118)	140	3	61T-D1	KTC-B	350.00	DEG C	3	BO2 INLET
119)	141	3	61T-D2	KTC-B	350.00	DEG C	3	BO2 OUTLET
120)	142	3	124T	KTC-B	350.00	DEG C	3	P1 INLET
121)	143	3	125T	KTC-B	350.00	DEG C	3	P1 OUTLET
122)	144	3	122T	KTC-B	350.00	DEG C	3	P2 INLET
123)	145	3	123T	KTC-B	350.00	DEG C	3	P2 OUTLET
124)	146	3	229T-D3	KTC-B	350.00	DEG C	3	HS9 OUT FDR
125)	147	3	74T-D9	KTC-B	350.00	DEG C	3	BO1 PRE HTR
126)	150	3	242T-D3	KTC-B	350.00	DEG C	3	HS13 OUT FDR
127)	151	3	249T-D3	KTC-B	350.00	DEG C	3	HS14 OUT FDR
128)	152	3	75T-D9	KTC-B	350.00	DEG C	3	BO2 PRE HTR
129)	153	3	137T-D2	KTC-B	350.00	DEG C	3	BO2 DWNCMR
130)	154	3	75T-D6	KTC-B	350.00	DEG C	3	BO2 PRE HTR
131)	155	3	136T-D2	KTC-B	350.00	DEG C	3	BO1 DWNCMR
132)	156	3	75T-D10	KTC-B	350.00	DEG C	3	SB2-TE6-S92
133)	158	3	29T	KTC-B	350.00	DEG C	3	BO1 STEAM
134)	160	3	2T-D27	KTC-B	350.00	DEG C	3	B2-TE1-S12
135)	185	3	33T-D1	KTC-B	350.00	DEG C	3	CD1 OUTLET
136)	186	3	31T-D1	KTC-B	350.00	DEG C	3	BO2 STM
137)	187	3	2T-D29	KTC-B	350.00	DEG C	3	B2-TE1-S84
138)	188	3	34T	KTC-B	300.00	DEG C	3	P6/7 OUTLET
139)	189	3	43T	KTC-B	300.00	DEG C	3	CD1 SPRAY
140)	194	3	2T-D30	KTC-B	350.00	DEG C	3	B2-TE1-S92
141)	485	3	210T-D3	KTC-B	350.00	DEG C	3	TS5 INLET
142)	486	3	213T-D1	KTC-B	350.00	DEG C	3	TS5 OUTLET
143)	487	3	214T-D3	KTC-B	350.00	DEG C	3	TS6 INLET
144)	255	3	201T-D18	KTC-E	350.00	DEG C	3	HS6 7-11P-2
145)	489	3	218T-D3	KTC-B	350.00	DEG C	3	TS7 INLET
146)	490	3	221T-D1	KTC-B	350.00	DEG C	3	TS7 OUTLET
147)	491	3	222T-D3	KTC-B	350.00	DEG C	3	TS8 INLET
148)	492	3	225T-D1	KTC-B	350.00	DEG C	3	TS8 OUTLET
149)	493	3	226T-D3	KTC-B	350.00	DEG C	3	TS9 INLET
150)	494	3	229T-D1	KTC-B	350.00	DEG C	3	TS9 OUTLET
151)	495	3	233T-D3	KTC-B	350.00	DEG C	3	TS10 INLET
152)	496	3	230T-D1	KTC-B	350.00	DEG C	3	TS10 OUTLET
153)	497	3	237T-D3	KTC-B	350.00	DEG C	3	TS11 INLET
154)	498	3	234T-D1	KTC-B	350.00	DEG C	3	TS11 OUTLET
155)	499	3	241T-D3	KTC-B	350.00	DEG C	3	TS12 INLET

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
156)	500	3	238T-D1	KTC-B	350.00	DEG C	3	TS12 OUTLET
157)	501	3	245T-D3	KTC-B	350.00	DEG C	3	TS13 INLET
158)	502	3	242T-D1	KTC-B	350.00	DEG C	3	TS13 OUTLET
159)	503	3	247T-D3	KTC-B	350.00	DEG C	3	TS14 INLET
160)	504	3	249T-D1	KTC-B	350.00	DEG C	3	TS14 OUTLET
161)	654	3	251T-D1	KTC-B	350.00	DEG C	3	HS5 INLET
162)	660	3	252T-D1	KTC-B	350.00	DEG C	3	HS5 OUTLET
163)	666	3	261T-D1	KTC-B	350.00	DEG C	3	HS10 INLET
164)	672	3	262T-D1	KTC-B	350.00	DEG C	3	HS10 OUTLET
165)	678	3	253T-D1	KTC-B	350.00	DEG C	3	HS6 INLET
166)	684	3	254T-D1	KTC-B	350.00	DEG C	3	HS6 OUTLET
167)	690	3	263T-D1	KTC-B	350.00	DEG C	3	HS11 INLET
168)	696	3	264T-D1	KTC-B	350.00	DEG C	3	HS11 OUTLET
169)	702	3	255T-D1	KTC-B	350.00	DEG C	3	HS7 INLET
170)	708	3	256T-D1	KTC-B	350.00	DEG C	3	HS7 OUTLET
171)	714	3	265T-D1	KTC-B	350.00	DEG C	3	HS12 INLET
172)	720	3	266T-D1	KTC-B	350.00	DEG C	3	HS12 OUTLET
173)	726	3	257T-D1	KTC-B	350.00	DEG C	3	HS8 INLET
174)	732	3	258T-D1	KTC-B	350.00	DEG C	3	HS8 OUTLET
175)	738	3	267T-D1	KTC-B	350.00	DEG C	3	HS13 INLET
176)	744	3	268T-D1	KTC-B	350.00	DEG C	3	HS13 OUTLET
177)	750	3	259T-D1	KTC-B	350.00	DEG C	3	HS9 INLET
178)	756	3	260T-D1	KTC-B	350.00	DEG C	3	HS9 OUTLET
179)	762	3	269T-D1	KTC-B	350.00	DEG C	3	HS14 INLET
180)	768	3	270T-D1	KTC-B	350.00	DEG C	3	HS14 OUTLET
181)	106	5	200T-D1	KTC-E	1000.00	DEG C	2	HS5 1-2J-2
182)	107	5	200T-D2	KTC-E	1000.00	DEG C	2	HS5 1-4L-2
183)	108	5	200T-D3	KTC-E	1000.00	DEG C	2	HS5 1-6M-2
184)	109	5	200T-D4	KTC-E	1000.00	DEG C	2	HS5 5-5C-1
185)	110	5	200T-D5	KTC-E	1000.00	DEG C	2	HS5 4-6M-2
186)	111	5	200T-D6	KTC-E	1000.00	DEG C	2	HS5 7-6M-2
187)	112	5	200T-D7	KTC-E	1000.00	DEG C	2	HS5 6-1A-1
188)	113	5	200T-D8	KTC-E	1000.00	DEG C	2	HS5 6-3B-1
189)	114	5	200T-D9	KTC-E	1000.00	DEG C	2	HS5 6-5C-1
190)	115	5	200T-D10	KTC-E	1000.00	DEG C	2	HS5 1-7N-2
191)	116	5	200T-D11	KTC-E	1000.00	DEG C	2	HS5 5-10G-1
192)	117	5	200T-D12	KTC-E	1000.00	DEG C	2	HS5 1-11P-2
193)	118	5	200T-D13	KTC-E	1000.00	DEG C	2	HS5 5-12H-1
194)	119	5	200T-D14	KTC-E	1000.00	DEG C	2	HS5 4-11P-2
195)	120	5	200T-D15	KTC-E	1000.00	DEG C	2	HS5 7-11P-2
196)	121	5	200T-D16	KTC-E	1000.00	DEG C	2	HS5 6-8E-1
197)	201	5	200T-D17	KTC-E	1000.00	DEG C	2	HS5 6-10G-1
198)	202	5	200T-D18	KTC-E	1000.00	DEG C	2	HS5 7-9O-2
199)	203	5	205T-D1	KTC-E	1000.00	DEG C	2	HS10 7-6M-2
200)	204	5	205T-D2	KTC-E	1000.00	DEG C	2	HS10 4-6M-2
201)	205	5	205T-D3	KTC-E	1000.00	DEG C	2	HS10 5-5C-1
202)	206	5	205T-D4	KTC-E	1000.00	DEG C	2	HS10 5-3B-1
203)	207	5	205T-D5	KTC-E	1000.00	DEG C	2	HS10 6-3B-1
204)	208	5	205T-D6	KTC-E	1000.00	DEG C	2	HS10 6-5C-1
205)	209	5	205T-D7	KTC-E	1000.00	DEG C	2	HS10 1-2J-2
206)	210	5	205T-D8	KTC-E	1000.00	DEG C	2	HS10 1-4L-2
207)	211	5	205T-D9	KTC-E	1000.00	DEG C	2	HS10 1-6M-2
208)	212	5	205T-D10	KTC-E	1000.00	DEG C	2	HS10 7-7N-2
209)	213	5	205T-D11	KTC-E	1000.00	DEG C	2	HS10 4-9O-2

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
210)	214	5	205T-D12	KTC-E	1000.00	DEG C	2	HS10 5-12H-1
211)	215	5	205T-D13	KTC-E	1000.00	DEG C	2	HS10 6-8E-1
212)	216	5	205T-D14	KTC-E	1000.00	DEG C	2	HS10 6-10G-1
213)	217	5	205T-D15	KTC-E	1000.00	DEG C	2	HS10 6-12H-1
214)	218	5	205T-D16	KTC-E	1000.00	DEG C	2	HS10 1-7N-2
215)	219	5	205T-D17	KTC-E	1000.00	DEG C	2	HS10 1-9O-2
216)	220	5	205T-D18	KTC-E	1000.00	DEG C	2	HS10 1-11P-2
217)	221	5	201T-D1	KTC-E	1000.00	DEG C	2	HS6 5-5C-1
218)	222	5	201T-D2	KTC-E	1000.00	DEG C	2	HS6 1-2J-2
219)	223	5	201T-D3	KTC-E	1000.00	DEG C	2	HS6 1-4L-2
220)	224	5	201T-D4	KTC-E	1000.00	DEG C	2	HS6 1-6M-2
221)	225	5	201T-D5	KTC-E	1000.00	DEG C	2	HS6 4-6M-2
222)	226	5	201T-D6	KTC-E	1000.00	DEG C	2	HS6 6-1A-1
223)	227	5	201T-D7	KTC-E	1000.00	DEG C	2	HS6 5-3B-1
224)	228	5	201T-D8	KTC-E	1000.00	DEG C	2	HS6 6-5C-1
225)	229	5	201T-D9	KTC-E	1000.00	DEG C	2	HS6 7-6M-2
226)	230	5	201T-D10	KTC-E	1000.00	DEG C	2	HS6 5-12H-1
227)	231	5	201T-D11	KTC-E	1000.00	DEG C	2	HS6 1-7N-2
228)	232	5	201T-D12	KTC-E	1000.00	DEG C	2	HS6 1-9O-2
229)	250	5	201T-D13	KTC-E	1000.00	DEG C	2	HS6 1-11P-2
230)	251	5	201T-D14	KTC-E	1000.00	DEG C	2	HS6 4-11P-2
231)	252	5	201T-D15	KTC-E	1000.00	DEG C	2	HS6 5-10G-1
232)	253	5	201T-D16	KTC-E	1000.00	DEG C	2	HS6 6-10G-1
233)	254	5	201T-D17	KTC-E	1000.00	DEG C	2	HS6 6-12H-1
234)	488	5	217T-D1	KTC-B	1000.00	DEG C	2	TS6 OUTLET
235)	256	5	206T-D1	KTC-E	1000.00	DEG C	2	HS11 4-6M-2
236)	257	5	206T-D2	KTC-E	1000.00	DEG C	2	HS11 1-2J-2
237)	258	5	206T-D3	KTC-E	1000.00	DEG C	2	HS11 1-4L-2
238)	259	5	206T-D4	KTC-E	1000.00	DEG C	2	HS11 1-6M-2
239)	260	5	206T-D5	KTC-E	1000.00	DEG C	2	HS11 5-3B-1
240)	261	5	206T-D6	KTC-E	1000.00	DEG C	2	HS11 6-3B-1
241)	262	5	206T-D7	KTC-E	1000.00	DEG C	2	HS11 6-5C-1
242)	263	5	206T-D8	KTC-E	1000.00	DEG C	2	HS11 5-5C-1
243)	264	5	206T-D9	KTC-E	1000.00	DEG C	2	HS11 7-6M-2
244)	265	5	206T-D10	KTC-E	1000.00	DEG C	2	HS11 4-11P-2
245)	267	5	206T-D11	KTC-E	1000.00	DEG C	2	HS11 1-7N-2
246)	268	5	206T-D12	KTC-E	1000.00	DEG C	2	HS11 7-9O-2
247)	269	5	206T-D13	KTC-E	1000.00	DEG C	2	HS11 5-8E-1
248)	270	5	206T-D14	KTC-E	1000.00	DEG C	2	HS11 6-8E-1
249)	271	5	206T-D15	KTC-E	1000.00	DEG C	2	HS11 6-10G-1
250)	272	5	206T-D16	KTC-E	1000.00	DEG C	2	HS11 6-12H-1
251)	273	5	206T-D17	KTC-E	1000.00	DEG C	2	HS11 5-12H-1
252)	274	5	206T-D18	KTC-E	1000.00	DEG C	2	HS11 7-11P-2
253)	275	5	202T-D1	KTC-E	1000.00	DEG C	2	HS7 4-6M-2
254)	276	5	202T-D2	KTC-E	1000.00	DEG C	2	HS7 7-2J-2
255)	277	5	202T-D3	KTC-E	1000.00	DEG C	2	HS7 1-4L-2
256)	278	5	202T-D4	KTC-E	1000.00	DEG C	2	HS7 1-2KC-2
257)	279	5	202T-D5	KTC-E	1000.00	DEG C	2	HS7 7-6M-2
258)	280	5	202T-D6	KTC-E	1000.00	DEG C	2	HS7 7-4L-2
259)	281	5	202T-D7	KTC-E	1000.00	DEG C	2	HS7 6-3B-1
260)	282	5	202T-D8	KTC-E	1000.00	DEG C	2	HS7 4-4L-2
261)	385	41	202T-D9	KTC-R	1000.00	DEG C	3	HS7 4-2J-2
262)	386	41	202T-D10	KTC-R	1000.00	DEG C	3	HS7 4-11P-2
263)	387	41	202T-D11	KTC-R	1000.00	DEG C	3	HS7 1-7N-2

