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CLARIFICATION OF A RECENT COMPARISON OF NATURAL CIRCULATION FLOWS IN "CODE VALIDATION AND UNCERTAINTIES IN SYSTEM THERMAL HYDRAULICS" BY F. D'AURIA AND G.M. GALASSI

Differences in the geometrical configuration between the CANDU® Primary Heat Transport System and other reactor systems make direct comparison of natural circulation results difficult. Although many similarities in natural circulation phenomena between CANDU and PWR's have been identified, the multiple, horizontal-channel reactor core allows phenomena like individual channel flow reversal to occur which do not have a counterpart in other systems

Recently, a quantitative comparison of the effectiveness of natural circulation flows in the CANDU type RD-14M facility and integral facilities simulating PWR and WWER geometries was published (D'Auria and Galassi (1998)). The RD-14M data presented in this comparison was inappropriately extracted and interpreted from an early paper for test T8802 (Ingham et al (1991)). The authors of this comparison incorrectly assumed the core flow for the RD-14M test was equivalent to the reported flow through only one of the steam generators. Because of the figure-of-eight configuration, this assumption is a factor of two too low under strictly unidirectional flow conditions. The error in this assumption becomes even greater following the onset of channel flow reversal. The RD-14M experimental data used is not consistent with the author's analysis methodology. As a consequence, the magnitudes of RD-14M natural circulation flows are severely underestimated.

Core mass flow rates for the RD-14M test used in this comparison, T8802, cannot be calculated due to insufficient instrumentation in this early test. However, a more recent, better instrumented test, T9211, was conducted at the same nominal conditions as T8802. Test T9211 was the only test conducted using similar conditions and test procedure. Experimental results for T9211 are comparable to T8802 as shown in Figure 1. The similarity between these two tests is also illustrated in Table 1 where initial conditions, boundary conditions and key experimental results are compared. Important results to note include the similarity of inventory for the first and second flow reversals, breakdown of flow through the boilers and break down of flow in one of the channels (dry out).

The core mass flow rate is obtained by adding the mass flow rate through each channel. Individual channel mass flows are determined by correcting single-phase inflow feeder flow rate measurements made at steady-state conditions at each inventory for density.

To make an accurate comparison of RD-14M with other facilities, the total core mass flow as shown in Figure 1 should have been used by D'Auria and Galassi (1998) instead of the flow through only one of the steam generators. As illustrated in Figure 1, both the effective range and the magnitude of the core mass flow rates are significantly larger than the values used in assessing RD-14M results. The referenced comparison implies significant core flow rates only occur over a narrow range of primary inventories (82 to 100%), whereas in reality effective core flow rates were measured at inventories as low as 48%. Similarly, the actual maximum core mass flow rate is a factor of three higher than that in the data used in the referenced comparison.

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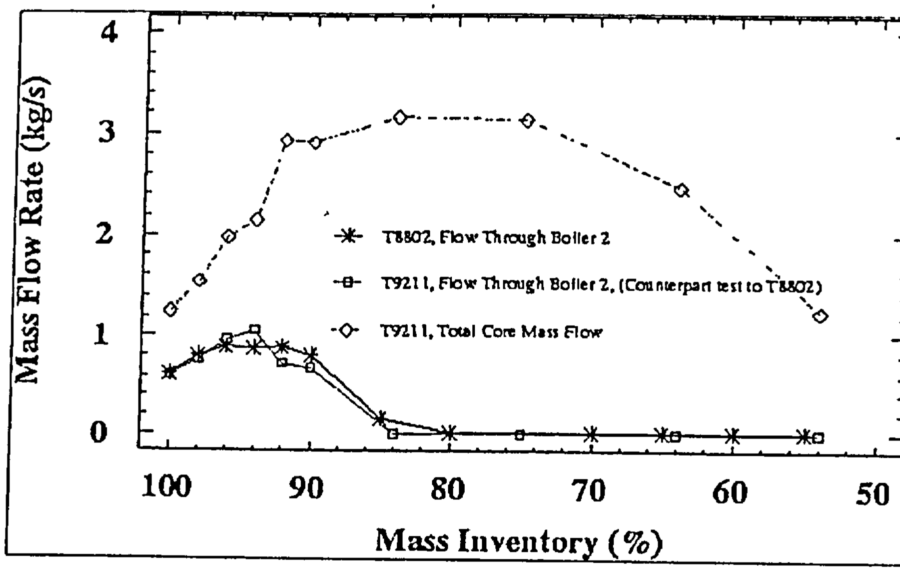


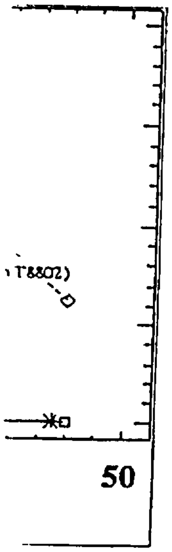
Figure 1: Comparison of above header and total core flow in RD-14M

TABLE 1. INITIAL CONDITIONS, BOUNDARY CONDITIONS AND KEY EXPERIMENTAL RESULTS FOR COUNTERPART EXPERIMENTS T8802 AND T9211

PARAMETER / RESULT	T8802	T9211
Initial primary pressure (MPa(g))	8.0	7.0
Secondary-side pressure (MPa(g))	4.3	4.0
Pass 1 - total power (kW)	100.0	101.9
Pass 2 - total power (kW)	101 5	101 7
Initial header 5 temperature (°C)	264 2	259.5
Initial header 6 temperature (°C)	246.9	242.9
Initial header 7 temperature (°C)	264.8	260.4
Initial header 8 temperature (°C)	248.0	244.1
Trace heating (kW)	22.0	22.0
Boiler feedwater temperature (°C)	57.1	164.9
% Mass inventory of first channel to reverse - pass 1	84%	91%
Channel number	HS5	HS7
% Mass inventory of second channel to reverse - pass 1	84%	82%
Channel number	HS7	HS7
% Mass inventory of first channel to reverse - pass 2	89%	91%
Channel number	HS10	HS12
% Mass inventory of second channel to reverse - pass 2	84%	82%
Channel number	HS11 & HS14	HS14
% Mass inventory where flow through boilers breaks down [a]	84%	82%
% Mass inventory at dry out [b]	48%	48%
Channel number	HS7	HS8

[a] Breakdown of flow through the boilers based on stalling of above header turbine flow meters These meters stall at flows below 0.4 L/s

[b] Dry out based on first channel to have at least two fuel element simulator temperatures exceed 600°C



-14M

.XPERIMENTAL
T9211

T9211
7.0
4.0
101.9
101.7
259.5
242 9
260.4
244.1
22.0
164.9
91%
HS7
82%
HS7
91%
HS12
82%
HS14
82%
48%
HS8

eters These meters

xceed 600°C

It is unfortunate that the differences in facility configurations and the nature of the data used in this comparison were misunderstood. The impact of these oversights is a gross underestimation of the core cooling effectiveness of natural circulation in CANDU geometries. Superimposition of the correct data on the published comparison clearly demonstrates that natural circulation flows in a CANDU type facility are quantitatively as high, if not higher, than flows encountered in integral facilities representing PWR and WWER geometries

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Ingham P J., Melnyk AJ. and Murray, T.V. (1991) Natural Circulation Experiments in RD-14M with Emergency Coolant Injection ANS International Topical Meeting-Safety of Thermal Reactors, Portland, Oregon, USA

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AN RD-14M EXPERIMENT FOR THE INTERCOMPARISON AND VALIDATION OF COMPUTER CODES FOR THERMALHYDRAULIC SAFETY ANALYSES OF HEAVY WATER REACTORS

by

R.S. Swartz

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This document is the property of AECL, and was prepared mainly for the dissemination of information for an IAEA international study "Consultancy on Intercomparison and Validation of Computer Codes for Thermalhydraulic Safety Analyses of Heavy Water Reactors."

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ABSTRACT

This report was prepared primarily for the dissemination of information for an IAEA (International Atomic Energy Agency) international study: "Consultancy on Intercomparison and Validation of Computer Codes for Thermalhydraulic Safety Analyses of Heavy Water Reactors." Experimental data from a RD-14M Large LOCA (loss-of-coolant accident) experiment is provided, along with a detailed description of the RD-14M facility. The information provided in this report is sufficient to prepare an idealization of the facility for simulation with a thermalhydraulics code, including initial and boundary conditions. Code predictions can then be compared to experimental results.

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VALUES AND IMPLICATIONS

The main objective, of this international activity, is to make available to the international community a selected RD-14M experimental data set, relevant to PHWRs (pressurized heavy water reactors), to serve as a benchmark for validation of thermalhydraulics computer codes used for safety analyses. This report provides the necessary experimental information, and the resulting exercise will strengthen the safety and licensing analysis capabilities of the participants.

2000 June 20

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1. INTRODUCTION

1.1 BACKGROUND

In early 1997, an IAEA (International Atomic Energy Agency) Coordinated Research Program was proposed on "The Intercomparison and Validation of Computer Codes for Thermalhydraulics Safety Analysis," under the auspices of the CANDU® (CANada Deuterium Uranium) Owner's Group (COG). A COG proposal was written, but was not included in the final 1997-98 COG program. In summer of 1999, it was decided that this project should proceed, sponsored by AECL. It was further decided that RD-14M data should be used - as RD-14M is a full vertical-scale representation of a CANDU circuit.

1.2 OBJECTIVE

The main objective, of this international activity, is to make available to the international community a selected experimental data set, relevant to PHWRs (pressurized heavy water reactors), to serve as benchmarks for validation of thermalhydraulics computer codes used for safety analyses of PHWRs, and to coordinate the comparison of code predictions against the selected data sets. Previously performed experiment(s) will be simulated by participants. The data supplied in this report provides a large-break LOCA (loss-of-coolant accident) benchmark in a full vertical-height scale integral facility containing many of the features of a CANDU reactor.

2. RD-14M DATA PROVIDED

An appropriate RD-14M test has been identified and is B9401, a critical (30 mm diameter) inlet header break experiment with high pressure pumped emergency coolant injection. In order to generate a computer idealization (input deck) of this experiment, participants will require a description of the facility. Therefore the following information is provided in this report:

- The RD-14M Facility Description and Characterization (Appendix A). This is a full reproduction of a stand-alone document, and as such has it's own table of contents, page numbering, appendices, etc.
- Information specific to test B9401, including set-up and initial conditions, and the instrument (scanning) list (Appendix B).