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
264)	388	41	202T-D12	KTC-R	1000.00	DEG C	3	HS7 1-9O-2
265)	389	41	202T-D13	KTC-R	1000.00	DEG C	3	HS7 1-11P-2
266)	390	41	202T-D14	KTC-R	1000.00	DEG C	3	HS7 7-11P-2
267)	391	41	202T-D15	KTC-R	1000.00	DEG C	3	HS7 6-8E-1
268)	392	41	202T-D16	KTC-R	1000.00	DEG C	3	HS7 6-10G-1
269)	393	41	202T-D17	KTC-R	1000.00	DEG C	3	HS7 6-12H-1
270)	394	41	202T-D18	KTC-R	1000.00	DEG C	3	HS7 7-9O-2
271)	395	41	207T-D1	KTC-R	1000.00	DEG C	3	HS12 4-6M-2
272)	396	41	207T-D2	KTC-R	1000.00	DEG C	3	HS12 1-2J-2
273)	397	41	207T-D3	KTC-R	1000.00	DEG C	3	HS12 1-4L-2
274)	398	41	207T-D4	KTC-R	1000.00	DEG C	3	HS12 1-6M-2
275)	399	41	207T-D5	KTC-R	1000.00	DEG C	3	HS12 5-3B-1
276)	400	41	207T-D6	KTC-R	1000.00	DEG C	3	HS12 6-1A-1
277)	401	41	207T-D7	KTC-R	1000.00	DEG C	3	HS12 5-1A-1
278)	402	41	207T-D8	KTC-R	1000.00	DEG C	3	HS12 6-5C-1
279)	403	41	207T-D9	KTC-R	1000.00	DEG C	3	HS12 5-5C-1
280)	404	41	207T-D10	KTC-R	1000.00	DEG C	3	HS12 4-11P-2
281)	405	41	207T-D11	KTC-R	1000.00	DEG C	3	HS12 1-7N-2
282)	406	41	207T-D12	KTC-R	1000.00	DEG C	3	HS12 1-9O-2
283)	407	41	207T-D13	KTC-R	1000.00	DEG C	3	HS12 1-11P-2
284)	408	41	207T-D14	KTC-R	1000.00	DEG C	3	HS12 5-10G-1
285)	409	41	207T-D15	KTC-R	1000.00	DEG C	3	HS12 6-8E-1
286)	410	41	207T-D16	KTC-R	1000.00	DEG C	3	HS12 6-10G-1
287)	411	41	207T-D17	KTC-R	1000.00	DEG C	3	HS12 6-12H-1
288)	412	41	207T-D18	KTC-R	1000.00	DEG C	3	HS12 5-12H-1
289)	413	41	203T-D1	KTC-R	1000.00	DEG C	3	HS8 1-6M-2
290)	414	41	203T-D2	KTC-R	1000.00	DEG C	3	HS8 1-4L-2
291)	415	41	203T-D3	KTC-R	1000.00	DEG C	3	HS8 1-2J-2
292)	416	41	203T-D4	KTC-R	1000.00	DEG C	3	HS8 7-2J-2
293)	417	41	203T-D5	KTC-R	1000.00	DEG C	3	HS8 4-2J-2
294)	418	41	203T-D6	KTC-R	1000.00	DEG C	3	HS8 6-5C-1
295)	419	41	203T-D7	KTC-R	1000.00	DEG C	3	HS8 6-3B-1
296)	420	41	203T-D8	KTC-R	1000.00	DEG C	3	HS8 6-1A-1
297)	421	41	203T-D9	KTC-R	1000.00	DEG C	3	HS8 5-1A-1
298)	422	41	203T-D10	KTC-R	1000.00	DEG C	3	HS8 1-11P-2
299)	423	41	203T-D11	KTC-R	1000.00	DEG C	3	HS8 1-9O-2
300)	424	41	203T-D12	KTC-R	1000.00	DEG C	3	HS8 1-7N-2
301)	425	41	203T-D13	KTC-R	1000.00	DEG C	3	HS8 7-7N-2
302)	426	41	203T-D14	KTC-R	1000.00	DEG C	3	HS8 4-7N-2
303)	427	41	203T-D15	KTC-R	1000.00	DEG C	3	HS8 7-11P-2
304)	428	41	203T-D16	KTC-R	1000.00	DEG C	3	HS8 6-10G-1
305)	429	41	203T-D17	KTC-R	1000.00	DEG C	3	HS8 6-8E-1
306)	430	41	203T-D18	KTC-R	1000.00	DEG C	3	HS8 5-8E-1
307)	431	41	208T-D1	KTC-R	1000.00	DEG C	3	HS13 7-6M-2
308)	432	41	208T-D2	KTC-R	1000.00	DEG C	3	HS13 5-5C-1
309)	433	41	208T-D3	KTC-R	1000.00	DEG C	3	HS13 1-2J-2
310)	434	41	208T-D4	KTC-R	1000.00	DEG C	3	HS13 1-4L-2
311)	435	41	208T-D5	KTC-R	1000.00	DEG C	3	HS13 1-6M-2
312)	436	41	208T-D6	KTC-R	1000.00	DEG C	3	HS13 6-1A-1
313)	437	41	208T-D7	KTC-R	1000.00	DEG C	3	HS13 6-3B-1
314)	438	41	208T-D8	KTC-R	1000.00	DEG C	3	HS13 6-5C-1
315)	439	41	208T-D9	KTC-R	1000.00	DEG C	3	HS13 4-6M-2
316)	440	41	208T-D10	KTC-R	1000.00	DEG C	3	HS13 7-11P-2
317)	441	41	208T-D11	KTC-R	1000.00	DEG C	3	HS13 5-12H-1

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
318)	442	41	208T-D12	KTC-R	1000.00	DEG C	3	HS13 1-7N-2
319)	443	41	208T-D13	KTC-R	1000.00	DEG C	3	HS13 1-9O-2
320)	444	41	208T-D14	KTC-R	1000.00	DEG C	3	HS13 1-11P-2
321)	445	41	208T-D15	KTC-R	1000.00	DEG C	3	HS13 6-8E-1
322)	446	41	208T-D16	KTC-R	1000.00	DEG C	3	HS13 6-10G-1
323)	447	41	208T-D17	KTC-R	1000.00	DEG C	3	HS13 6-12H-1
324)	448	41	208T-D18	KTC-R	1000.00	DEG C	3	HS13 4-11P-2
325)	449	41	204T-D1	KTC-R	1000.00	DEG C	3	HS9 1-2J-2
326)	450	41	204T-D2	KTC-R	1000.00	DEG C	3	HS9 1-4L-2
327)	451	41	204T-D3	KTC-R	1000.00	DEG C	3	HS9 1-6M-2
328)	452	41	204T-D4	KTC-R	1000.00	DEG C	3	HS9 6-1A-1
329)	453	41	204T-D5	KTC-R	1000.00	DEG C	3	HS9 6-3B-1
330)	454	41	204T-D6	KTC-R	1000.00	DEG C	3	HS9 6-5C-1
331)	455	41	204T-D7	KTC-R	1000.00	DEG C	3	HS9 7-6M-2
332)	456	41	204T-D8	KTC-R	1000.00	DEG C	3	HS9 5-5C-1
333)	457	41	204T-D9	KTC-R	1000.00	DEG C	3	HS9 4-6M-2
334)	458	41	204T-D10	KTC-R	1000.00	DEG C	3	HS9 1-7N-2
335)	459	41	204T-D11	KTC-R	1000.00	DEG C	3	HS9 1-9O-2
336)	460	41	204T-D12	KTC-R	1000.00	DEG C	3	HS9 1-11P-2
337)	461	41	204T-D13	KTC-R	1000.00	DEG C	3	HS9 6-8E-1
338)	462	41	204T-D14	KTC-R	1000.00	DEG C	3	HS9 6-10G-1
339)	463	41	204T-D15	KTC-R	1000.00	DEG C	3	HS9 6-12H-1
340)	464	41	204T-D16	KTC-R	1000.00	DEG C	3	HS9 7-9O-2
341)	465	41	204T-D17	KTC-R	1000.00	DEG C	3	HS9 7-7N-2
342)	466	41	204T-D18	KTC-R	1000.00	DEG C	3	HS9 4-11P-2
343)	467	41	209T-D1	KTC-R	1000.00	DEG C	3	HS14 4-6M-2
344)	468	41	209T-D2	KTC-R	1000.00	DEG C	3	HS14 7-6M-2
345)	469	41	209T-D3	KTC-R	1000.00	DEG C	3	HS14 6-1A-1
346)	470	41	209T-D4	KTC-R	1000.00	DEG C	3	HS14 6-3B-1
347)	471	41	209T-D5	KTC-R	1000.00	DEG C	3	HS14 7-2J-2
348)	472	41	209T-D6	KTC-R	1000.00	DEG C	3	HS14 5-3B-1
349)	473	41	209T-D7	KTC-R	1000.00	DEG C	3	HS14 4-4L-2
350)	474	41	209T-D8	KTC-R	1000.00	DEG C	3	HS14 1-6M-2
351)	475	41	209T-D9	KTC-R	1000.00	DEG C	3	HS14 5-5C-1
352)	476	41	209T-D10	KTC-R	1000.00	DEG C	3	HS14 4-11P-2
353)	477	41	209T-D11	KTC-R	1000.00	DEG C	3	HS14 7-9O-2
354)	478	41	209T-D12	KTC-R	1000.00	DEG C	3	HS14 7-7N-2
355)	479	41	209T-D13	KTC-R	1000.00	DEG C	3	HS14 6-10G-1
356)	480	41	209T-D14	KTC-R	1000.00	DEG C	3	HS14 6-12H-1
357)	481	41	209T-D15	KTC-R	1000.00	DEG C	3	HS14 1-7N-2
358)	482	41	209T-D16	KTC-R	1000.00	DEG C	3	HS14 1-9O-2
359)	483	41	209T-D17	KTC-R	1000.00	DEG C	3	HS14 1-11P-2
360)	484	41	209T-D18	KTC-R	1000.00	DEG C	3	HS14 5-12H-1
361)	525	41	331T-D1	KTC-R	350.00	DEG C	3	BO1/2 FDWTR
362)	526	41	332T-D1	KTC-R	350.00	DEG C	3	BO1 FDWTR
363)	527	41	333T-D1	KTC-R	350.00	DEG C	3	BO2 FDWTR
364)	528	41	114T-D1	KTC-R	350.00	DEG C	3	ECI HDR8
365)	609	41	321T-D1	KTC-R	350.00	DEG C	3	P14 DIS TEMP
366)	610	41	112T-D1	KTC-R	350.00	DEG C	3	ECI HDR6
367)	611	41	2T-D13	KTC-R	350.00	DEG C	3	B2-TB4-S37
368)	612	41	2T-D14	KTC-R	350.00	DEG C	3	B2-TB4-S25
369)	613	41	2T-D15	KTC-R	350.00	DEG C	3	B2-TB4-S12
370)	614	41	2T-D16	KTC-R	350.00	DEG C	3	B2-TB4-S50
371)	615	41	238T-D3	KTC-R	350.00	DEG C	3	HS12 OUT FDR