The experimental data collected for RD-14M, in engineering units, is also provided, on CD-ROM, with the data format described in Appendix C.

3. SUMMARY

The information provided in this report provides a complete benchmark to facilitate the validation of thermalhydraulics computer codes used for safety analyses of PHWRs.

4. ACKNOWLEDGEMENTS

The following are all authors of the reports reproduced here: J.R. Buell, D. P. Byskal, J.W. Findlay, J.M. Gervais, P.J. Ingham, T.M. McDougall, A.J. Melnyk, J.E. Middleton, S.D. Parrott, T.V. Sanderson, and R.S. Swartz.

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APPENDIX A

RD-14M FACILITY DESCRIPTION AND CHARACTERIZATION

The following is a reproduction of a stand-alone report describing the RD-14M facility.

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RD-14M FACILITY DESCRIPTION AND CHARACTERIZATION

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RD-14M FACILITY DESCRIPTION AND CHARACTERIZATION

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ABSTRACT

The RD-14M facility is a large-scale pressurized-water loop representing the major components found in the primary heat transport system of a CANDU® reactor. The facility was constructed to allow simulation of the primary heat transport system behaviour under various postulated accident conditions, such as loss of coolant, or loss of forced flow. This document reviews the facility design philosophy and describes the facility in detail, including characterizations of some of the major loop components.

The construction of the RD-14M facility was funded by COG, with operation currently funded through COG and AECL.

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1. INTRODUCTION

RD-14M is an 11 MW, full-elevation-scaled thermalhydraulic test facility possessing most of the key components of a CANDU® (CANada Deuterium Uranium) PHTS (primary heat transport system). Figure 1.1 shows a simplified schematic of the RD-14M facility. The facility is arranged in the standard CANDU two-pass, figure-of-eight configuration. The reactor core is simulated by ten, 6 m-long horizontal channels (test sections). Each test section has simulated end-fittings and seven electrical heaters, or fuel element simulators (FES), designed to have many of the characteristics of the CANDU fuel bundle. Test sections are connected to headers via full-length feeders. Above header piping is also CANDU-typical including two full-height, U-tube steam generators or boilers (BO1 and B02) and two bottom-suction centrifugal pumps (P1 and P2). Steam generated in the secondary, or shell, side of the steam generators is condensed in a jet condenser (CD1) and returned as feedwater to the boilers. The primary-side pressure is controlled by a pressurizer/surge tank (TK1) using a 100-kW electric heater (HR1). 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.

The RD-14M loop is extensively instrumented. Approximately 600 instruments are scanned and recorded using a dedicated data acquisition system during RD-14M experiments. In addition to above-header pressures, temperatures, volumetric flows, and void fraction measurements, the test sections are extensively instrumented. Inlet and outlet temperature, pressure, volumetric flow and void fraction are measured for each test section. Fuel element sheath temperatures are measured around the inside circumference of the test bundle and along the length of the test section.

Experiments are conducted in RD-14M to gain an improved understanding of the thermalhydraulic behaviour of a CANDU during loss-of-coolant accidents, under forced and natural circulation conditions, and during shutdown scenarios. The data collected from this facility are used to identify and examine phenomena observed in the heat transport system and forms a database for use in developing and validating computer models used to predict CANDU behaviour.

Integral experiments have been performed in loops of increasing size starting with RD-4 (1974), then progressing to RD-12 (1976 to 1983), to the full-height single-channel-per-pass RD-14 loop (1984-1987), and finally to the current RD-14M loop (commissioned in 1988). Each of these pressurized-water loops contains the essential geometric and physical characteristics of a CANDU heat transport system. The RD-14M loop is shown schematically in Figure 1.1, and a

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CANDU® is a registered trademark of Atomic Energy of Canada Limited (AECL) loop layout is provided in Figure 1.2. Table 1.1 compares the characteristics of this facility and those of a typical CANDU reactor.

This report is a detailed description of the RD-14M facility. It includes the philosophy of the RD-14M design, detailed diagrams, and tables of specific facility characteristics. To clarify certain aspects of CANDU related research, some of the CANDU systems features will also be discussed.

The present report is a revision to the original facility description [1.1] to reflect ongoing modifications to the facility, and to address the need for more flexible and comprehensive loop documentation. The present report is designed as a "living" document, so that when new features are added to the facility, only the relevant sections of this document need be revised and reissued.

1.100 BACKGROUND - FEATURES OF THE CANDU REACTOR DESIGN

The salient features of the CANDU reactor system are depicted in Figures 1.3 to 1.5. A low-pressure, heavy-water moderator is held in a calandria vessel through which channels containing fuel bundles pass (Figure 1.3). These channels are made of two concentric tubes - the calandria and pressure tubes - with an insulating gap of inert gas between them. This assembly is necessary to reduce heat transfer to the moderator fluid, which is at low temperature and pressure (nominally 65°C and 20 kPa (g)), from the coolant circulating through the pressure tubes, which is at high temperature and pressure (nominally 300°C and 10 MPa (g)). Pressure tubes are about 6-m long and 100-mm inside diameter, and they contain 12 or 13 fuel bundles. The bundles are 500-mm long and consist of 28 or 37 fuel elements (depending on the reactor) held together by end plates. A 37-element bundle is shown in Figure 1.4.

Heat generated in the CANDU reactor core is removed by the primary coolant and transported to the steam generators where it is rejected to the secondary coolant to produce steam, which drives the turbine-generator set. A simple schematic diagram of the primary and secondary circuits in the CANDU reactor cooling system is shown in Figure 1.5. The CANDU system has several distinguishing features:

(1) The natural uranium is contained in physically separate horizontal channels in the reactor core. The fittings at the ends of these channels allow for on-line refuelling of the reactor.
(2) Coolant is distributed to, and collected from, the individual fuel channels in the nuclear reactor core by feeders that are connected to common headers.
(3) The primary heat transport circuit is built in the form of a figure-of-eight loop, with two core passes per loop.
(4) Emergency coolant is supplied to all headers in the event of a loss-of-coolant accident (LOCA) resulting from a break in the cooling circuit.

1. INTRODUCTION

1.200 DESIGN PHILOSOPHY

RD-14 was designed and constructed starting in 1981. Due to funding limitations, the RD-14 reference design chosen was two, 5.5-MW, 37-element channels (i.e., one channel per pass), with 1:1 scaling of vertical distances throughout the loop. This determined the sizing of the piping and various components (e.g., steam generators, pumps, headers). The values for various loop parameters dictated by the choice of reference design were:

- maximum thermal power per pass: 5.5 MW
- maximum surface heat flux per pass: 590 kW/m
- rated flow rate (one 37-element channel): 24 kg/s

The modification of RD-14 to RD-14M provides for the study of the interaction of multiple heated channels in parallel in a full-height loop. As described in Appendix A, five, 7-element heated sections per pass were chosen to replace the single, 37-element heated channel. The cross-sectional area of the associated below header pipework was scaled at 7:37 to preserve heat and mass fluxes in the multichannel facility.

The design of each of the loop components is described separately in later sections.

As noted in Reference [1.2] and Appendix A, the large number of non-dimensional groups to be considered precludes the scaling of two-phase flow dynamics with complete similarity. However, if the model is made of a similar solid material and has a similar fluid under the same system pressures as the prototype, scaling is simplified. Reference [1.3] (reprinted in Appendix A) presents an appropriate set of similarity criteria to be used under such conditions. Using 1:1 scaling of vertical elevations and axial lengths simplifies the scaling of the facility.

It is appropriate to choose the piping diameters such that the flow velocities will be scaled 1:1. This ensures that the characteristic transit times will be approximately equal in both the facility and the reactor.

A more detailed discussion of the scaling rationale, design philosophy, and influence of scaling on experimental results can be found in Appendix A.

In RD-14M, consideration was given to the following experimental program in the design of the loop, the loop peripherals, and the loop instrumentation:

(a) Safety-Type Transients

Conventional primary blowdown and cold-water injection tests in which important experimental parameters include:

- break size and location
- initial conditions
- power history
- number of parallel channels
- channel elevation
- secondary-side cooldown rate
- effect of noncondensible gas on the cold-water injection phase, and
- effect of the primary pump speed.

(b) Process Dynamics and Control-Type Transients

(i) Primary heat transport system (PHTS) flow stability tests, including:

- the flow stability map as a function of power input, pump speed and system pressure,
- an assessment of control schemes intended to limit oscillatory response to a process upset,
- the effect of parallel channels, and
- the effect of the pressurizer/surge tank.

(ii) Tests to investigate the density-driven flow characteristics of the loop, including:

- full and partial inventory testing,
- the effect of the pressurizer/surge tank,
- the effect of noncondensible gases, and
- the effect of secondary-side pressure and temperature.

(iii)Pump rundown transients

(iv)Secondary-side feedwater interruptions

(c) Component-Type Transients

Extensive instrumentation on the primary and secondary sides of the loop permits in-situ assessment of component behaviour such as:

- transient behaviour of the secondary-side cooling circuit, and
- transient pump behaviour in a piping configuration representative of a CANDU reactor.

1. INTRODUCTION

1.210 End-Fittings

The purpose of the end-fitting in a CANDU reactor is to allow access to the fuel for on-power fuelling. The end-fittings consist of a shield plug and liner flow annulus contained within a body tube. The RD-14M end-fitting shield plug and liner flow annulus are sized to the reactor flow annulus through the 7:37 ratio. The RD-14M end-fitting simulator is also designed to reproduce the differential pressure and scaled thermal mass of the reactor end-fitting.

1.220 Header Interconnects

Most CANDU reactors have the outlet headers connected by an interconnect line to mitigate oscillatory behaviour under two-phase conditions.

RD-14M interconnects are designed for simulating both Darlington and CANDU-6 interconnects. The Darlington interconnect is dynamically scaled based on resistances, while the CANDU-6 interconnect is geometrically scaled in the same way as other RD-14M primary pipework (pipe length and elevation change are preserved, while the pipe diameter is scaled down).

1.230 Fuel Element Simulators

The RD-14M fuel element simulators (FES) are designed to model CANDU natural uranium fuel in power density or heat flux, and in heat capacity or heat-up rate.

1.240 Feeder Piping

Piping between the heated sections and the headers was modeled to represent specific feeders in the Darlington reactor. Five reactor channel/feeder geometries were selected, representing one top channel, three middle channels, and one bottom channel. Below are the representative feeders:

- Heated Section HS5 and HS10 Feeders:
  The feeder layout and heated section elevation were based on Darlington channel B10.
- Heated Section HS6 and HS11 Feeders:
  The feeder layout and heated section elevation were based on Darlington channel L2.
- Heated Section HS7 and HS12 Feeders:
  The feeder layout and heated section elevation were based on Darlington channel M11.
- Heated Section HS8 and HS13 Feeders:
  The feeder layout and heated section elevation were based on Darlington channel O5.
- Heated Section HS9 and HS14 Feeders:
  The feeder layout and heated section elevation were based on Darlington channel X12.

1. INTRODUCTION

1.300 GENERAL DESCRIPTION OF THE RD-14M LOOP

The RD-14M loop, shown schematically in Figure 1.1, is a figure-of-eight, full-elevation representation of a CANDU reactor PHTS capable of operating at reactor typical temperatures and pressures. The loop began operating in 1988 at Whiteshell Laboratories. While the loop configuration is similar to a figure-of-eight geometry of a typical CANDU circuit, it is not intended to be a scale model of any particular reactor. The intent is to reproduce the important geometric features of a reactor primary heat transport system and the appropriate operating conditions (e g., fluid pressure, temperature).

Features of the loop include:

(1) Variable geometry: the loop piping is assembled using Grayloc hubs, thereby allowing rapid changes in the heat transport system geometry.

(2) Provision of ten full-length channels, each containing seven electrically heated rods, simulating fuel rods. The fuel rod simulators, which have uniform heat flux distribution, have a heat capacity and surface heat flux similar to that of reactor fuel. Four independent power supplies each provide a maximum of 2.75 MW to two or three heated sections. There is provision to blank off all but one channel per pass.

(3) Provision of two full-height steam generators. The steam generators are of the recirculating U-tube type complete with internal preheaters and cyclone steam separators like many of the CANDU power reactor units.

(4) Provision of two high-head primary circulating pumps. The RD-14M pumps are single-stage, bottom suction, centrifugal pumps with single discharge volutes. The pumps are driven by alternating-current induction motors with variable speed drives, which allow the pump speed to be controlled over the full range of 0 to 3600 rpm. This eliminates the need for flow control valves and permits simulation of pump rundown by controlling the impeller speed.

(5) An emergency coolant injection (ECI) system, and fast-acting valves on various discharge lines, permit testing over the entire LOCA sequence (blowdown, transition cooling, and long-term cooling phases). Both pumped and accumulator ECI systems are available.

(6) Provision of low and high power secondary sides (the low power system gives better secondary-side control during low power tests).

1. INTRODUCTION

1.400 REPORT CONTENTS

This report describes the RD-14M facility in detail.

The primary heat transport system is discussed in Chapter 2, and includes the primary system piping (feeders, above header piping, and header interconnects), test sections (fuel element simulators and end-fittings), headers, steam generators, and pumps.

The secondary heat transport system is discussed in Chapter 3, and includes the secondary system piping, steam generators, jet condenser, pumps, heat exchangers, and the operation and control of the secondary system.

The emergency coolant injection (ECI) system is discussed in Chapter 4, and includes information on each of the different modes of ECI: high-pressure accumulator, high-pressure pumped, simulated high-pressure pumped, low-pressure recovery, and gravity feed.

Auxiliary systems are discussed in Chapter 5, and includes the surge tank, drain system for natural circulation tests, blowdown system, loop insulation, trace heating, make-up water addition systems, and event sequencer.

All instrumentation and the data acquisition system are discussed in Chapter 6. The different types of instrumentation for the primary and secondary systems, as well as the ECI and other auxiliary systems are discussed, and a list of all instrument devices is given.

Special case instrumentation is discussed in Chapter 7. This chapter will be used to discuss instrumentation added to RD-14M for future experimental campaigns.

Characterization of loop components is discussed in Chapter 8, and includes characterization of orifices, turbine flowmeters, end-fittings, inlet headers, and pumps, as well as discussing overall flow resistances, overall heat losses, and the zero and span shift of Rosemount differential pressure cells.

The design rationale, or scaling, of the RD-14M facility is discussed in Appendix A. Additional schematics and engineering drawings are given in Appendix B. Fuel element simulator (FES) thermocouple locations are given in Appendix C (this appendix will be updated any time an FES is rebuilt). The fast-fill, degas, and electrical systems are discussed in Appendices D, E, and F, respectively.

This report is set-up so that revisions can easily be made. Revision numbers are reported on the bottom of each page, and changes are noted in the table on page iv at the front of this report.

Lastly, the symbols used in the numerous schematics in this report follow the legend of symbols shown in Figure 1.6.

1. INTRODUCTION

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1. INTRODUCTION

TABLE 1.1

COMPARISON OF CHARACTERISTICS OF RD-4, RD-12, RD-14 AND RD-1M WITH THOSE OF A TYPICAL CANDU REACTOR

Characteristic	RD-4	RD-12	RD-14	RD-14M	Typical Reactor
Operating Pressure (MPa)	4.5	10	10	10	10
Loop Volume (m^3)	0.053	0.34	0.95	1.01	60
Heated sections:	directly heated tube	directly heated 7-rod bundle	indirectly heated 37-rod bundle	indirectly heated 7-rod bundle	nuclear fuel 37-element bundle
Number per pass	1	1	1	5	95
Length (m)	1.5	4	6	6	12 x 0.5
Rod Diameter (mm)		15.2	13.1	13.1	13.1
Flow Tube ID (mm)	21	51.7	103.4	44.8	103.4
Power (kW per channel)	100	1000	5500	3 x 750, 2 x 950	5410*
Pumps:	single stage	single stage	single stage	single stage	single stage
Impeller Diameter (mm)	153	356	381	381	813
Rated Flow (kg/s)	0.47	6	24	24	24*
Rated Head (m)	43	140	224	224	215
Specific Speed	760	319	565	565	2000
Steam Generators:	U-tube	recirculating U-tube	recirculating U-tube	recirculating U-tube	recirculating U-tube
Number of Tubes	1	42	44	44	37*
Tube ID (mm)	18.8	10.7	13.6	13.6	14.8
Secondary Heat-Transfer		7.99	41	41	32.9*
Secondary Volume (m^3)		0.23	0.9	0.9	0.13
Elevation Difference, Heated Section to top of U-tubes (m)	8	9.6	21.9	21.9	21.9