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
372)	616	41	234T-D3	KTC-R	350.00	DEG C	3	HS11 OUT FDR
373)	617	41	230T-D3	KTC-R	350.00	DEG C	3	HS10 OUT FDR
374)	618	41	221T-D3	KTC-R	350.00	DEG C	3	HS7 OUT FDR
375)	619	41	213T-D3	KTC-R	350.00	DEG C	3	HS5 OUT FDR
376)	620	41	217T-D3	KTC-R	350.00	DEG C	3	HS6 OUT FDR
377)	621	41	2T-D25	KTC-R	350.00	DEG C	3	B2-TE1-S37
378)	622	41	113T-D1	KTC-R	350.00	DEG C	3	ECI HDR7
379)	623	41	2T-D26	KTC-R	350.00	DEG C	3	B2-TE1-S25
380)	624	41	1T-D33	KTC-R	350.00	DEG C	3	B1-TE6-S12
381)	625	41	1T-D32	KTC-R	350.00	DEG C	3	B1-TE6-S25
382)	626	41	1T-D31	KTC-R	350.00	DEG C	3	B1-TE6-S37
383)	627	41	111T-D1	KTC-R	350.00	DEG C	3	ECI HDR5
384)	628	41	1T-D34	KTC-R	350.00	DEG C	3	B1-TE6-S50
385)	629	41	81T	KTC-R	350.00	DEG C	3	BLWDWN LINE
386)	630	41	1T-D36	KTC-R	350.00	DEG C	3	B1-TE6-S92
387)	631	41	48T-D1	KTC-R	350.00	DEG C	3	ECI TANK
388)	632	41	2T-D32	KTC-R	350.00	DEG C	3	B2-TE6-S25
389)	633	41	75T-D7	KTC-R	350.00	DEG C	3	SB2-TB1-S84
390)	634	41	2T-D34	KTC-R	350.00	DEG C	3	B2-TE6-S50
391)	635	41	75T-D8	KTC-R	350.00	DEG C	3	SB2-TB11-S84
392)	636	41	2T-D36	KTC-R	350.00	DEG C	3	B2-TE6-S92
393)	637	41	74T-D4	KTC-R	350.00	DEG C	3	SB1-TC5-S16
394)	638	41	74T-D5	KTC-R	350.00	DEG C	3	SB1-TB6-S96
395)	639	41	74T-D7	KTC-R	350.00	DEG C	3	SB1-TB1-S84
396)	640	41	74T-D8	KTC-R	350.00	DEG C	3	SB1-TB11-S84
397)	641	41	74T-D10	KTC-R	350.00	DEG C	3	SB1-TE6-S92
398)	642	41	75T-D1	KTC-R	350.00	DEG C	3	SB2-TB1-S4
399)	643	41	75T-D2	KTC-R	350.00	DEG C	3	SB2-TB11-S8
400)	649	41	200T-D19	KTC-R	1000.00	DEG C	3	HS5 5-1A-1
401)	650	41	200T-D20	KTC-R	1000.00	DEG C	3	HS5 5-3B-1
402)	651	41	200T-D21	KTC-R	1000.00	DEG C	3	HS5 4-2J-2
403)	652	41	200T-D22	KTC-R	1000.00	DEG C	3	HS5 4-4L-2
404)	653	41	200T-D23	KTC-R	1000.00	DEG C	3	HS5 7-4L-2
405)	656	41	200T-D26	KTC-R	1000.00	DEG C	3	HS5 4-7N-2
406)	657	41	200T-D27	KTC-R	1000.00	DEG C	3	HS5 4-9O-2
407)	661	41	205T-D19	KTC-R	1000.00	DEG C	3	HS10 7-2J-2
408)	662	41	205T-D20	KTC-R	1000.00	DEG C	3	HS10 7-4L-2
409)	664	41	205T-D22	KTC-R	1000.00	DEG C	3	HS10 4-4L-2
410)	665	41	205T-D23	KTC-R	1000.00	DEG C	3	HS10 5-1A-1
411)	667	41	205T-D25	KTC-R	1000.00	DEG C	3	HS10 4-7N-2
412)	673	41	201T-D19	KTC-R	1000.00	DEG C	3	HS6 5-1A-1
413)	674	41	201T-D20	KTC-R	1000.00	DEG C	3	HS6 4-2J-2
414)	675	41	201T-D21	KTC-R	1000.00	DEG C	3	HS6 4-4L-2
415)	676	41	201T-D22	KTC-R	1000.00	DEG C	3	HS6 7-2J-2
416)	677	41	201T-D23	KTC-R	1000.00	DEG C	3	HS6 7-4L-2
417)	679	41	201T-D25	KTC-R	1000.00	DEG C	3	HS6 7-9O-2
418)	681	41	201T-D27	KTC-R	1000.00	DEG C	3	HS6 4-7N-2
419)	682	41	201T-D28	KTC-R	1000.00	DEG C	3	HS6 4-9O-2
420)	683	41	201T-D29	KTC-R	1000.00	DEG C	3	HS6 7-7N-2
421)	685	41	206T-D19	KTC-R	1000.00	DEG C	3	HS11 4-2J-2
422)	686	41	206T-D20	KTC-R	1000.00	DEG C	3	HS11 4-4L-2
423)	687	41	206T-D21	KTC-R	1000.00	DEG C	3	HS11 5-1A-1
424)	688	41	206T-D22	KTC-R	1000.00	DEG C	3	HS11 7-4L-2
425)	691	41	206T-D25	KTC-R	1000.00	DEG C	3	HS11 4-7N-2

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
426)	692	41	206T-D26	KTC-R	1000.00	DEG C	3	HS11 4-9O-2
427)	693	41	206T-D27	KTC-R	1000.00	DEG C	3	HS11 7-7N-2
428)	703	41	202T-D25	KTC-R	1000.00	DEG C	3	HS7 4-7N-2
429)	704	41	202T-D26	KTC-R	1000.00	DEG C	3	HS7 4-9O-2
430)	705	41	202T-D27	KTC-R	1000.00	DEG C	3	HS7 7-7N-2
431)	709	41	207T-D19	KTC-R	1000.00	DEG C	3	HS12 4-4L-2
432)	715	41	207T-D25	KTC-R	1000.00	DEG C	3	HS12 4-7N-2
433)	716	41	207T-D26	KTC-R	1000.00	DEG C	3	HS12 4-9O-2
434)	718	41	207T-D28	KTC-R	1000.00	DEG C	3	HS12 5-8E-1
435)	721	41	203T-D19	KTC-R	1000.00	DEG C	3	HS8 5-5C-1
436)	722	41	203T-D20	KTC-R	1000.00	DEG C	3	HS8 5-3B-1
437)	723	41	203T-D21	KTC-R	1000.00	DEG C	3	HS8 4-6M-2
438)	724	41	203T-D22	KTC-R	1000.00	DEG C	3	HS8 4-4L-2
439)	725	41	203T-D23	KTC-R	1000.00	DEG C	3	HS8 7-6M-2
440)	727	41	203T-D25	KTC-R	1000.00	DEG C	3	HS8 5-10G-1
441)	728	41	203T-D26	KTC-R	1000.00	DEG C	3	HS8 4-11P-2
442)	729	41	203T-D27	KTC-R	1000.00	DEG C	3	HS8 4-9O-2
443)	730	41	203T-D28	KTC-R	1000.00	DEG C	3	HS8 7-9O-2
444)	733	41	208T-D19	KTC-R	1000.00	DEG C	3	HS13 7-2J-2
445)	734	41	208T-D20	KTC-R	1000.00	DEG C	3	HS13 7-4L-2
446)	735	41	208T-D21	KTC-R	1000.00	DEG C	3	HS13 5-1A-1
447)	736	41	208T-D22	KTC-R	1000.00	DEG C	3	HS13 5-3B-1
448)	737	41	208T-D23	KTC-R	1000.00	DEG C	3	HS13 4-4L-2
449)	739	41	208T-D25	KTC-R	1000.00	DEG C	3	HS13 7-7N-2
450)	740	41	208T-D26	KTC-R	1000.00	DEG C	3	HS13 7-9O-2
451)	741	41	208T-D27	KTC-R	1000.00	DEG C	3	HS13 5-8E-1
452)	742	41	208T-D28	KTC-R	1000.00	DEG C	3	HS13 5-10G-1
453)	743	41	208T-D29	KTC-R	1000.00	DEG C	3	HS13 4-7N-2
454)	745	41	204T-D19	KTC-R	1000.00	DEG C	3	HS9 7-2J-2
455)	746	41	204T-D20	KTC-R	1000.00	DEG C	3	HS9 7-4L-2
456)	747	41	204T-D21	KTC-R	1000.00	DEG C	3	HS9 5-1A-1
457)	748	41	204T-D22	KTC-R	1000.00	DEG C	3	HS9 4-4L-2
458)	749	41	204T-D23	KTC-R	1000.00	DEG C	3	HS9 4-2J-2
459)	753	41	204T-D27	KTC-R	1000.00	DEG C	3	HS9 4-7N-2
460)	754	41	204T-D28	KTC-R	1000.00	DEG C	3	HS9 4-9O-2
461)	757	41	209T-D19	KTC-R	1000.00	DEG C	3	HS14 4-2J-2
462)	761	41	209T-D23	KTC-R	1000.00	DEG C	3	HS14 5-1A-1
463)	763	41	209T-D25	KTC-R	1000.00	DEG C	3	HS14 4-7N-2
464)	764	41	209T-D26	KTC-R	1000.00	DEG C	3	HS14 4-9O-2
465)	765	41	209T-D27	KTC-R	1000.00	DEG C	3	HS14 5-8E-1
466)	766	41	209T-D28	KTC-R	1000.00	DEG C	3	HS14 5-10G-1
467)	351	15	OR25-DP	ORFM	650.00	KPA	3	ECI INJ LINE
468)	196	22	PM1-1A	PM-AMP	379.00	AMP	2	P1 AMPS
469)	199	22	PM2-1A	PM-AMP	379.00	AMP	2	P2 AMPS
470)	82	20	PS1-1W	POWER	4.00	MW	2	PS1 POWER
471)	83	20	PS2-1W	POWER	4.00	MW	2	PS2 POWER
472)	84	20	PS3-1W	POWER	4.00	MW	2	PS3 POWER
473)	85	20	PS4-1W	POWER	4.00	MW	2	PS4 POWER
474)	197	23	PM1-1Y	RPM	3600.00	RPM	2	P1 SPEED
475)	200	23	PM2-1Y	RPM	3600.00	RPM	2	P2 SPEED
476)	64	6	3T	RTD	350.00	DEG C	3	BO1 INLT PLN
477)	65	6	26T	RTD	350.00	DEG C	3	BO1 OUTLT PLN
478)	66	6	30T	RTD	350.00	DEG C	3	BO1 STM
479)	67	6	37T	RTD	350.00	DEG C	3	BO1/2 FDWTR