* - average per channel

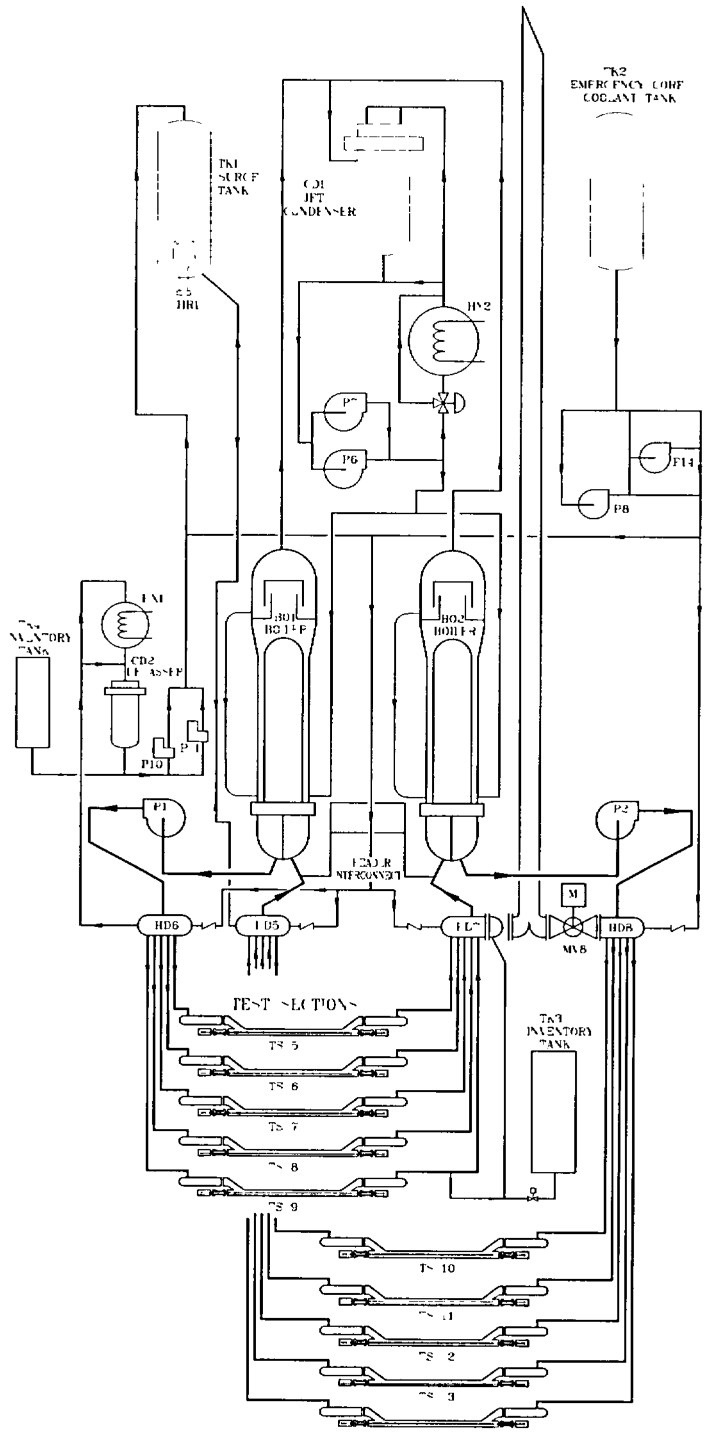

FIGURE 1.1: RD-14M Loop Schematic

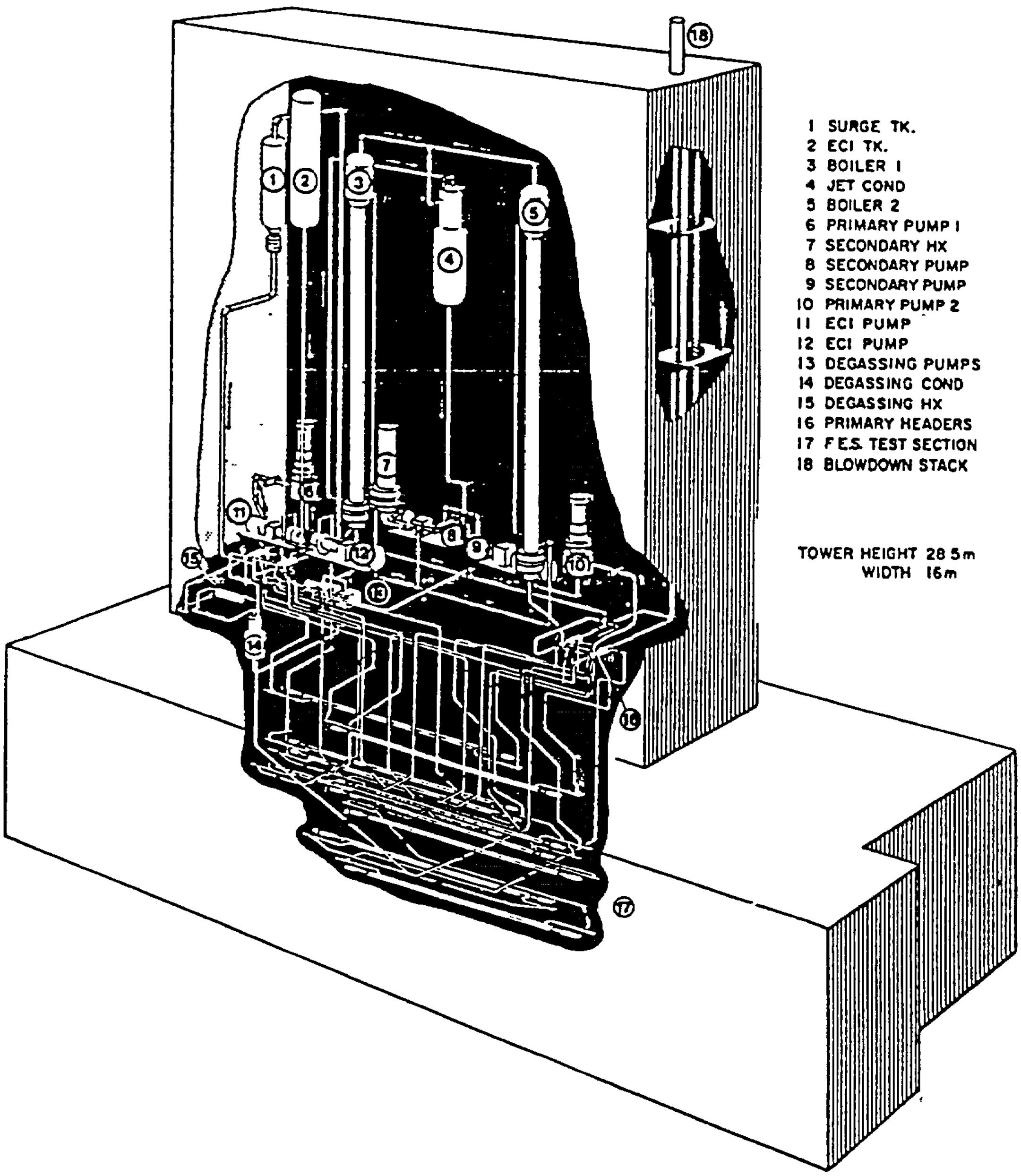

FIGURE 1.2: RD-14M Loop Layout

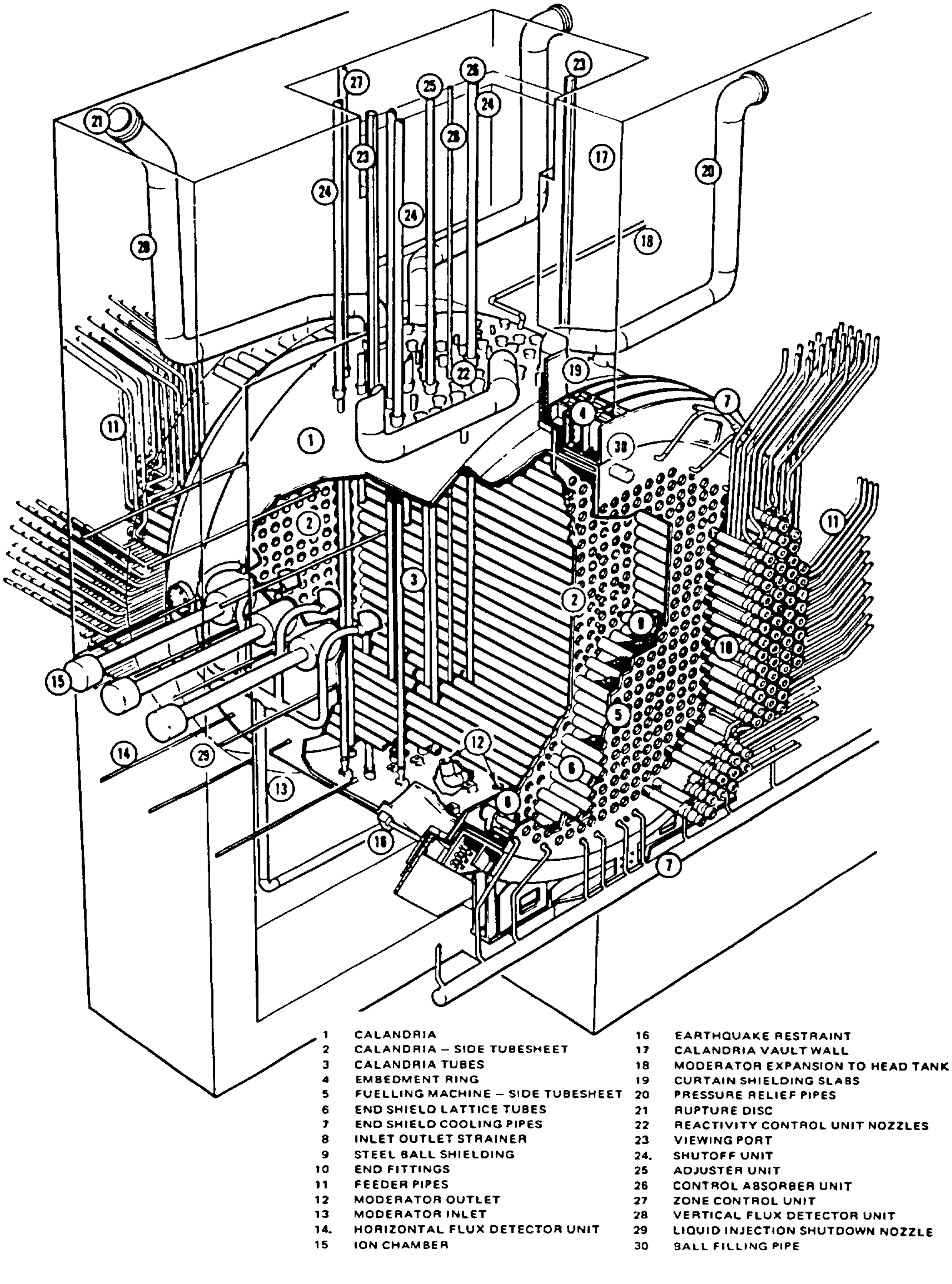

FIGURE 1.3: CANDU Reactor Assembly

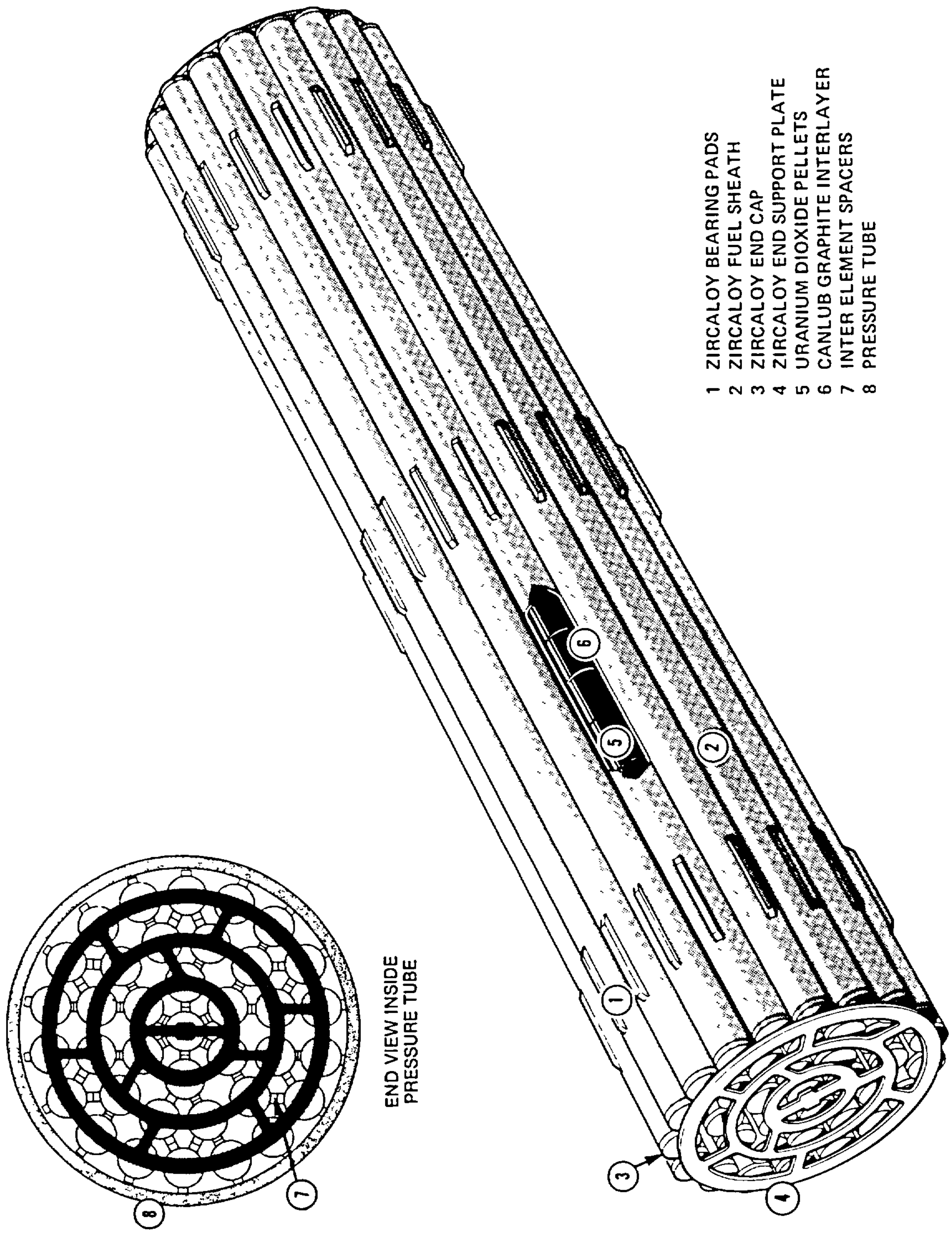

FIGURE 1.4: 37-Element Fuel Bundle for a CANDU Reactor

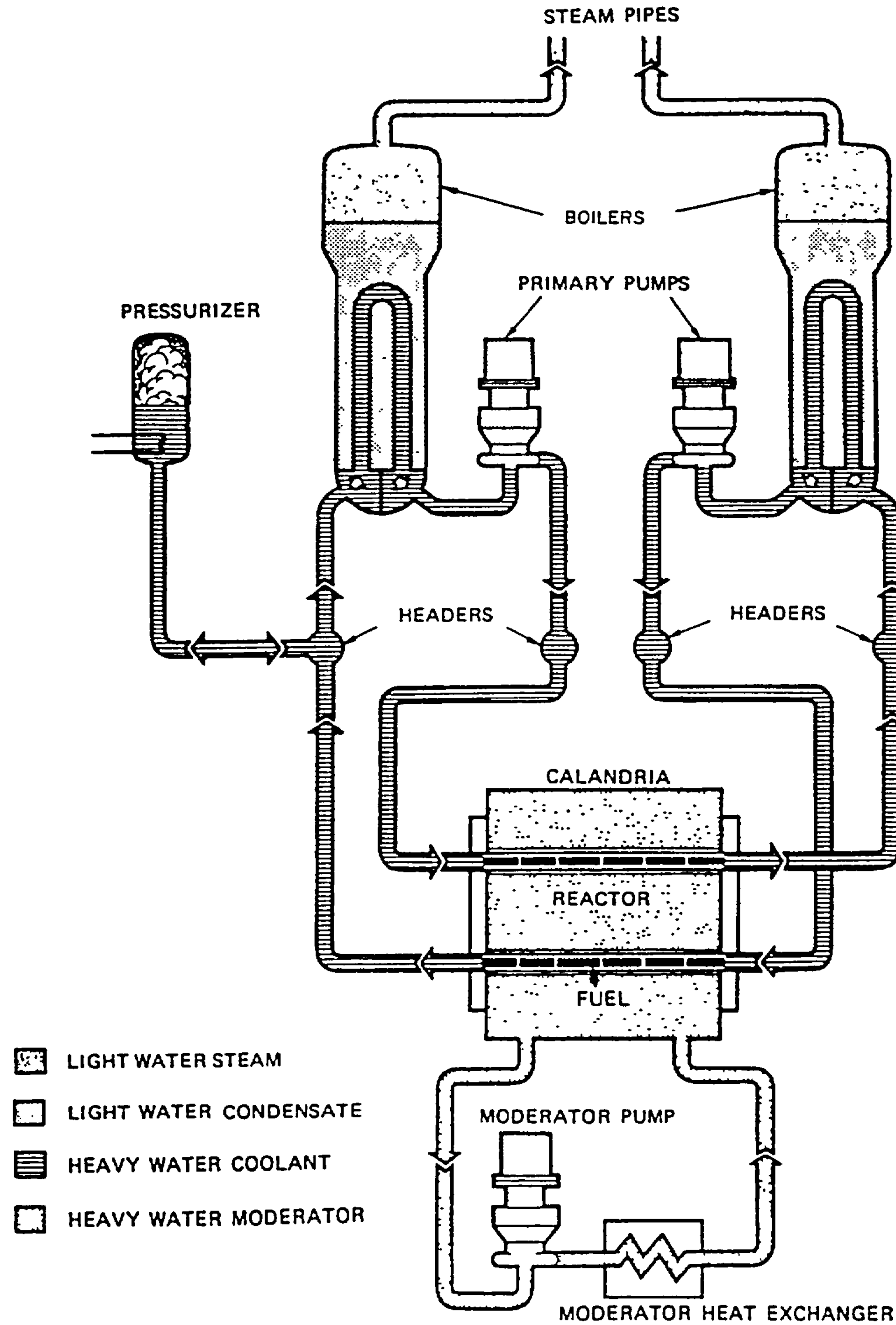

FIGURE 1.5: CANDU Primary Heat Transport System Schematic

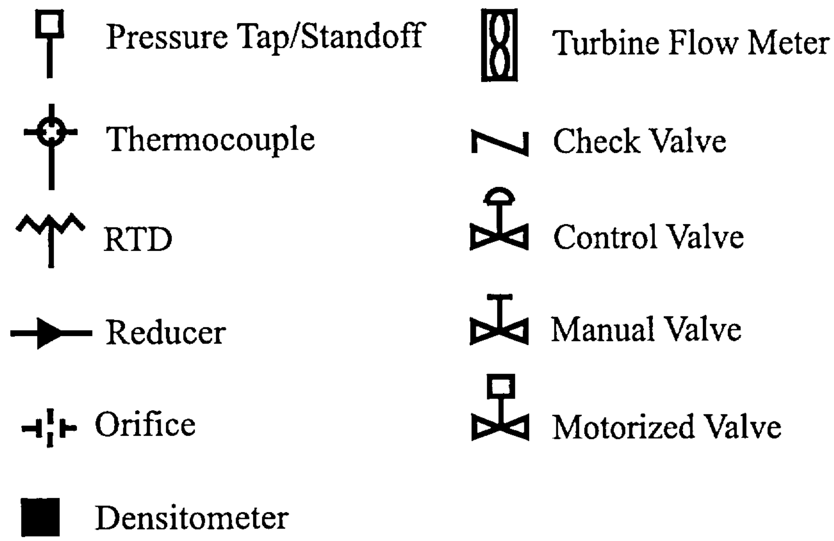

FIGURE 1.6: Symbols Used in Facility Description Drawings/Schematics

2. PRIMARY HEAT TRANSPORT SYSTEM

2. PRIMARY HEAT TRANSPORT SYSTEM

The RD-14M primary heat transport system is comprised of piping (inlet and outlet feeders, piping from the headers to the steam generators, header interconnect), the test sections (fuel element simulators, end-fittings, pressure tubes), headers, steam generators, and pumps. Each of these components is discussed in detail in the sections to follow.

2.100 PRIMARY SYSTEM PIPING

All RD-14M primary circuit piping is made from ASTM A106 Grade B carbon steel. Components and spool pieces are assembled using Grayloc hubs for ease of handling and for a good closure seal. Long-radius elbows are used to minimize hydraulic losses. The fittings are all butt welded, followed by a visual inspection and a hydrostatic test to 18.75 MPa (g).

2.110 Inlet and Outlet Feeders

Piping between the heated sections and the headers was modeled to represent Darlington Nuclear Generating Station (NGS) feeders. Five reactor channel/feeder geometries were selected, representing one top channel (B10), three middle channels (L2, M11 and O5), and one bottom channel (X12).

Orifices are installed in some inlet feeder lines both in RD-14M and the reactor. These orifices control the division of flow among the parallel channels. Table 2.1 shows the size and location of the various orifices in the RD-14M feeders.

Elevation diagrams for each of the inlet and outlet feeders are shown in Figures 2.1-2.10. A summary of the inlet and outlet feeders for each of the heated sections is given in Table 2.2.

The inlet feeder of HS9 has a drain connection, as shown in Figure 2.9 (Station 12). A similar drain connection is installed on the inlet feeder of HS14 (Station 12 of Figure 2.10). These connections can be used to drain primary fluid to the inventory tank (TK3) during an experiment. A discussion of the drain tank (TK3) is given in Section 5.200. These drains are not typically used.

For single-channel-per-pass tests, unused channels are blanked off at the Grayloc connections near the headers (e.g., Stations 1 and 59 in Figure 2.1).

Instrumentation installed on the feeders includes thermocouples, differential and gauge pressure transducers, turbine flowmeters, gamma densitometers, and conductivity probes (on HS11 outlet feeder for some tests). Figures 2.1-2.10 give the locations of the various instrumentation sites. Details of the instrumentation are discussed in Chapter 6. Some of the instrumentation listed in the elevation diagrams have never been used.

2. PRIMARY HEAT TRANSPORT SYSTEM

Instrumentation was added specifically for tests using a new trace heating system on the outlet feeder of TS11 (see Section 5.500). This instrumentation is not included in the legend for Figure 2.4, rather it is discussed in Section 7.100.

2.120 Above-Header Piping

In RD-14M, the above-header piping, from the headers to the steam generators, includes the steam generator inlets, pump suctions, and pump discharges. The steam generator inlet and pump suction lines are constructed from 4-inch (nominal), schedule-80 pipe. The pump discharge lines are constructed from 3-inch (nominal), schedule-160 pipe, up to the turbine flowmeters, and 3-inch (nominal), schedule-40 pipe, between the turbine flowmeters and the headers.