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
480)	68	6	14T	RTD	350.00	DEG C	3	BO2 IN PLN
481)	69	6	15T	RTD	350.00	DEG C	3	BO2 OUTLT PLN
482)	70	6	45T	RTD	350.00	DEG C	3	SRG TANK
483)	71	6	32T	RTD	350.00	DEG C	3	BO2 STM
484)	73	6	24T	RTD	350.00	DEG C	3	HDR5
485)	74	6	6T	RTD	350.00	DEG C	3	HDR6
486)	75	6	12T	RTD	350.00	DEG C	3	HDR7
487)	76	6	18T	RTD	350.00	DEG C	3	HDR8
488)	81	1	TIME MRK	START	5.00	VOLTS	1	TEST CHANNEL
489)	167	25	3F-M1	STM-F	2.77	KG/S	3	BO1 STM M F
490)	171	25	4F-M1	STM-F	2.77	KG/S	3	BO2 STM M F
491)	78	16	1F	TFM	30.00	L/S	1	P1 OUT
492)	79	16	2F	TFM	30.00	L/S	1	P2 OUT
493)	235	16	231F-D1	TFM	10.00	L/S	1	ECI HDR5
494)	236	16	233F-D1	TFM	10.00	L/S	1	ECI HDR7
495)	237	16	232F-D1	TFM	10.00	L/S	1	ECI HDR6
496)	238	16	234F-D1	TFM	15.00	L/S	1	ECI HDR8
497)	365	16	177F-D1	TFM	6.00	L/S	1	HS5 INLET
498)	366	16	178F-D1	TFM	6.00	L/S	1	HS5 OUTLET
499)	367	16	179F-D1	TFM	6.00	L/S	1	HS6 INLET
500)	368	16	180F-D1	TFM	6.00	L/S	1	HS6 OUTLET
501)	369	16	181F-D1	TFM	6.00	L/S	1	HS7 INLET
502)	370	16	182F-D1	TFM	6.00	L/S	1	HS7 OUTLET
503)	371	16	183F-D1	TFM	6.00	L/S	1	HS8 INLET
504)	372	16	184F-D1	TFM	6.00	L/S	1	HS8 OUTLET
505)	373	16	185F-D1	TFM	6.00	L/S	1	HS9 INLET
506)	374	16	186F-D1	TFM	6.00	L/S	1	HS9 OUTLET
507)	375	16	187F-D1	TFM	6.00	L/S	1	HS10 INLET
508)	376	16	188F-D1	TFM	6.00	L/S	1	HS10 OUTLET
509)	377	16	189F-D1	TFM	6.00	L/S	1	HS11 INLET
510)	378	16	190F-D1	TFM	6.00	L/S	1	HS11 OUTLET
511)	379	16	191F-D1	TFM	6.00	L/S	1	HS12 INLET
512)	380	16	192F-D1	TFM	6.00	L/S	1	HS12 OUTLET
513)	381	16	193F-D1	TFM	6.00	L/S	1	HS13 INLET
514)	382	16	194F-D1	TFM	6.00	L/S	1	HS13 OUTLET
515)	383	16	195F-D1	TFM	6.00	L/S	1	HS14 INLET
516)	384	16	196F-D1	TFM	6.00	L/S	1	HS14 OUTLET
517)	90	17	237F-D1	TFM	0.30	L/S	3	INV TANK FLOW
518)	101	17	19F	TFM	15.00	L/S	3	CD1 SPRAY
519)	168	17	5F-D2	TFM	3.00	L/S	3	BO1 FDWTR
520)	173	17	6F-D2	TFM	3.00	L/S	3	B02 FDWTR
521)	283	27	12VF-DT3	VFM	5.00	VDC	2	BO2 INLET
522)	284	27	12VF-DT4	VFM	5.00	VDC	2	BO2 INLET
523)	313	27	11VF-DT1	VFM	5.00	VDC	2	BO1 INLET
524)	314	27	11VF-DT2	VFM	5.00	VDC	2	BO1 INLET
525)	315	27	11VF-DT3	VFM	5.00	VDC	2	BO1 OUTLET
526)	316	27	11VF-DT4	VFM	5.00	VDC	2	BO1 OUTLET
527)	317	27	12VF-DT1	VFM	5.00	VDC	2	BO2 OUTLET
528)	318	27	12VF-DT2	VFM	5.00	VDC	2	BO2 OUTLET
529)	1	33	1VF-DTX	VFM-IV	5.00	VDC	2	P1 OUT
530)	2	33	1VF-DTZ	VFM-IV	5.00	VDC	2	P1 OUT
531)	3	33	1VF-DTY	VFM-IV	5.00	VDC	2	P1 OUT
532)	123	33	4VF-DTX	VFM-IV	5.00	VDC	2	P2 OUTLET
533)	124	33	4VF-DTZ	VFM-IV	5.00	VDC	2	P2 OUTLET

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	Channel Number	Device Number	Device Code	Device	Calbrtn	Units	Calc Type	Location
534)	125	33	4VF-DTY	VFM-IV	5.00	VDC	2	P2 OUTLET
535)	128	43	34VF	VFM-V	5.00	VDC	2	HS14 OUTLET
536)	129	43	33VF	VFM-V	5.00	VDC	2	HS14 INLET
537)	130	43	32VF	VFM-V	5.00	VDC	2	HS13 OUTLET
538)	131	43	31VF	VFM-V	5.00	VDC	2	HS13 INLET
539)	161	43	25VF	VFM-V	5.00	VDC	2	HS10 INLET
540)	162	43	26VF	VFM-V	5.00	VDC	2	HS10 OUTLET
541)	163	43	27VF	VFM-V	5.00	VDC	2	HS11 INLET
542)	164	43	28VF	VFM-V	5.00	VDC	2	HS11 OUTLET
543)	165	43	29VF	VFM-V	5.00	VDC	2	HS12 INLET
544)	166	43	30VF	VFM-V	5.00	VDC	2	HS12 OUTLET
545)	243	43	24VF	VFM-V	5.00	VDC	2	HS9 OUTLET
546)	244	43	23VF	VFM-V	5.00	VDC	2	HS9 INLET
547)	245	43	22VF	VFM-V	5.00	VDC	2	HS8 OUTLET
548)	285	43	21VF	VFM-V	5.00	VDC	2	HS8 INLET
549)	286	43	20VF	VFM-V	5.00	VDC	2	HS7 OUTLET
550)	287	43	19VF	VFM-V	5.00	VDC	2	HS7 INLET
551)	288	43	18VF	VFM-V	5.00	VDC	2	HS6 OUTLET
552)	327	43	17VF	VFM-V	5.00	VDC	2	HS6 INLET
553)	328	43	16VF	VFM-V	5.00	VDC	2	HS5 OUTLET
554)	329	43	15VF	VFM-V	5.00	VDC	2	HS5 INLET
555)	159	18	PS1-1V	VOLT	500.00	VDC	2	PS1 VOLTS
556)	241	18	PS2-1V	VOLT	500.00	VDC	2	PS2 VOLTS
557)	242	18	PS3-1V	VOLT	500.00	VDC	2	PS3 VOLTS
558)	266	18	PS4-1V	VOLT	500.00	VDC	2	PS4 VOLTS

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RD-14M Initial Averaged readings

Experiment B9401

Data File: B9401R.DAT 2-JUN-94 15:06:04
Scanning File: SCNLST.DAT 1-JUN-94 10:39:57

Channels:558 Scans: 600 Scan Rate: 0.100 sec/scan Total Time: 60.000

CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
10	COND A	BO2 INLET	3.167	VDC	0.01	0.00
11	COND B	BO2 OUTLET	3.399	VDC	0.01	0.00
560	ECI DP1	77P-HDR5	-11.373	KPA	0.91	0.07
561	ECI DP2	77P-HDR6	-12.623	KPA	0.90	0.07
562	ECI DP3	77P-HDR7	-12.623	KPA	1.35	0.11
563	ECI DP4	77P-HDR8	-12.623	KPA	1.77	0.14
92	1H	ECI TANK	2897.186	MM	3.78	0.30
93	5H	SRG TANK	1307.147	MM	6.00	0.48
94	4H	CD1	1383.877	MM	5.50	0.44
169	2H-D1	BO1 DRUM LEV	849.695	MM	5.94	0.47
172	3H-D1	BO2 DRUM LEV	834.363	MM	5.85	0.47
334	8H-D1	BO1 LEVEL	8711.589	MM	33.49	2.67
335	9H-D1	BO2 LEVEL	9017.362	MM	30.15	2.41
7	12Q-D2	P2 DELP	105.811	KPA	0.01	0.00
72	135F	BO1 DWNCMR	11.635	KPA	0.15	0.01
198	57Q-D1	HDR5-HDR6	1531.358	KPA	7.74	0.62
322	5Q-D2	P1 DELP	105.811	KPA	0.01	0.00
326	136F	BO2 DWNCMR	11.110	KPA	0.17	0.01
330	58Q-D1	HDR7-HDR8	1538.856	KPA	6.97	0.56
331	35Q-D2	HDR8-HDR5	1269.726	KPA	0.08	0.01
336	35Q-D1	HDR8-HDR5	1513.862	KPA	6.03	0.48
337	36Q-D2	HDR6-HDR7	1269.726	KPA	0.08	0.01
338	36Q-D1	HDR6-HDR7	1566.349	KPA	7.44	0.59
339	3Q-D1	BO1 DELP	223.705	KPA	1.34	0.11
340	4Q-D1	BO1-P1	6.049	KPA	0.12	0.01
341	5Q-D1	P1 DELP	1811.098	KPA	8.48	0.68
342	6Q-D1	P1-HDR6	29.121	KPA	0.49	0.04
345	9Q-D1	HDR7-BO2	19.664	KPA	0.44	0.04
346	10Q-D1	BO2 DELP	197.837	KPA	1.35	0.11
347	11Q-D1	BO2-P2	6.405	KPA	0.11	0.01
348	12Q-D1	P2 DELP	1792.353	KPA	8.38	0.67
349	13Q-D1	P2-HDR8	21.060	KPA	0.59	0.05
352	16Q-D1	HDR5-BO1	18.351	KPA	0.44	0.04
530	24Q-D1	HS5	814.852	KPA	5.89	0.47
531	24Q-D2	HS5	185.168	KPA	0.03	0.00
532	44Q-D1	HS12-HDR5	130.932	KPA	1.98	0.16
533	25Q-D1	HS6	788.609	KPA	4.36	0.35
534	25Q-D2	HS6	185.168	KPA	0.03	0.00
535	39Q-D1	HDR6-HS7	219.956	KPA	2.03	0.16
536	26Q-D1	HS7	1219.750	KPA	4.86	0.39
537	26Q-D2	HS7	608.410	KPA	0.06	0.00
538	46Q-D1	HS14-HDR5	114.311	KPA	1.47	0.12
539	27Q-D1	HS8	1189.758	KPA	5.41	0.43
540	27Q-D2	HS8	608.410	KPA	0.06	0.00

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
541	41Q-D1	HDR6-HS9	674.452	KPA	3.96	0.32
542	28Q-D1	HS9	790.483	KPA	4.74	0.38
543	28Q-D2	HS9	185.168	KPA	0.03	0.00
544	47Q-D1	HS5-HDR7	68.385	KPA	0.79	0.06
545	48Q-D1	HS6-HDR7	81.726	KPA	1.20	0.10
546	50Q-D1	HS8-HDR7	99.659	KPA	1.29	0.10
547	52Q-D1	HDR8-HS10	696.946	KPA	4.47	0.36
548	53Q-D1	HDR8-HS11	658.206	KPA	4.03	0.32
554	55Q-D1	HDR8-HS13	268.527	KPA	2.59	0.21
569	37Q-D1	HDR6-HS5	700.695	KPA	3.71	0.30
570	29Q-D1	HS10	758.617	KPA	5.74	0.46
571	29Q-D2	HS10	185.168	KPA	0.03	0.00
572	38Q-D1	HDR6-HS6	686.949	KPA	3.83	0.31
573	30Q-D1	HS11	794.232	KPA	4.51	0.36
574	30Q-D2	HS11	185.168	KPA	0.03	0.00
575	42Q-D1	HS10-HDR5	64.668	KPA	1.85	0.15
576	31Q-D1	HS12	1131.648	KPA	4.61	0.37
577	31Q-D2	HS12	608.410	KPA	0.06	0.00
578	40Q-D1	HDR6-HS8	287.929	KPA	2.41	0.19
579	32Q-D1	HS13	1165.389	KPA	4.83	0.39
580	32Q-D2	HS13	608.410	KPA	0.06	0.00
581	45Q-D1	HS13-HDR5	86.756	KPA	1.66	0.13
582	33Q-D1	HS14	782.985	KPA	4.54	0.36
583	33Q-D2	HS14	185.168	KPA	0.03	0.00
584	43Q-D1	HS11-HDR5	71.884	KPA	1.62	0.13
585	49Q-D1	HS7-HDR7	125.465	KPA	1.64	0.13
586	51Q-D1	HS9-HDR7	109.937	KPA	1.32	0.11
587	54Q-D1	HDR8-HS12	249.126	KPA	2.85	0.23
588	56Q-D1	HDR8-HS14	631.963	KPA	3.66	0.29
292	B11-DP	B2-TB11-DP	127.017	KPA	7.49	0.60
293	B1-DP	B2-TB1-DP	141.413	KPA	7.87	0.63
294	E4-DP	B2-TE4-DP	137.064	KPA	8.49	0.68
170	5F-M1	BO1 FW M FLO	2.399	KG/S	0.17	0.01
174	6F-M1	BO2 FW M FLO	2.864	KG/S	0.05	0.00
100	12P-D1	HDR5	10018.404	KPA	13.17	1.05
102	31P-D1	CD1 PRESS	4403.386	KPA	7.03	0.56
103	27P	ECI TANK	21.428	KPA	5.45	0.43
104	2P	BO2 DRUM	4420.446	KPA	8.54	0.68
105	1P	BO1 DRUM	4436.067	KPA	9.38	0.75
177	26P-D1	SRG TANK	9876.502	KPA	12.26	0.98
178	6P-D1	HDR7	10018.404	KPA	15.62	1.25
179	10P-D1	HDR8	11564.890	KPA	9.23	0.74
323	4P-D1	HDR6	11546.145	KPA	20.27	1.62
549	86P-D1	HS7 INLET	11386.809	KPA	11.38	0.91
550	95P-D1	HS10 INLET	10880.687	KPA	12.77	1.02
551	92P-D1	HS9 INLET	10908.805	KPA	7.59	0.61
552	98P-D1	HS11 INLET	10927.550	KPA	8.35	0.67
553	104P-D1	HS13 INLET	11311.828	KPA	8.24	0.66
555	111P-D1	HS5 OUTLET	10177.738	KPA	21.13	1.69
556	112P-D1	HS6 OUTLET	10187.111	KPA	23.20	1.85
557	114P-D1	HS8 OUTLET	10205.856	KPA	24.69	1.97
558	118P-D1	HS12 OUTLET	10290.211	KPA	24.37	1.95
559	120P-D1	HS14 OUTLET	10262.093	KPA	22.11	1.77
589	80P-D1	HS5 INLET	10880.687	KPA	13.87	1.11