Elevation diagrams of the piping between headers HDR5 and HDR6, and between headers HDR7 and HDR8, are shown in Figures 2.11 and 2.12, respectively. An overall schematic is given in Figure 2.13. With a few minor exceptions, the piping and instrumentation between headers HDR5 and HDR6 is symmetric to that between headers HDR7 and HDR8. The exceptions are as follows:

- Pipe wall surface thermocouples are installed on the steam generator BO1 inlet pipe (Station 9 on Figure 2.11), the pump P2 suction pipe (Station 29 on Figure 2.12), and on the pump P2 discharge pipe (Station 43 on Figure 2.12). These thermocouples are not duplicated on the opposite side of the loop.
- A pipe connects into the pump P2 suction line from the distilled water system (Station 25 on Figure 2.12) for filling the loop.
- The pump P2 discharge pipe contains an extra Grayloc fitting (Station 42 on Figure 2.12).

Instrumentation installed on the above-header piping includes pipe surface and fluid thermocouples, differential and gauge pressure taps, turbine flowmeters, and gamma densitometers. Details of the instrumentation are discussed in Chapter 6.

2.130 Outlet Header Interconnect

An isometric view of the RD-14M outlet header interconnect is shown in Figure 2.14. The Darlington NGS and CANDU-6 piping geometries are sufficiently different that two header interconnect lines are provided in RD-14M, as shown. The interconnects have a common takeoff point on the riser lines from the two outlet headers (Stations 1 and 50 in Figure 2.14), and are isolated from each other by the installation of appropriate Grayloc blanks at the tee junctions (Stations 10 and 33, or 35 and 42, in Figure 2.14).

The Darlington and common portions of the interconnect are constructed using 1-inch (nominal), schedule-80 pipe. The CANDU-6 portion of the interconnect, piping above Stations 10 and 33 in Figure 2.14, is constructed using 0.5-inch (nominal), schedule-80 pipe.

Flow restriction orifices are provided in both common lines (Stations 5 and 46) and midway on the Darlington line (Station 37), as shown in Figure 2.14. Standoffs are provided for the connection of differential pressure cells across each of the orifices. To provide a longer path length, two 'H' sections are included in the CANDU-6 line. Single-beam gamma densitometers can be installed at Stations 16 and 26. Details of the instrumentation are discussed in Chapter 6.

2.200 TEST SECTIONS

A test section in RD-14M consists of an electrically heated section (fuel element simulators), inlet and outlet end-fitting simulators, a pressure tube, and a strongback to provide support for the test section. Separate discussions of the test-section components are provided below.

Table 2.3 gives the elevation of each of the ten heated sections, as well as the nominal full flow rates and power.

2.210 Fuel Element Simulators

The fuel element simulators (FES) are capable of operating at heat fluxes of 0.75 MW/m^2 and sheath temperatures to 1000°C. The arrangement and numbering of the 7-element FES in the flow tube are shown in Figure 2.15.

Of the seven elements in each heated section, five are instrumented with type-K thermocouples, and the other two are uninstrumented. Each instrumented element contains six sheath and two centre-line thermocouples. The nominal location of each thermocouple within an FES is given in Figure 2.16. Appendix C gives the actual location of each FES thermocouple.

Each RD-14M FES consists of a central core of magnesium oxide that is surrounded by a 7.62-mm (OD), electrically-heated Inconel-625 tube (all dimensions are given after swaging). This tube is insulated from a 13.18-mm (OD), type-304 stainless-steel sheath by an annulus of boron nitride, as shown in Figure 2.17. Table 2.4 gives the thermophysical properties of the materials. Each FES element is divided into 12 heated sections, 495-mm long, separated by short unheated sections to simulate reactor fuel bundles (see Figure 2.17). The end-plates are simulated by Inconel-750 clips, which hold the bundle together at the unheated points (see Figure 2.18). A small Chromel spiral-spacer wire is brazed to each heated region to maintain pin spacing. Small stainless-steel longitudinal spacer wires act as bearing pads to support the bundle away from the flow tube. Water-cooled O-ring seals on the ends of each heater pin allow for differential thermal expansion due to a temperature difference of up to 800°C across the elements.

2.211 Power Supplies Controllers

Electrical power to the ten heated sections is controlled through four model 233400 Research Inc. direct current power supplies. The maximum capacity of each power supply is 431 V at 6875 A direct current (total power of 2963 kW per power supply). Table 2.3 lists the nominal full power for each heated section. The power supplies can be controlled in manual or automatic mode.

In the manual mode, heater power is controlled via a ten-turn potentiometer (mounted on the control panel).

Two automatic controllers have been used. Originally a Research Inc. 61011 process controller was used, and was replaced in 1996 July with a Love model 2600 process controller.

The Research Inc. controllers were proportional-integral-derivative (PID) units. Total load power, load voltage, or load current was used as a feedback signal to each process controller. These controllers allowed for two set-points. Typically these were set at full and decay power levels. The same PID settings were used at both set-points, compromising the quality of the resulting control action.

The Love controllers are also PID units, and use total load power, load voltage, or load current as a feedback signal to each process controller (load power is typically used). These controllers can be programmed to have four separate set-points, along with unique PID settings for each set-point. Step changes between set-points (e.g., for power pulses or step-backs) can be initiated remotely using the event sequencer (see Section 5.700). The power supply/controller system exhibits a second-order response to a step change in set-point. Dynamics of the transient, including degree of damping, depend on actual PID settings.

2.212 Trip Coverage

The heated sections are protected by a multiple input alarm annunciation and trip system. This system monitors FES sheath temperatures, inlet and outlet feeder temperatures, heated section O-ring temperatures, and cooling-water low-flow switches. The temperature set-points are set by the operators and the low-flow instruments are switches that are either on or off. Any high inlet, outlet, or O-ring temperature will trip the power supplies; typically, any two of the nine sheath temperatures, measured at the ends of the heated test sections, going high will cause the power supplies to trip; and any flow switches indicating low flow will trip the power supplies.

2.220 End-Fitting Simulators

In RD-14M, the end-fitting simulators are offset from the heated sections to accommodate in-line electrical connections to the fuel element simulators. 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).

Construction details of the end-fitting simulator are provided in Figure 2.19, and the interior details are provided in Figure 2.20. The RD-14M end-fitting simulator consists of four basic components:

1) End-Fitting Body

   The end-fitting body is constructed from a seamless 88.9-mm (OD), 76.2-mm (ID), 1330-mm long (overall), carbon-steel tube, as shown in Figure 2.19. An end cap seals the end-fitting body at one end. The other end of the end-fitting contains a nominal 3-inch Grayloc fitting that connects the end-fitting body to a lateral pipe welded to the pressure tube. A feeder nozzle, consisting of a nominal 1.5-inch Grayloc fitting, is welded to the end-fitting body. The angle the feeder connects to the end-fitting is either 32° or 58° (relative to horizontal), depending on the heated section. The note in Figure 2.19 indicates the angle for each feeder. The feeder elevation drawings, Figures 2.1 to 2.10, also indicate the connection angle. The end-fitting shown in Figures 2.19 and 2.20 is oriented to make a 32° connection with the feeder. For feeders with a 58° connection, the outer-body tube is be rotated at the 3-inch Grayloc fitting.

2) Liner Tube

   The liner tube is a 60.3-mm (OD), 54.8-mm (ID), 1250-mm long, type-316 seamless stainless-steel pipe. A coupling, located near the end cap, holds the liner tube centred within the end-fitting body. The liner tube also connects to the lateral pipe near the location of the 3-inch Grayloc fitting. The liner-tube has a set of holes located at one end. These holes consist of three sets of axially-spaced holes (21.5-mm diameter) equally spaced around the liner-tube circumference (120° apart), as shown in Figure 2.20.

3) Shield Plug

   The shield plug is located at the heated-section end of the end-fitting, in the vicinity of the 3-inch Grayloc fitting. This component is made from a 54-mm diameter, 350-mm long carbon steel bar. The shield plug contains four symmetric flow passages located 90° apart.

4) Lateral Pipe

This component connects the end-fitting body to the pressure tube. The lateral pipe connects to the pressure tube at a 45° angle, 205 mm from the end of the pressure tube. The lateral pipe consists of a 45° elbow, a reducer, and a short pipe length.

The RD-14M end-fitting simulator is offset horizontally from the pressure tube to allow for the electrical power connections to the heated section. Referring to Figure 2.19, the end-fitting has the following connections:

- a nominal 1.5-inch, schedule-40, Grayloc feeder nozzle (regardless of the feeder pipe size - 1-, 1.25-, or 1.5-inch),
- 0.5-inch drain connections to both the dead-space and the annulus;
- a 0.5-inch vent connection to the dead-space; and
- pressure and temperature taps in the end-fitting dead-space.

The instrument device codes for the pressure taps and the temperature connections are given in Figures 2.1 to 2.10. Although the instrument sites exist, instrumentation may not be connected to all sites

The flow path for an inlet end-fitting is through the feeder nozzle, along the annulus between the liner tube and the end-fitting body, through the liner-tube holes into the shield plug, and through the four holes in the shield plug into the lateral pipe connecting the end-fitting to the pressure tube. The flow direction is reversed for an outlet end-fitting. A dead-space volume exists that is enclosed by the shield plug, the end cap, and the liner tube.

The orientation of the shield plug with respect to the liner-tube holes varies among all the RD-14M end-fittings. The orientation shown in Figure 2.20 is only an example. The actual orientation for each end-fitting is unknown.

The inside diameter of the liner tube is 54.8 mm, and the outside diameter of the shield plug is 54.0 mm. Thus there is a 0.4-mm gap between the liner tube and the shield plug. This means there is a flow path between the dead-space volume and the heated channel.

The total volume of each RD-14M end-fitting simulator is approximately 5 L. This includes 3 L of fluid in the dead-space volume, and 2 L of fluid in the annulus and between the shield plug and the entrance to the pressure tube. The total metal mass of the end-fitting is 33.1 kg.

2.230 Pressure Tubes

The test-section pressure tubes are constructed from 6.3-m long, 57.2-mm (OD) ASTM type-316, stainless-steel tubes that are honed out to 44.8 mm (ID). The pressure tubes are designed to a maximum operating pressure and temperature of 12.5 MPa (g) and 350°C.

2.240 Strongback

As shown in Figure 2.21, each pressure tube is enclosed in a strongback. The strongback prevents the pressure tube from bowing due to differential thermal expansion between the top and the bottom of the tube during an experiment. The strongback is also used to protect the heated sections while being handled. Vermiculite loose-fill thermal insulation between the strongback and the pressure tube minimizes heat losses.

2.300 HEADERS

A standard criterion for scaling reactor headers does not exist. The RD-14M headers, shown schematically in Figures 2.22 to 2.25, were sized based on compromises between physical considerations (i.e., flow path, feeder orientation, thermal mass, fluid volume, and instrumentation requirements) and practical limitations (i.e., provincial pressure vessel code standards and room size). The headers are fabricated from 1-m long, 8-inch (nominal), schedule-80 (12-mm wall thickness) carbon-steel pipes. This configuration allows the investigation of both axial and transverse effects.

The five feeder nozzles on each header are positioned at angles typical of the nozzles on the Darlington NGS headers (two horizontal, two 36° down from horizontal, and one 72° down from horizontal). A 1.5-inch (nominal) nozzle is provided at one end of each header for emergency coolant injection (ECI). A 3-inch (nominal) nozzle is provided on the top of each inlet header for connection to the pump discharge, and two 4-inch (nominal) nozzles are provided on each outlet header (one on the top for the boiler inlet, and one on the side, 15° up from the horizontal, for the relief valve). Provisions are made for the following: 2 water-cooled pressure taps, 1 resistance temperature device (RTD) tap, and 2 thermocouple taps.

One end each of outlet header HDR7 and inlet header HDR8 can be connected either to an end cap or a fast-acting ball valve. The end caps, shown in Figure 2.26, include provision for instrumentation such as thermocouples or conductivity probes. The two sizes are designed to contain the same fluid volume. The two different diameters are required to accommodate other equipment located near the headers.

For blowdown experiments, a 6-inch (nominal) or 2-inch (nominal) ball valve replaces the end cap on outlet header HDR7 or inlet header HDR8. This ball valve is incorporated into the design of the header with a minimum possible change in the header volume (see Figure 5 4).

In partial-inventory natural circulation experiments, fluid can be drained from the loop via a drain valve provided on header HDR7 (Station 7, Figure 2.24). See also Section 5.200 and Figure 5.3.

In steam generator condensation tests, inventory is discharged from header HDR8, through a connection on the end cap. The end caps are shown in Figure 2.26. See also Section 5.200 and Figure 5.3.

Detailed engineering drawings of the RD-14M headers are provided in Appendix B.

2.400 STEAM GENERATORS

Each steam generator used in a CANDU reactor consists of an inverted vertical U-tube bundle installed in a shell. The steam-separating equipment (i.e., steam separators and dryers) are housed in the upper end of the shell.

The RD-14M steam generators were scaled approximately 1:1 with reactor steam generators in terms of individual tube diameter, mass flux, and heat flux. This results in primary-side and secondary-side conditions (temperatures and pressures) very similar to those in a reactor. Reactor steam generator parameters are compared to those of RD-14M in Table 2.5. This section will describe the primary side of the RD-14M steam generators. The secondary side is described in section 3.200.

The RD-14M steam generators were manufactured by Versatile Vickers, and are shown in Figure 2.27. Each vessel consists of a vertical, carbon-steel shell, 12 m in length overall, with a bolted flange closure. The volume of each inlet and outlet plenum is 25.7 L. The forty-four U-tubes are made of Incoloy-800 and have a outside diameter of 15.88 mm and a wall thickness of 1.13 mm. The design heat-transport removal capacity of each steam generator is 5.5 MW at a primary-side flow rate of 24 kg/s. The maximum operating pressure of the primary side is 10 MPa (g) at an inlet temperature of 309°C.

Primary-side instrumentation provided in the steam generators includes pressure taps and thermocouples in the plena and the U-tubes. Figure 2.28 provides tube numbering details and indicates which tubes are instrumented. Figures 2.29 and 2.30 provide the locations of the primary-side tube temperature and pressure measurements (secondary-side steam generator thermocouple locations are shown in Figure 3.10). Other primary-side instruments are shown in Figure 2.27. All of the primary-side steam generator instruments are also listed in Table 6.1.

The lengths and heights of the U-tubes are given in Table 2.6.

Over time, some U-tubes have developed leaks around the penetrations of instruments. These tubes have been subsequently plugged as they cannot be repaired. Memoranda are issued any time a tube is plugged, and all tube plugs are indicated in the electronic database [2.1].

2.500 PRIMARY PUMPS

Current CANDU reactor designs utilize from four to twelve heat transfer pumps per reactor. In each case, these pumps are vertical, single-stage, single-suction centrifugal pumps. Single discharge is the most common pump-type used.

For the fluid dynamics to be modeled completely, the RD-14M primary pumps (P1 and P2) should have the same specific speed as a typical reactor pump. The pump head and flow rate in RD-14M are required by loop scaling to be 220 m and 24 kg/s, respectively. Thus, for matching of specific speeds, the RD-14M primary pumps would be required to operate at shaft speeds in excess of 15 000 rpm. Since this is not practical, the RD-14M primary pumps do not represent a reactor pump with complete similitude. Primary heat transport pumps for some CANDU stations are compared to the RD-14M pumps in Table 2.7.

Bingham vertical, single-stage, bottom-suction, centrifugal pumps with single-discharge volutes were selected for RD-14M. The volume of the volute, with impeller installed, is 16.85 L. The pumps are illustrated in Figure 2.32. The pumps are driven by alternating-current induction motors with variable speed drives, which allow the pump speed to be controlled over the full range of 0 to 3600 rpm. This eliminates the need for flow control valves and permits simulation of pump rundown by controlling the impeller speed.

External heat exchangers provide cooling to the pump seal and bottom main bearing at a flow rate of 0.27 L/s and a temperature of 24°C. The Kingsbury vertical-thrust-bearing assembly, and the radial top and bottom ball bearings, are cooled by a separate cooling water connection with a maximum temperature of 24°C at a flow of 0.3 L/s.

2.510 Pump Speed Control

The primary pumps are controlled either manually or automatically. In manual mode (typical use), the pump speed of each pump is independently controlled using the pump speeds (rpm) as the feedback signals. In automatic mode (not typically used), feedback from the primary flows (1F and 2F) control the pump speed to maintain pre-set flows.

2.520 Pump Rundown Controller

A signal generator may be used to rundown the pumps in simulation of a reactor primary-pump rundown. The signal generator is switched in when needed, and is used in place of the controller discussed in Section 2.510.

Rundown transients for the RD-14M pumps and for a typical reactor primary pump are shown in Figure 8.6.

REFERENCE

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

2. PRIMARY HEAT TRANSPORT SYSTEM

TABLE 2.1

FEEDER FLOW-BALANCING ORIFICES

Heated Section Number	Component Label for Orifice Site	Orifice Throat Diameter[1] (mm)	Pipe Internal Diameter (mm)	Figure Number	Station Number
HS5	OR9	15.13	26.64	2.1	5
HS6	OR10	15.64	26.64	2.3	5
HS7	OR11	n/a[2]	35.05	2.5	5
HS8	OR12	23.50	35.05	2.7	5
HS8	OR14	n/a[2]	40.89	2.7	56
HS9	OR13	n/a[3]	40.89 to 26.64 reducer[3]	2.9	1
HS10	OR15	15.13	26.64	2.2	5
HS11	OR16	15.67	26.64	2.4	5
HS12	OR17	n/a[2]	35.05	2.6	5
HS13	OR18	23.46	35.05	2.8	5
HS13	OR20	n/a[2]	40.89	2.8	56
HS14	OR19	n/a[3]	40.89 to 26.64 reducer[3]	2.10	1

[1] Orifice diameters taken from AECL Drawing A2-60W15-1.
[2] Orifice not installed at this site; therefore, full pipe diameter through Grayloc fitting.
[3] Orifice site located in a Grayloc/Reducer; however, no orifice is installed at this location.

TABLE 2.2

HEATED SECTIONS NOMINAL FEEDER SIZES

Heated Section Number	Elevation Diagram Figure Number	Nominal Pipe Size for Inlet Feeder[1] (inches)	Nominal Pipe Size for Outlet Feeder[1] (inches)
HS5	2.1	1	1.25
HS10	2.2	1	1.25
HS6	2.3	1	1.25
HS11	2.4	1	1.25
HS7	2.5	1.25	1.5
HS12	2.6	1.25	1.5
HS8	2.7	1.25	1.5
HS13	2.8	1.25	1.5
HS9	2.9	1	1.25
HS14	2.10	1	1.25

[1] All pipe sizes are made from schedule-40 carbon-steel pipe.

TABLE 2.3

HEATED SECTIONS PARAMETERS

Heated Section Number	Elevation (m)	Nominal Full Flow (kg/s)	Nominal Full Power (kW)
HS5	6.51	4.3	750
HS6	3.96	4.3	750
HS7	3.66	5.5	946
HS8	3.11	5.5	946
HS9	0.48	4.3	750
HS10	6.51	4.3	750
HS11	3.96	4.3	750
HS12	3.66	5.5	946
HS13	3.11	5.5	946
HS14	0.48	4.3	750

TABLE 2.4

THERMOPHYSICAL PROPERTIES OF FES COMPONENT MATERIALS

k - Thermal Conductivity (W/m·K)					
Temperature (°C)	BN[1]	Inconel 625	Nickel 200	MgO	Stainless Steel 304
100	15.4	10.9	67	9.6	16.2
200	14.5	12.4	62	8.5	17.9
300	13.5	13.9	57	7.1	19.3
400	12.3	15.4	56	5.9	20.8
500	11.3	16.9	58	4.8	22.2
600	10.3	18.4		3.9	23.6
700	9.3	19.9		3.2	25.0
800	8.3	21.6		2.4	26 3
900	7.4	23.4		1.9	
1000	6.6	25.6		1.5	
α - Thermal Diffusivity [mm^2/s]					
Temperature (°C)	BN[1]	Inconel 625	Nickel 200	MgO	Stainless Steel 304
100	7.21	3.02			4.04
200	5.66	3.24		2.4	4.25
300	4.71	3.44		1.9	4.46
400	3.92	3.62		1.5	4.67
500	3.33	3.78		1.2	4.91
600	2.85	3.93		0.97	5.13
700	2.44	4.08		0.79	5.36
800	2.06	4.24		0.59	
900	1.75	4.45		0.46	
1000	1.51	4.70		0.36	
ρ - Density [kg/m^3]					
	BN[1]	Inconel 625	Nickel 200	MgO	Stainless Steel 304
	2010	8440	8890	3590	7900