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
590	101P-D1	HS12 INLET	11330.573	KPA	13.10	1.05
591	83P-D1	HS6 INLET	10890.060	KPA	8.81	0.70
592	107P-D1	HS14 INLET	10955.668	KPA	8.40	0.67
593	89P-D1	HS8 INLET	11293.083	KPA	9.06	0.72
594	113P-D1	HS7 OUTLET	10243.348	KPA	20.04	1.60
595	115P-D1	HS9 OUTLET	10233.975	KPA	20.31	1.62
596	116P-D1	HS10 OUTLET	10224.603	KPA	20.65	1.65
597	117P-D1	HS11 OUTLET	10224.603	KPA	20.61	1.65
598	119P-D1	HS13 OUTLET	10243.348	KPA	19.91	1.59
297	77P	ECI LINE PRE	188.951	KPA	1.91	0.15
299	36P-D1	BLWDWN LINE	-2.274	KPA	0.11	0.01
132	74T-D6	BO1 PRE HTR	232.232	DEG C	1.19	0.10
133	225T-D3	HS8 OUT FDR	296.091	DEG C	0.11	0.01
134	23T-D2	HDR5	294.779	DEG C	0.19	0.01
135	5T-D2	HDR6	260.662	DEG C	0.13	0.01
136	11T-D2	HDR7	297.403	DEG C	0.14	0.01
137	17T-D2	HDR8	261.318	DEG C	0.16	0.01
138	60T-D1	BO1 INLET	295.435	DEG C	0.22	0.02
139	60T-D2	BO1 OUTLET	261.318	DEG C	0.23	0.02
140	61T-D1	BO2 INLET	295.216	DEG C	0.17	0.01
141	61T-D2	BO2 OUTLET	261.537	DEG C	0.15	0.01
142	124T	P1 INLET	260.881	DEG C	0.14	0.01
143	125T	P1 OUTLET	260.881	DEG C	0.11	0.01
144	122T	P2 INLET	261.318	DEG C	0.18	0.01
145	123T	P2 OUTLET	260.881	DEG C	0.40	0.03
146	229T-D3	HS9 OUT FDR	298.278	DEG C	0.23	0.02
147	74T-D9	BO1 PRE HTR	244.041	DEG C	0.45	0.04
150	242T-D3	HS13 OUT FDR	297.184	DEG C	0.24	0.02
151	249T-D3	HS14 OUT FDR	297.840	DEG C	0.15	0.01
152	75T-D9	BO2 PRE HTR	249.071	DEG C	0.49	0.04
153	137T-D2	BO2 DWNCMR	259.131	DEG C	0.13	0.01
154	75T-D6	BO2 PRE HTR	226.765	DEG C	1.99	0.16
155	136T-D2	BO1 DWNCMR	259.569	DEG C	0.12	0.01
156	75T-D10	SB2-TE6-S92	248.197	DEG C	0.50	0.04
158	29T	BO1 STEAM	258.694	DEG C	0.13	0.01
160	2T-D27	B2-TE1-S12	285.375	DEG C	0.13	0.01
185	33T-D1	CD1 OUTLET	257.600	DEG C	0.09	0.01
186	31T-D1	BO2 STM	258.257	DEG C	0.10	0.01
187	2T-D29	B2-TE1-S84	263.724	DEG C	0.12	0.01
188	34T	P6/7 OUTLET	189.121	DEG C	2.26	0.18
189	43T	CD1 SPRAY	94.082	DEG C	0.48	0.04
194	2T-D30	B2-TE1-S92	263.068	DEG C	0.16	0.01
485	210T-D3	TS5 INLET	262.412	DEG C	0.26	0.02
486	213T-D1	TS5 OUTLET	298.278	DEG C	0.26	0.02
487	214T-D3	TS6 INLET	261.756	DEG C	0.28	0.02
488	217T-D1	TS6 OUTLET	293.924	DEG C	0.17	0.01
489	218T-D3	TS7 INLET	262.849	DEG C	0.26	0.02
490	221T-D1	TS7 OUTLET	293.466	DEG C	0.27	0.02
491	222T-D3	TS8 INLET	263.724	DEG C	0.26	0.02
492	225T-D1	TS8 OUTLET	297.622	DEG C	0.24	0.02
493	226T-D3	TS9 INLET	262.630	DEG C	0.23	0.02
494	229T-D1	TS9 OUTLET	298.715	DEG C	0.24	0.02
495	233T-D3	TS10 INLET	262.630	DEG C	0.27	0.02
496	230T-D1	TS10 OUTLET	297.622	DEG C	0.25	0.02

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
497	237T-D3	TS11 INLET	261.974	DEG C	0.25	0.02
498	234T-D1	TS11 OUTLET	297.622	DEG C	0.26	0.02
499	241T-D3	TS12 INLET	261.537	DEG C	0.26	0.02
500	238T-D1	TS12 OUTLET	291.061	DEG C	0.25	0.02
501	245T-D3	TS13 INLET	261.756	DEG C	0.26	0.02
502	242T-D1	TS13 OUTLET	297.403	DEG C	0.23	0.02
503	247T-D3	TS14 INLET	262.412	DEG C	0.25	0.02
504	249T-D1	TS14 OUTLET	298.278	DEG C	0.26	0.02
654	251T-D1	HS5 INLET	261.100	DEG C	0.23	0.02
660	252T-D1	HS5 OUTLET	297.184	DEG C	0.21	0.02
666	261T-D1	HS10 INLET	260.662	DEG C	0.22	0.02
672	262T-D1	HS10 OUTLET	297.403	DEG C	0.27	0.02
678	253T-D1	HS6 INLET	260.881	DEG C	0.24	0.02
684	254T-D1	HS6 OUTLET	296.966	DEG C	0.24	0.02
690	263T-D1	HS11 INLET	260.881	DEG C	0.25	0.02
696	264T-D1	HS11 OUTLET	296.091	DEG C	0.25	0.02
702	255T-D1	HS7 INLET	261.974	DEG C	0.23	0.02
708	256T-D1	HS7 OUTLET	293.029	DEG C	0.27	0.02
714	265T-D1	HS12 INLET	260.225	DEG C	0.28	0.02
720	266T-D1	HS12 OUTLET	289.530	DEG C	0.27	0.02
726	257T-D1	HS8 INLET	262.412	DEG C	0.27	0.02
732	258T-D1	HS8 OUTLET	297.184	DEG C	0.26	0.02
738	267T-D1	HS13 INLET	261.756	DEG C	0.26	0.02
744	268T-D1	HS13 OUTLET	297.184	DEG C	0.28	0.02
750	259T-D1	HS9 INLET	262.849	DEG C	0.26	0.02
756	260T-D1	HS9 OUTLET	298.934	DEG C	0.29	0.02
762	269T-D1	HS14 INLET	262.193	DEG C	0.26	0.02
768	270T-D1	HS14 OUTLET	298.278	DEG C	0.27	0.02
106	200T-D1	HS5 1-2J-2	289.925	DEG C	0.26	0.02
107	200T-D2	HS5 1-4L-2	299.422	DEG C	0.15	0.01
108	200T-D3	HS5 1-6M-2	305.920	DEG C	0.13	0.01
109	200T-D4	HS5 5-5C-1	303.421	DEG C	0.26	0.02
110	200T-D5	HS5 4-6M-2	312.419	DEG C	0.15	0.01
111	200T-D6	HS5 7-6M-2	310.419	DEG C	0.16	0.01
112	200T-D7	HS5 6-1A-1	295.423	DEG C	0.14	0.01
113	200T-D8	HS5 6-3B-1	295.423	DEG C	0.25	0.02
114	200T-D9	HS5 6-5C-1	308.420	DEG C	0.26	0.02
115	200T-D10	HS5 1-7N-2	304.421	DEG C	0.26	0.02
116	200T-D11	HS5 5-10G-1	317.417	DEG C	0.25	0.02
117	200T-D12	HS5 1-11P-2	321.416	DEG C	0.25	0.02
118	200T-D13	HS5 5-12H-1	321.416	DEG C	0.24	0.02
119	200T-D14	HS5 4-11P-2	324.416	DEG C	0.22	0.02
120	200T-D15	HS5 7-11P-2	326.415	DEG C	0.26	0.02
121	200T-D16	HS5 6-8E-1	313.418	DEG C	0.24	0.02
201	200T-D17	HS5 6-10G-1	321.916	DEG C	0.33	0.03
202	200T-D18	HS5 7-9O-2	316.418	DEG C	0.24	0.02
203	205T-D1	HS10 7-6M-2	310.919	DEG C	0.26	0.02
204	205T-D2	HS10 4-6M-2	308.420	DEG C	0.26	0.02
205	205T-D3	HS10 5-5C-1	305.421	DEG C	0.22	0.02
206	205T-D4	HS10 5-3B-1	303.421	DEG C	0.23	0.02
207	205T-D5	HS10 6-3B-1	299.922	DEG C	0.24	0.02
208	205T-D6	HS10 6-5C-1	302.921	DEG C	0.22	0.02
209	205T-D7	HS10 1-2J-2	291.424	DEG C	0.22	0.02
210	205T-D8	HS10 1-4L-2	301.921	DEG C	0.25	0.02

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
211	205T-D9	HS10 1-6M-2	310.419	DEG C	0.25	0.02
212	205T-D10	HS10 7-7N-2	315.418	DEG C	0.25	0.02
213	205T-D11	HS10 4-9O-2	314.418	DEG C	0.22	0.02
214	205T-D12	HS10 5-12H-1	327.915	DEG C	0.20	0.02
215	205T-D13	HS10 6-8E-1	313.918	DEG C	0.23	0.02
216	205T-D14	HS10 6-10G-1	314.418	DEG C	0.24	0.02
217	205T-D15	HS10 6-12H-1	322.416	DEG C	0.24	0.02
218	205T-D16	HS10 1-7N-2	305.920	DEG C	0.25	0.02
219	205T-D17	HS10 1-9O-2	314.418	DEG C	0.26	0.02
220	205T-D18	HS10 1-11P-2	330.414	DEG C	0.19	0.02
221	201T-D1	HS6 5-5C-1	301.921	DEG C	0.16	0.01
222	201T-D2	HS6 1-2J-2	300.422	DEG C	0.14	0.01
223	201T-D3	HS6 1-4L-2	298.922	DEG C	0.17	0.01
224	201T-D4	HS6 1-6M-2	311.419	DEG C	0.23	0.02
225	201T-D5	HS6 4-6M-2	305.421	DEG C	0.13	0.01
226	201T-D6	HS6 6-1A-1	295.423	DEG C	0.26	0.02
227	201T-D7	HS6 5-3B-1	298.422	DEG C	0.24	0.02
228	201T-D8	HS6 6-5C-1	301.422	DEG C	0.21	0.02
229	201T-D9	HS6 7-6M-2	307.420	DEG C	0.20	0.02
230	201T-D10	HS6 5-12H-1	321.416	DEG C	0.22	0.02
231	201T-D11	HS6 1-7N-2	301.422	DEG C	0.20	0.02
232	201T-D12	HS6 1-9O-2	315.418	DEG C	0.31	0.03
250	201T-D13	HS6 1-11P-2	323.916	DEG C	0.14	0.01
251	201T-D14	HS6 4-11P-2	324.416	DEG C	0.16	0.01
252	201T-D15	HS6 5-10G-1	321.416	DEG C	0.21	0.02
253	201T-D16	HS6 6-10G-1	318.917	DEG C	0.19	0.02
254	201T-D17	HS6 6-12H-1	322.916	DEG C	0.28	0.02
255	201T-D18	HS6 7-11P-2	332.175	DEG C	0.28	0.02
256	206T-D1	HS11 4-6M-2	311.419	DEG C	0.27	0.02
257	206T-D2	HS11 1-2J-2	295.923	DEG C	0.27	0.02
258	206T-D3	HS11 1-4L-2	298.422	DEG C	0.26	0.02
259	206T-D4	HS11 1-6M-2	304.421	DEG C	0.23	0.02
260	206T-D5	HS11 5-3B-1	299.422	DEG C	0.27	0.02
261	206T-D6	HS11 6-3B-1	300.422	DEG C	0.25	0.02
262	206T-D7	HS11 6-5C-1	302.921	DEG C	0.24	0.02
263	206T-D8	HS11 5-5C-1	307.420	DEG C	0.24	0.02
264	206T-D9	HS11 7-6M-2	307.920	DEG C	0.28	0.02
265	206T-D10	HS11 4-11P-2	319.917	DEG C	0.40	0.03
267	206T-D11	HS11 1-7N-2	308.420	DEG C	0.35	0.03
268	206T-D12	HS11 7-9O-2	318.917	DEG C	0.31	0.02
269	206T-D13	HS11 5-8E-1	308.920	DEG C	0.35	0.03
270	206T-D14	HS11 6-8E-1	310.919	DEG C	0.23	0.02
271	206T-D15	HS11 6-10G-1	315.918	DEG C	0.32	0.03
272	206T-D16	HS11 6-12H-1	325.415	DEG C	0.31	0.02
273	206T-D17	HS11 5-12H-1	320.417	DEG C	0.31	0.03
274	206T-D18	HS11 7-11P-2	327.415	DEG C	0.31	0.02
275	202T-D1	HS7 4-6M-2	312.919	DEG C	0.34	0.03
276	202T-D2	HS7 7-2J-2	311.419	DEG C	0.22	0.02
277	202T-D3	HS7 1-4L-2	309.919	DEG C	0.25	0.02
278	202T-D4	HS7 1-2KC-2	381.401	DEG C	0.29	0.02
279	202T-D5	HS7 7-6M-2	316.418	DEG C	0.27	0.02
280	202T-D6	HS7 7-4L-2	313.918	DEG C	0.23	0.02
281	202T-D7	HS7 6-3B-1	302.421	DEG C	0.21	0.02
282	202T-D8	HS7 4-4L-2	300.922	DEG C	0.30	0.02

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
385	202T-D9	HS7 4-2J-2	302.986	DEG C	0.63	0.05
386	202T-D10	HS7 4-11P-2	321.106	DEG C	0.56	0.04
387	202T-D11	HS7 1-7N-2	323.605	DEG C	0.53	0.04
388	202T-D12	HS7 1-9O-2	322.356	DEG C	0.53	0.04
389	202T-D13	HS7 1-11P-2	326.730	DEG C	0.56	0.04
390	202T-D14	HS7 7-11P-2	333.603	DEG C	0.56	0.04
391	202T-D15	HS7 6-8E-1	320.481	DEG C	0.57	0.05
392	202T-D16	HS7 6-10G-1	321.731	DEG C	0.54	0.04
393	202T-D17	HS7 6-12H-1	328.604	DEG C	0.54	0.04
394	202T-D18	HS7 7-9O-2	330.479	DEG C	0.54	0.04
395	207T-D1	HS12 4-6M-2	318.607	DEG C	0.58	0.05
396	207T-D2	HS12 1-2J-2	305.485	DEG C	0.54	0.04
397	207T-D3	HS12 1-4L-2	308.609	DEG C	0.36	0.03
398	207T-D4	HS12 1-6M-2	311.109	DEG C	0.51	0.04
399	207T-D5	HS12 5-3B-1	304.235	DEG C	0.58	0.05
400	207T-D6	HS12 6-1A-1	301.111	DEG C	0.58	0.05
401	207T-D7	HS12 5-1A-1	300.486	DEG C	0.52	0.04
402	207T-D8	HS12 6-5C-1	314.233	DEG C	0.56	0.04
403	207T-D9	HS12 5-5C-1	306.735	DEG C	0.56	0.04
404	207T-D10	HS12 4-11P-2	326.105	DEG C	0.53	0.04
405	207T-D11	HS12 1-7N-2	316.107	DEG C	0.55	0.04
406	207T-D12	HS12 1-9O-2	317.982	DEG C	0.52	0.04
407	207T-D13	HS12 1-11P-2	325.480	DEG C	0.57	0.05
408	207T-D14	HS12 5-10G-1	326.105	DEG C	0.55	0.04
409	207T-D15	HS12 6-8E-1	321.106	DEG C	0.63	0.05
410	207T-D16	HS12 6-10G-1	320.481	DEG C	0.58	0.05
411	207T-D17	HS12 6-12H-1	324.855	DEG C	0.56	0.04
412	207T-D18	HS12 5-12H-1	325.480	DEG C	0.49	0.04
413	203T-D1	HS8 1-6M-2	315.482	DEG C	0.54	0.04
414	203T-D2	HS8 1-4L-2	311.733	DEG C	0.55	0.04
415	203T-D3	HS8 1-2J-2	309.859	DEG C	0.59	0.05
416	203T-D4	HS8 7-2J-2	311.109	DEG C	0.59	0.05
417	203T-D5	HS8 4-2J-2	309.234	DEG C	0.56	0.04
418	203T-D6	HS8 6-5C-1	315.482	DEG C	0.60	0.05
419	203T-D7	HS8 6-3B-1	309.234	DEG C	0.61	0.05
420	203T-D8	HS8 6-1A-1	300.486	DEG C	0.58	0.05
421	203T-D9	HS8 5-1A-1	298.612	DEG C	0.61	0.05
422	203T-D10	HS8 1-11P-2	327.979	DEG C	0.63	0.05
423	203T-D11	HS8 1-9O-2	322.356	DEG C	0.62	0.05
424	203T-D12	HS8 1-7N-2	318.607	DEG C	0.62	0.05
425	203T-D13	HS8 7-7N-2	324.855	DEG C	0.60	0.05
426	203T-D14	HS8 4-7N-2	323.605	DEG C	0.63	0.05
427	203T-D15	HS8 7-11P-2	344.225	DEG C	0.84	0.07
428	203T-D16	HS8 6-10G-1	324.855	DEG C	0.64	0.05
429	203T-D17	HS8 6-8E-1	315.482	DEG C	0.64	0.05
430	203T-D18	HS8 5-8E-1	322.356	DEG C	0.61	0.05
431	208T-D1	HS13 7-6M-2	320.481	DEG C	0.68	0.05
432	208T-D2	HS13 5-5C-1	313.608	DEG C	0.61	0.05
433	208T-D3	HS13 1-2J-2	306.735	DEG C	0.63	0.05
434	208T-D4	HS13 1-4L-2	318.607	DEG C	0.58	0.05
435	208T-D5	HS13 1-6M-2	314.858	DEG C	0.66	0.05
436	208T-D6	HS13 6-1A-1	302.986	DEG C	0.65	0.05
437	208T-D7	HS13 6-3B-1	307.360	DEG C	0.63	0.05
438	208T-D8	HS13 6-5C-1	318.607	DEG C	0.62	0.05

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
439	208T-D9	HS13 4-6M-2	316.107	DEG C	0.63	0.05
440	208T-D10	HS13 7-11P-2	338.602	DEG C	0.63	0.05
441	208T-D11	HS13 5-12H-1	336.727	DEG C	0.68	0.05
442	208T-D12	HS13 1-7N-2	316.732	DEG C	0.61	0.05
443	208T-D13	HS13 1-9O-2	320.481	DEG C	0.59	0.05
444	208T-D14	HS13 1-11P-2	328.604	DEG C	0.62	0.05
445	208T-D15	HS13 6-8E-1	323.605	DEG C	0.63	0.05
446	208T-D16	HS13 6-10G-1	330.479	DEG C	0.61	0.05
447	208T-D17	HS13 6-12H-1	331.104	DEG C	0.65	0.05
448	208T-D18	HS13 4-11P-2	326.730	DEG C	0.64	0.05
449	204T-D1	HS9 1-2J-2	300.486	DEG C	0.60	0.05
450	204T-D2	HS9 1-4L-2	307.360	DEG C	0.59	0.05
451	204T-D3	HS9 1-6M-2	309.859	DEG C	0.68	0.05
452	204T-D4	HS9 6-1A-1	298.612	DEG C	0.63	0.05
453	204T-D5	HS9 6-3B-1	306.110	DEG C	0.63	0.05
454	204T-D6	HS9 6-5C-1	312.358	DEG C	0.61	0.05
455	204T-D7	HS9 7-6M-2	309.859	DEG C	0.62	0.05
456	204T-D8	HS9 5-5C-1	312.358	DEG C	0.59	0.05
457	204T-D9	HS9 4-6M-2	312.358	DEG C	0.62	0.05
458	204T-D10	HS9 1-7N-2	317.357	DEG C	0.65	0.05
459	204T-D11	HS9 1-9O-2	321.106	DEG C	0.59	0.05
460	204T-D12	HS9 1-11P-2	327.354	DEG C	0.60	0.05
461	204T-D13	HS9 6-8E-1	319.856	DEG C	0.61	0.05
462	204T-D14	HS9 6-10G-1	324.230	DEG C	0.60	0.05
463	204T-D15	HS9 6-12H-1	331.728	DEG C	0.63	0.05
464	204T-D16	HS9 7-9O-2	326.105	DEG C	0.63	0.05
465	204T-D17	HS9 7-7N-2	327.979	DEG C	0.66	0.05
466	204T-D18	HS9 4-11P-2	326.730	DEG C	0.64	0.05
467	209T-D1	HS14 4-6M-2	312.983	DEG C	0.64	0.05
468	209T-D2	HS14 7-6M-2	315.482	DEG C	0.66	0.05
469	209T-D3	HS14 6-1A-1	294.238	DEG C	0.67	0.05
470	209T-D4	HS14 6-3B-1	296.112	DEG C	0.63	0.05
471	209T-D5	HS14 7-2J-2	304.235	DEG C	3.25	0.26
472	209T-D6	HS14 5-3B-1	299.237	DEG C	0.62	0.05
473	209T-D7	HS14 4-4L-2	302.986	DEG C	0.67	0.05
474	209T-D8	HS14 1-6M-2	308.609	DEG C	0.72	0.06
475	209T-D9	HS14 5-5C-1	312.983	DEG C	0.66	0.05
476	209T-D10	HS14 4-11P-2	324.230	DEG C	0.67	0.05
477	209T-D11	HS14 7-9O-2	326.730	DEG C	0.68	0.05
478	209T-D12	HS14 7-7N-2	315.482	DEG C	0.65	0.05
479	209T-D13	HS14 6-10G-1	321.106	DEG C	0.66	0.05
480	209T-D14	HS14 6-12H-1	330.479	DEG C	0.65	0.05
481	209T-D15	HS14 1-7N-2	317.357	DEG C	0.65	0.05
482	209T-D16	HS14 1-9O-2	319.856	DEG C	0.65	0.05
483	209T-D17	HS14 1-11P-2	325.480	DEG C	0.72	0.06
484	209T-D18	HS14 5-12H-1	325.480	DEG C	0.70	0.06
525	331T-D1	BO1/2 FDWTR	31.689	DEG C	0.26	0.02
526	332T-D1	BO1 FDWTR	111.512	DEG C	0.32	0.03
527	333T-D1	BO2 FDWTR	106.482	DEG C	0.34	0.03
528	114T-D1	ECI HDR8	82.207	DEG C	0.43	0.03
609	321T-D1	P14 DIS TEMP	31.470	DEG C	0.24	0.02
610	112T-D1	ECI HDR6	102.327	DEG C	0.59	0.05
611	2T-D13	B2-TB4-S37	272.690	DEG C	0.24	0.02
612	2T-D14	B2-TB4-S25	278.595	DEG C	0.24	0.02

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
613	2T-D15	B2-TB4-S12	285.375	DEG C	0.23	0.02
614	2T-D16	B2-TB4-S50	268.754	DEG C	0.24	0.02
615	238T-D3	HS12 OUT FDR	285.812	DEG C	0.24	0.02
616	234T-D3	HS11 OUT FDR	296.091	DEG C	0.23	0.02
617	230T-D3	HS10 OUT FDR	295.435	DEG C	0.24	0.02
618	221T-D3	HS7 OUT FDR	288.874	DEG C	0.23	0.02
619	213T-D3	HS5 OUT FDR	296.528	DEG C	0.22	0.02
620	217T-D3	HS6 OUT FDR	294.341	DEG C	0.25	0.02
621	2T-D25	B2-TE1-S37	259.787	DEG C	0.24	0.02
622	113T-D1	ECI HDR7	87.456	DEG C	0.46	0.04
623	2T-D26	B2-TE1-S25	278.814	DEG C	0.25	0.02
624	1T-D33	B1-TE6-S12	284.500	DEG C	0.26	0.02
625	1T-D32	B1-TE6-S25	279.689	DEG C	0.24	0.02
626	1T-D31	B1-TE6-S37	274.877	DEG C	0.22	0.02
627	111T-D1	ECI HDR5	91.174	DEG C	0.45	0.04
628	1T-D34	B1-TE6-S50	271.378	DEG C	0.25	0.02
629	81T	BLWDWN LINE	45.685	DEG C	0.76	0.06
630	1T-D36	B1-TE6-S92	262.849	DEG C	0.22	0.02
631	48T-D1	ECI TANK	27.096	DEG C	0.23	0.02
632	2T-D32	B2-TE6-S25	278.595	DEG C	0.24	0.02
633	75T-D7	SB2-TB1-S84	257.819	DEG C	0.24	0.02
634	2T-D34	B2-TE6-S50	269.629	DEG C	0.23	0.02
635	75T-D8	SB2-TB11-S84	258.257	DEG C	0.24	0.02
636	2T-D36	B2-TE6-S92	262.412	DEG C	0.24	0.02
637	74T-D4	SB1-TC5-S16	257.382	DEG C	0.23	0.02
638	74T-D5	SB1-TB6-S96	239.011	DEG C	0.81	0.06
639	74T-D7	SB1-TB1-S84	258.475	DEG C	0.22	0.02
640	74T-D8	SB1-TB11-S84	258.257	DEG C	0.26	0.02
641	74T-D10	SB1-TE6-S92	248.197	DEG C	0.44	0.04
642	75T-D1	SB2-TB1-S4	258.694	DEG C	0.27	0.02
643	75T-D2	SB2-TB11-S8	259.350	DEG C	0.26	0.02
649	200T-D19	HS5 5-1A-1	298.612	DEG C	0.72	0.06
650	200T-D20	HS5 5-3B-1	303.610	DEG C	0.66	0.05
651	200T-D21	HS5 4-2J-2	296.112	DEG C	0.57	0.05
652	200T-D22	HS5 4-4L-2	301.736	DEG C	0.64	0.05
653	200T-D23	HS5 7-4L-2	306.735	DEG C	0.69	0.05
656	200T-D26	HS5 4-7N-2	311.733	DEG C	0.66	0.05
657	200T-D27	HS5 4-9O-2	316.732	DEG C	0.56	0.05
661	205T-D19	HS10 7-2J-2	302.361	DEG C	0.76	0.06
662	205T-D20	HS10 7-4L-2	308.609	DEG C	0.67	0.05
664	205T-D22	HS10 4-4L-2	304.235	DEG C	0.68	0.05
665	205T-D23	HS10 5-1A-1	296.112	DEG C	0.67	0.05
667	205T-D25	HS10 4-7N-2	305.485	DEG C	0.68	0.05
673	201T-D19	HS6 5-1A-1	294.238	DEG C	0.63	0.05
674	201T-D20	HS6 4-2J-2	299.237	DEG C	0.66	0.05
675	201T-D21	HS6 4-4L-2	310.484	DEG C	0.65	0.05
676	201T-D22	HS6 7-2J-2	302.361	DEG C	0.64	0.05
677	201T-D23	HS6 7-4L-2	307.984	DEG C	0.74	0.06
679	201T-D25	HS6 7-9O-2	320.481	DEG C	0.63	0.05
681	201T-D27	HS6 4-7N-2	311.109	DEG C	0.70	0.06
682	201T-D28	HS6 4-9O-2	318.607	DEG C	0.72	0.06
683	201T-D29	HS6 7-7N-2	315.482	DEG C	0.63	0.05
685	206T-D19	HS11 4-2J-2	294.238	DEG C	0.61	0.05
686	206T-D20	HS11 4-4L-2	302.361	DEG C	0.66	0.05

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
687	206T-D21	HS11 5-1A-1	294.238	DEG C	0.77	0.06
688	206T-D22	HS11 7-4L-2	306.735	DEG C	0.69	0.06
691	206T-D25	HS11 4-7N-2	309.859	DEG C	0.65	0.05
692	206T-D26	HS11 4-9O-2	320.481	DEG C	0.76	0.06
693	206T-D27	HS11 7-7N-2	314.233	DEG C	0.75	0.06
703	202T-D25	HS7 4-7N-2	315.482	DEG C	0.78	0.06
704	202T-D26	HS7 4-9O-2	326.730	DEG C	0.70	0.06
705	202T-D27	HS7 7-7N-2	327.354	DEG C	0.79	0.06
709	207T-D19	HS12 4-4L-2	307.984	DEG C	0.72	0.06
715	207T-D25	HS12 4-7N-2	319.856	DEG C	0.76	0.06
716	207T-D26	HS12 4-9O-2	321.106	DEG C	0.73	0.06
718	207T-D28	HS12 5-8E-1	317.982	DEG C	0.82	0.07
721	203T-D19	HS8 5-5C-1	314.233	DEG C	0.76	0.06
722	203T-D20	HS8 5-3B-1	306.735	DEG C	0.88	0.07
723	203T-D21	HS8 4-6M-2	321.106	DEG C	0.72	0.06
724	203T-D22	HS8 4-4L-2	307.984	DEG C	0.78	0.06
725	203T-D23	HS8 7-6M-2	329.854	DEG C	0.86	0.07
727	203T-D25	HS8 5-10G-1	328.604	DEG C	0.79	0.06
728	203T-D26	HS8 4-11P-2	330.479	DEG C	0.78	0.06
729	203T-D27	HS8 4-9O-2	326.730	DEG C	0.74	0.06
730	203T-D28	HS8 7-9O-2	336.727	DEG C	0.72	0.06
733	208T-D19	HS13 7-2J-2	308.609	DEG C	1.16	0.09
734	208T-D20	HS13 7-4L-2	316.732	DEG C	0.79	0.06
735	208T-D21	HS13 5-1A-1	304.860	DEG C	0.75	0.06
736	208T-D22	HS13 5-3B-1	311.733	DEG C	0.75	0.06
737	208T-D23	HS13 4-4L-2	310.484	DEG C	0.73	0.06
739	208T-D25	HS13 7-7N-2	319.232	DEG C	0.79	0.06
740	208T-D26	HS13 7-9O-2	330.479	DEG C	0.73	0.06
741	208T-D27	HS13 5-8E-1	324.855	DEG C	0.89	0.07
742	208T-D28	HS13 5-10G-1	329.229	DEG C	0.72	0.06
743	208T-D29	HS13 4-7N-2	317.982	DEG C	0.73	0.06
745	204T-D19	HS9 7-2J-2	309.234	DEG C	0.67	0.05
746	204T-D20	HS9 7-4L-2	307.360	DEG C	0.80	0.06
747	204T-D21	HS9 5-1A-1	299.237	DEG C	0.65	0.05
748	204T-D22	HS9 4-4L-2	310.484	DEG C	0.68	0.05
749	204T-D23	HS9 4-2J-2	301.111	DEG C	0.72	0.06
753	204T-D27	HS9 4-7N-2	318.607	DEG C	0.82	0.07
754	204T-D28	HS9 4-9O-2	323.605	DEG C	0.70	0.06
757	209T-D19	HS14 4-2J-2	299.237	DEG C	0.68	0.05
761	209T-D23	HS14 5-1A-1	297.362	DEG C	0.71	0.06
763	209T-D25	HS14 4-7N-2	317.982	DEG C	0.65	0.05
764	209T-D26	HS14 4-9O-2	323.605	DEG C	0.66	0.05
765	209T-D27	HS14 5-8E-1	321.731	DEG C	0.76	0.06
766	209T-D28	HS14 5-10G-1	326.730	DEG C	0.66	0.05
351	OR25-DP	ECI INJ LINE	0.365	KPA	2.36	0.19
196	PM1-1A	P1 AMPS	200.818	AMP	22.96	1.83
199	PM2-1A	P2 AMPS	205.554	AMP	20.01	1.60
82	PS1-1W	PS1 POWER	2.297	MW	0.01	0.00
83	PS2-1W	PS2 POWER	1.688	MW	0.20	0.02
84	PS3-1W	PS3 POWER	2.319	MW	0.05	0.00
85	PS4-1W	PS4 POWER	1.688	MW	0.19	0.01
197	PM1-1Y	P1 SPEED	3392.118	RPM	18.93	1.51
200	PM2-1Y	P2 SPEED	3393.917	RPM	16.90	1.35
64	3T	BO1 INLT PLN	294.997	DEG C	0.46	0.04

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF	
65	26T	BO1 OUTLT PL	262.193	DEG C	0.51	0.04	
66	30T	BO1 STM	257.382	DEG C	0.70	0.06	
67	37T	BO1/2 FDWTR	185.869	DEG C	0.64	0.05	
68	14T	BO2 IN PLN	295.216	DEG C	0.47	0.04	
69	15T	BO2 OUTLT PL	260.662	DEG C	0.48	0.04	
70	45T	SRG TANK	308.994	DEG C	0.29	0.02	
71	32T	BO2 STM	256.944	DEG C	0.35	0.03	
73	24T	HDR5	296.747	DEG C	0.44	0.04	
74	6T	HDR6	262.193	DEG C	0.43	0.03	
75	12T	HDR7	297.403	DEG C	0.53	0.04	
76	18T	HDR8	263.724	DEG C	0.48	0.04	
81	TIME MRK	TEST CHANNEL	-1.147	VOLTS	0.96	0.08	
167	3F-M1	BO1 STM M F	1.914	KG/S	0.03	0.00	
171	4F-M1	BO2 STM M F	2.002	KG/S	0.03	0.00	
78	1F	P1 OUT	27.848	L/S	0.12	0.01	
79	2F	P2 OUT	27.488	L/S	0.17	0.01	
235	231F-D1	ECI HDR5	-0.005	L/S	0.00	0.00	
236	233F-D1	ECI HDR7	0.015	L/S	0.01	0.00	
237	232F-D1	ECI HDR6	0.020	L/S	0.01	0.00	
238	234F-D1	ECI HDR8	0.022	L/S	0.01	0.00	
365	177F-D1	HS5 INLET	5.054	L/S	0.01	0.00	
366	178F-D1	HS5 OUTLET	5.576	L/S	0.00	0.00	
367	179F-D1	HS6 INLET	5.135	L/S	0.00	0.00	
368	180F-D1	HS6 OUTLET	5.591	L/S	0.01	0.00	
369	181F-D1	HS7 INLET	6.139	L/S	0.00	0.00	***
370	182F-D1	HS7 OUTLET	6.139	L/S	0.00	0.00	***
371	183F-D1	HS8 INLET	6.139	L/S	0.00	0.00	***
372	184F-D1	HS8 OUTLET	6.139	L/S	0.00	0.00	***
373	185F-D1	HS9 INLET	5.126	L/S	0.00	0.00	
374	186F-D1	HS9 OUTLET	5.567	L/S	0.00	0.00	
375	187F-D1	HS10 INLET	4.964	L/S	0.01	0.00	
376	188F-D1	HS10 OUTLET	5.426	L/S	0.01	0.00	
377	189F-D1	HS11 INLET	5.129	L/S	0.01	0.00	
378	190F-D1	HS11 OUTLET	5.552	L/S	0.00	0.00	
379	191F-D1	HS12 INLET	6.139	L/S	0.00	0.00	***
380	192F-D1	HS12 OUTLET	6.139	L/S	0.00	0.00	***
381	193F-D1	HS13 INLET	6.139	L/S	0.00	0.00	***
382	194F-D1	HS13 OUTLET	6.139	L/S	0.00	0.00	***
383	195F-D1	HS14 INLET	5.009	L/S	0.00	0.00	
384	196F-D1	HS14 OUTLET	5.480	L/S	0.00	0.00	
90	237F-D1	INV TANK FLO	0.000	L/S	0.00	0.00	
101	19F	CD1 SPRAY	9.306	L/S	0.13	0.01	
168	5F-D2	BO1 FDWTR	2.384	L/S	0.15	0.01	
173	6F-D2	B02 FDWTR	2.860	L/S	0.05	0.00	
283	12VF-DT3	BO2 INLET	2.687	VDC	0.03	0.00	
284	12VF-DT4	BO2 INLET	2.709	VDC	0.03	0.00	
313	11VF-DT1	BO1 INLET	2.644	VDC	0.02	0.00	
314	11VF-DT2	BO1 INLET	2.712	VDC	0.03	0.00	
315	11VF-DT3	BO1 OUTLET	2.609	VDC	0.03	0.00	
316	11VF-DT4	BO1 OUTLET	2.552	VDC	0.03	0.00	
317	12VF-DT1	BO2 OUTLET	2.499	VDC	0.03	0.00	
318	12VF-DT2	BO2 OUTLET	2.599	VDC	0.04	0.00	
1	1VF-DTX	P1 OUT	3.742	VDC	0.08	0.01	
2	1VF-DTZ	P1 OUT	3.014	VDC	0.06	0.00	

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CHN	CODE	LOCATION	VALUE	UNITS	STD DEV	95% CONF
3	1VF-DTY	P1 OUT	3.562	VDC	0.07	0.01
123	4VF-DTX	P2 OUTLET	2.732	VDC	0.06	0.01
124	4VF-DTZ	P2 OUTLET	3.007	VDC	0.06	0.00
125	4VF-DTY	P2 OUTLET	2.617	VDC	0.07	0.01
128	34VF	HS14 OUTLET	3.347	VDC	0.02	0.00
129	33VF	HS14 INLET	3.961	VDC	0.03	0.00
130	32VF	HS13 OUTLET	3.814	VDC	0.02	0.00
131	31VF	HS13 INLET	3.747	VDC	0.02	0.00
161	25VF	HS10 INLET	4.014	VDC	0.02	0.00
162	26VF	HS10 OUTLET	3.834	VDC	0.02	0.00
163	27VF	HS11 INLET	3.941	VDC	0.02	0.00
164	28VF	HS11 OUTLET	3.817	VDC	0.02	0.00
165	29VF	HS12 INLET	3.774	VDC	0.02	0.00
166	30VF	HS12 OUTLET	3.812	VDC	0.02	0.00
243	24VF	HS9 OUTLET	3.724	VDC	0.02	0.00
244	23VF	HS9 INLET	4.061	VDC	0.02	0.00
245	22VF	HS8 OUTLET	3.794	VDC	0.02	0.00
285	21VF	HS8 INLET	3.732	VDC	0.02	0.00
286	20VF	HS7 OUTLET	3.784	VDC	0.02	0.00
287	19VF	HS7 INLET	3.767	VDC	0.02	0.00
288	18VF	HS6 OUTLET	3.851	VDC	0.02	0.00
327	17VF	HS6 INLET	3.981	VDC	0.02	0.00
328	16VF	HS5 OUTLET	3.829	VDC	0.02	0.00
329	15VF	HS5 INLET	3.929	VDC	0.02	0.00
159	PS1-1V	PS1 VOLTS	361.406	VDC	6.21	0.50
241	PS2-1V	PS2 VOLTS	384.150	VDC	27.04	2.16
242	PS3-1V	PS3 VOLTS	351.159	VDC	2.64	0.21
266	PS4-1V	PS4 VOLTS	373.653	VDC	26.94	2.15

*** Off-scale (calibrated ±6.0 L/s)

...concluded

AVAILABLE

RD-14M Void Fraction Meter Data

Experiment B9401

Data file: B9401E.DAT 12:43:24 2-JUN-94

200 Scans -- EMPTY SCAN -- 16:10:59 5-MAY-94

	CHN	DEVICE	LOCATION	MAX	MIN	AVERAGE	% ERR
1)	1	1VF-DTX	P1 OUT	4.784	4.251	4.551	11.70
2)	2	1VF-DTZ	P1 OUT	4.734	4.284	4.531	9.93
3)	3	1VF-DTY	P1 OUT	4.741	4.281	4.524	10.17
4)	123	4VF-DTX	P2 OUTLET	3.872	3.494	3.684	10.24
5)	124	4VF-DTZ	P2 OUTLET	4.699	4.299	4.474	8.94
6)	125	4VF-DTY	P2 OUTLET	3.717	3.322	3.519	11.22
7)	127	35VF	HIC W	4.529	4.354	4.424	3.95
8)	128	34VF	HS14 OUTLET	4.531	4.426	4.484	2.34
9)	129	33VF	HS14 INLET	4.576	4.426	4.504	3.33
10)	130	32VF	HS13 OUTLET	4.549	4.429	4.489	2.67
11)	131	31VF	HS13 INLET	4.561	4.414	4.496	3.28
12)	161	25VF	HS10 INLET	4.574	4.469	4.516	2.32
13)	162	26VF	HS10 OUTLET	4.549	4.431	4.481	2.62
14)	163	27VF	HS11 INLET	4.539	4.436	4.491	2.28
15)	164	28VF	HS11 OUTLET	4.564	4.451	4.501	2.50
16)	165	29VF	HS12 INLET	4.576	4.439	4.509	3.05
17)	166	30VF	HS12 OUTLET	4.581	4.439	4.509	3.16
18)	243	24VF	HS9 OUTLET	4.554	4.441	4.501	2.50
19)	244	23VF	HS9 INLET	4.609	4.479	4.541	2.86
20)	245	22VF	HS8 OUTLET	4.571	4.444	4.499	2.83
21)	283	12VF-DT3	BO2 INLET	4.626	4.411	4.531	4.74
22)	284	12VF-DT4	BO2 INLET	4.586	4.399	4.491	4.17
23)	285	21VF	HS8 INLET	4.569	4.424	4.499	3.22
24)	286	20VF	HS7 OUTLET	4.561	4.444	4.504	2.61
25)	287	19VF	HS7 INLET	4.576	4.446	4.504	2.89
26)	288	18VF	HS6 OUTLET	4.614	4.491	4.556	2.69
27)	313	11VF-DT1	BO1 INLET	4.636	4.409	4.506	5.05
28)	314	11VF-DT2	BO1 INLET	4.611	4.414	4.511	4.38
29)	315	11VF-DT3	BO1 OUTLET	4.614	4.411	4.521	4.48
30)	316	11VF-DT4	BO1 OUTLET	4.604	4.431	4.531	3.81
31)	317	12VF-DT1	BO2 OUTLET	4.534	4.331	4.446	4.55
32)	318	12VF-DT2	BO2 OUTLET	4.654	4.369	4.524	6.30
33)	327	17VF	HS6 INLET	4.524	4.384	4.476	3.13
34)	328	16VF	HS5 OUTLET	4.556	4.426	4.491	2.89
35)	329	15VF	HS5 INLET	4.484	4.384	4.429	2.26

continued...

AVAILABLE RC-2491

200 Scans -- FULL SCAN -- 12:43:24 2-JUN-94

	CHN	DEVICE	DESCR	READING	LOCATION
PRESSURE:	100	12P-D1	GP-R	10027.78 KPA	HDR5
TEMPERATURE:	73	24T	RTD	261.10 DEG C	HDR5

	CHN	DEVICE	LOCATION	MAX	MIN	AVERAGE	% ERR
1)	1	1VF-DTX	P1 OUT	3.927	3.439	3.659	13.32
2)	2	1VF-DTZ	P1 OUT	3.097	2.809	2.959	9.71
3)	3	1VF-DTY	P1 OUT	3.754	3.284	3.492	13.46
4)	123	4VF-DTX	P2 OUTLET	2.979	2.629	2.777	12.60
5)	124	4VF-DTZ	P2 OUTLET	3.139	2.837	2.994	10.10
6)	125	4VF-DTY	P2 OUTLET	2.737	2.434	2.592	11.67
7)	127	35VF	HIC W	4.509	4.361	4.439	3.32
8)	128	34VF	HS14 OUTLET	3.342	3.247	3.297	2.88
9)	129	33VF	HS14 INLET	4.011	3.892	3.954	3.03
10)	130	32VF	HS13 OUTLET	3.797	3.697	3.747	2.67
11)	131	31VF	HS13 INLET	3.802	3.679	3.739	3.28
12)	161	25VF	HS10 INLET	4.101	3.924	3.999	4.44
13)	162	26VF	HS10 OUTLET	3.829	3.694	3.774	3.58
14)	163	27VF	HS11 INLET	4.039	3.842	3.929	5.03
15)	164	28VF	HS11 OUTLET	3.827	3.704	3.762	3.26
16)	165	29VF	HS12 INLET	3.837	3.667	3.782	4.49
17)	166	30VF	HS12 OUTLET	3.844	3.684	3.762	4.25
18)	243	24VF	HS9 OUTLET	3.727	3.594	3.679	3.60
19)	244	23VF	HS9 INLET	4.216	3.971	4.049	6.05
20)	245	22VF	HS8 OUTLET	3.884	3.687	3.754	5.26
21)	283	12VF-DT3	BO2 INLET	2.669	2.512	2.577	6.11
22)	284	12VF-DT4	BO2 INLET	2.682	2.514	2.599	6.44
23)	285	21VF	HS8 INLET	3.814	3.634	3.712	4.85
24)	286	20VF	HS7 OUTLET	3.914	3.699	3.754	5.73
25)	287	19VF	HS7 INLET	3.804	3.697	3.749	2.87
26)	288	18VF	HS6 OUTLET	3.892	3.729	3.804	4.27
27)	313	11VF-DT1	BO1 INLET	2.584	2.432	2.517	6.06
28)	314	11VF-DT2	BO1 INLET	2.654	2.502	2.584	5.90
29)	315	11VF-DT3	BO1 OUTLET	2.652	2.492	2.574	6.21
30)	316	11VF-DT4	BO1 OUTLET	2.592	2.414	2.504	7.09
31)	317	12VF-DT1	BO2 OUTLET	2.587	2.412	2.499	7.00
32)	318	12VF-DT2	BO2 OUTLET	2.702	2.442	2.582	10.07
33)	327	17VF	HS6 INLET	4.009	3.927	3.971	2.08
34)	328	16VF	HS5 OUTLET	3.864	3.714	3.779	3.97
35)	329	15VF	HS5 INLET	4.019	3.869	3.919	3.83

...concluded

AVAILABLE

RC-2491

RD-14M POWER MEASUREMENTS

Experiment B9401

Computer: FLUKE 1722A

Method: Voltage - True R.M.S.
Current - Voltage across shunt by true R.M.S.
Power - Calculated

File: B9401F.DAT

Experiment starting time: 15:15:49 02-Jun-94
Experiment ending time: 15:31:13 02-Jun-94

SCAN NO	DEVICE	VOLTAGE (VOLTS)	CURRENT (AMPS)	POWER (KW)	SAMPLING TIME	SECONDS OFFSET
1)	HS5	335.70	2298.81	771.71	15:11:21	-268.
	HS6	336.30	2303.70	774.73	15:11:43	-246.
	HS7	374.00	2189.24	818.78	15:12:05	-224.
	HS8	374.00	2549.70	953.59	15:12:27	-202.
	HS9	337.60	2328.63	786.14	15:12:49	-180.
	HS10	332.10	2291.23	760.92	15:13:11	-158.
	HS11	332.70	2299.64	765.09	15:13:33	-136.
	HS12	368.00	2166.76	797.37	15:13:55	-114.
	HS13	368.00	2554.60	940.09	15:14:17	-92.
	HS14	333.50	2311.74	770.97	15:14:39	-70.
2)	HS5	335.80	2300.06	772.36	15:15:16	-33.
	HS6	336.60	2305.95	776.18	15:15:38	-11.
	HS7	374.10	2189.81	819.21	15:16:00	11.
	HS8	116.19	781.42	90.79	15:16:21	32.
	HS9	64.44	438.55	28.26	15:16:43	54.
	HS10	65.50	451.02	29.54	15:17:05	76.
	HS11	65.94	456.71	30.12	15:17:26	97.
	HS12	74.14	438.62	32.52	15:17:48	119.
	HS13	75.68	527.47	39.92	15:18:10	141.
	HS14	66.12	456.23	30.17	15:18:31	162.
3)	HS5	64.99	449.19	29.19	15:19:09	200.
	HS6	65.17	448.43	29.22	15:19:31	222.
	HS7	77.17	453.22	34.98	15:19:52	243.
	HS8	77.25	527.85	40.78	15:20:14	265.
	HS9	64.90	448.72	29.12	15:20:36	287.
	HS10	65.46	455.65	29.83	15:20:57	308.
	HS11	65.44	454.83	29.76	15:21:19	330.
	HS12	54.28	316.64	17.19	15:21:41	352.
	HS13	54.07	370.00	20.01	15:22:04	375.
	HS14	65.83	462.19	30.43	15:22:26	397.
4)	HS5	63.43	436.39	27.68	15:23:03	434.
	HS6	64.04	440.09	28.18	15:23:24	455.
	HS7	77.47	455.21	35.27	15:23:46	477.
	HS8	77.33	529.28	40.93	15:24:08	499.
	HS9	64.00	442.79	28.34	15:24:29	520.
	HS10	64.87	445.83	28.92	15:24:51	542.
	HS11	64.87	446.55	28.97	15:25:13	564.
	HS12	75.72	438.84	33.23	15:25:34	585.
	HS13	75.82	526.73	39.94	15:25:56	607.
	HS14	64.70	446.84	28.91	15:26:17	628.

continued...

SCAN NO	DEVICE	VOLTAGE (VOLTS)	CURRENT (AMPS)	POWER (KW)	SAMPLING TIME	SECONDS OFFSET
5)	HS5	63.99	443.91	28.41	15:26:54	665.
	HS6	64.39	444.43	28.62	15:27:16	687.
	HS7	78.19	458.26	35.83	15:27:38	709.
	HS8	78.64	539.40	42.42	15:27:59	730.
	HS9	64.94	449.31	29.18	15:28:21	752.
	HS10	65.04	449.97	29.27	15:28:43	774.
	HS11	65.30	451.70	29.50	15:29:04	795.
	HS12	75.74	436.76	33.08	15:29:26	817.
	HS13	75.85	528.56	40.09	15:29:48	839.
	HS14	65.18	444.44	28.97	15:30:09	860.

...concluded

APPENDIX C

FORMAT OF TEST DATA

Files related to test B9401 have been saved on a CD-ROM.

The main data file is B9401.DAT, which contains the experimental data in engineering units. The first row of the data file contains the experiment name, the creation date, the program used to generate the ASCII data file, the number of scans in the experiment (including "time"), and the number of channels that were scanned. The format is as follows (FORTRAN format statement):

2x,'Experiment: ',A5,3x,'Date: ',A11,2x,'Program: ',A20,4x,'# of Scans: ',I5,'#of Channels: ',I5

The second row contains the device codes for each channel and the third row contains the measurement units. Please note that all pressure units in the data are in kPa(g). Both the second and third rows use the following format (FORTRAN format statement):

768(A11,' ')

The fourth and remaining rows contain the data with the first column being "time", followed by one scan for each device. The data was written in the following format (FORTRAN format statement):

769(F12.5)

Other files which are included on the CD-ROM are the scanning list (B9401B.DAT), average file (B9401R.DAT), void fraction full/empty file (B9401E.DAT), fluke (power) file (B9401F.DAT), and test setup file (B9401G.DAT).

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