[1] Boron Nitride

TABLE 2.5

STEAM GENERATOR COMPARISON

Parameter	BRUCE B	CANDU-6	RD-14M
Tube Outside Diameter (mm)	12.96	15.9	15.9
Tube Wall Thickness (mm)	1.13	1.13	1.13
Primary Mass Flux ($kg/m^2 \cdot s$)	3 750	4 215	3 750
Heat Flux (kW/m^2)	120	165	130
Tube Bundle Height (m)	8.56	9.42	9.4
Overall Height (m)	15	18.7	12
Tube Material	Inconel-600	Incoloy-800	Incoloy-800
Recirculation Ratio (full power)	5:1	5.7:1	6:1

TABLE 2.6

STEAM GENERATOR U-TUBE LENGTHS

U-Tube Group (see Figure 2.28)	Number of Tubes in Group	Height[1] (m)	Total Length of U-Tube (m)
A	10	9.414	18.902
B	11	9.436	18.971
C	10	9.458	19.041
D	7	9.481	19.110
E	6	9.502	19.179

[1] Height is from the tubesheet to the top of the U-tube

TABLE 2.7

PUMP COMPARISON

Parameter	BRUCE B	CANDU-6	RD-14M
Number of Pumps	4	4	2
Rated Head (m)	213	215	225
Rated Speed (rpm)	1790	1790	3560
Rated Flow (L/s)	3300	2230	31
Impeller Diameter (mm)	800	743	360
Specific Speed * (rpm·USgpm$^{1/2}$ /ft$^{3/4}$)	3000	2420	560
Power Absorbed* (kW)		4200	76

* - at rated condition

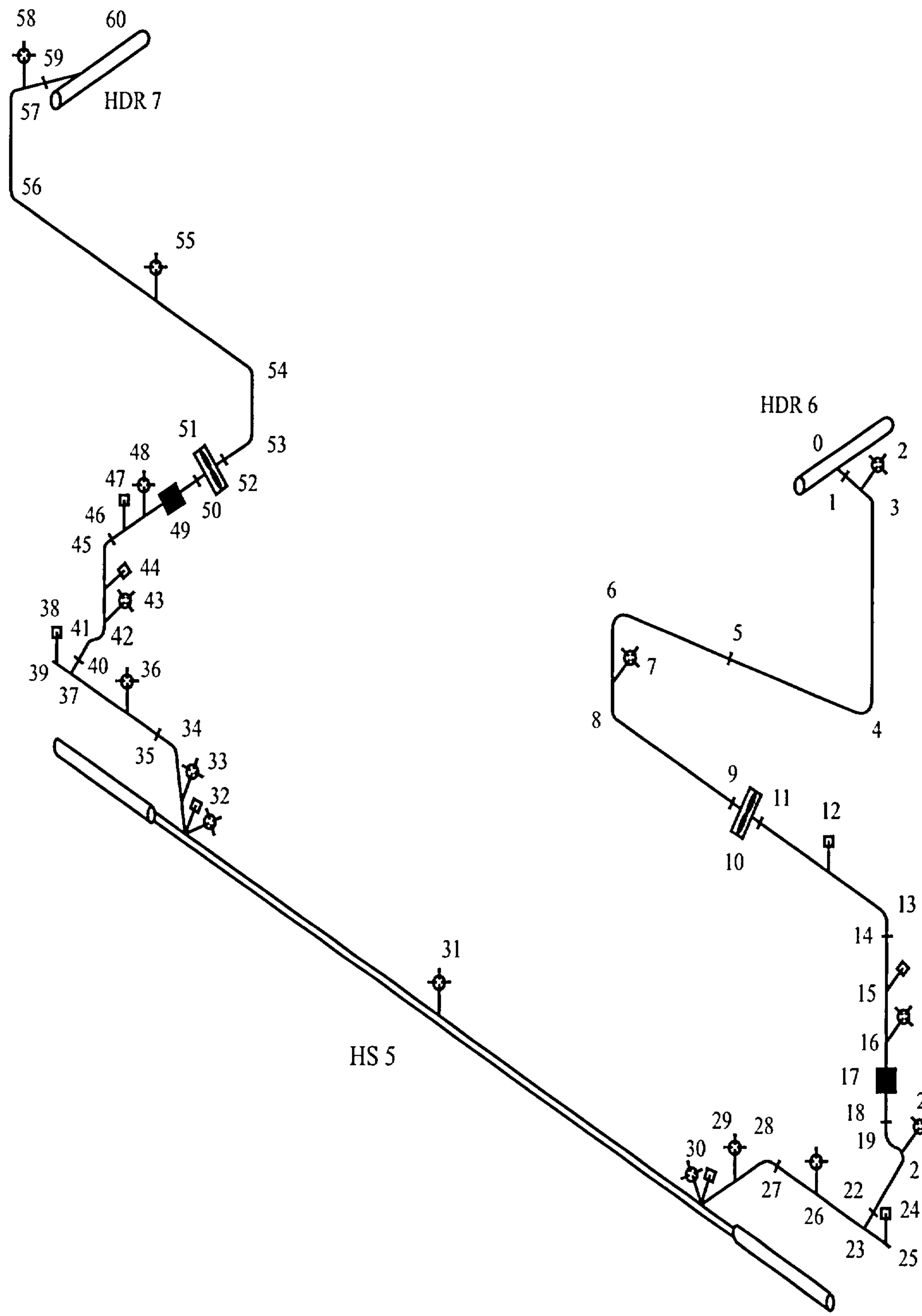

FIGURE 2.1: Elevation Diagram for Heated Section HS5 Feeders

2. PRIMARY HEAT TRANSPORT SYSTEM

FIGURE 2.1 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR6 Centreline	10.71			
			0.21	40.89	36
1	Grayloc/Reducer	10.59			
			0.25	26.64	36
2	Thermocouple (210T-D1)	10.44			
			0.26	26.64	36
3	Elbow (54°)	10.29			
			1.00	26.64	90
4	Elbow (90°)	9.29			
			1.57	26.64	0
5	Grayloc/Orifice (OR9)	9.29		15.13	
			0.50	26.64	0
6	Elbow (90°)	9.29			
			0.30	26.64	90
7	Thermocouple (210T-D2)	8.99			
			0.66	26.64	90
8	Elbow (60°)	8.33			
			0.66	26.64	30
9	Grayloc	8.00			
10	Turbine Flowmeter (177F-D1)		0.21	29.46	30
11	Grayloc	7.90			
			0.21	26.64	30
12	Standoff	7.80			
			0.21	26.64	30
13	Elbow (60°)	7.69			
			0.10	26.64	90
14	Grayloc	7.59			
			0.20	26.64	90
15	Standoff (24Q-D1/D2, 80P-D1,37Q-D1,67Q-D1)	7.39			
			0.06	26.64	90
16	Thermocouple	7.33			
17	Void Fraction Meter (15VF)		0.43	26.64	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Grayloc	6.90			
			0.08	26.64	90
19	Elbow (38°)	6.82			
			0.05	26.64	52
20	Thermocouple (210T-D3)	6.78			
			0.05	26.64	52
21	Elbow (48°)	6.74			
			0.13	26.64	58
22	Grayloc/Reducer	6.64			
			0.15	26.64	58
23	End-Fitting Tee	6 51			
			0.13	76.20	0
24	Standoff (81P-D1)	6.51			
			0.08	76.20	0
25	End-Fitting Cap	6.51			
23	End-Fitting Tee	6.51			
			0.36	76.20	0
26	Thermocouple (211T-D1,271T-D1)	6.51			
			0.76	76.20	0
27	Grayloc	6.51			
			0.10	76.20	0
28	Elbow (90°)/Reducer	6.51			
			0.15	42.90	0
29	Thermocouple (251T-D1)	6.51			
			0.15	42.90	0
30	HS5 Inlet Tee/Standoff/Thermocouple (80P-D2,67Q-D1,291T-D1)	6.51			
			2.85	44.80	0
31	Thermocouple (291T-D2)	6.51			
			3.05	44.80	0
32	HS5 Outlet Tee/Standoff/Thermocouple (111P-D2,68Q-D1,291T-D3)	6.51			
			0.15	42.90	0
33	Thermocouple (252T-D1)	6.51			
			0.15	42.90	0
34	Elbow (90°)/Reducer	6.51			
			0.10	76.20	0
35	Grayloc	6.51			
			0.76	76.20	0
36	Thermocouple (212T-D1,272T-D1)	6.51			
			0.36	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	6.51			
			0.13	76 20	0
38	Standoff (82P-D1)	6.51			
			0.08	76.20	0
39	End-Fitting Cap	6.51			
37	End-Fitting Tee	6.51			
			0.15	40.89	58
40	Grayloc/Reducer	6.62			
			0.12	35.05	58
41	Elbow (48°)	6.72			
			0.10	35.05	52
42	Elbow (38°)	6.80			
			0.20	35.05	90
43	Thermocouple (213T-D1)	7.00			
			0.20	35.05	90
44	Standoff (24Q-D1/D2,111P-D1, 47Q-D1,68Q-D1)	7.20			
			0.40	35.05	90
45	Elbow (60°)	7.60			
			0.10	35.05	30
46	Grayloc	7.65			
			0.20	35.05	30
47	Standoff	7.75			
			0 06	35.05	30
48	Thermocouple	7.78			
49	Void Fraction Meter (16VF)		0.43	35.05	30
50	Grayloc	8.00			
51	Turbine Flowmeter (178F-D1)		0.21	33.99	30
52	Grayloc	8.10			
			0.46	35.05	30
53	Elbow (60°)	8.33			
			0.96	35.05	90
54	Elbow (90°)	9.29			
			1.00	35.05	0
55	Thermocouple (213T-D2)	9.29			
			2.85	35.05	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (90°)	9.29			
			1.00	35.05	90
57	Elbow (54°)	10.29			
			0.26	35 05	36
58	Thermocouple (213T-D3)	10.44			
			0.25	35.05	36
59	Grayloc/Reducer	10.59			
			0.21	40.89	36
60	Header HDR7 Centreline	10.71			

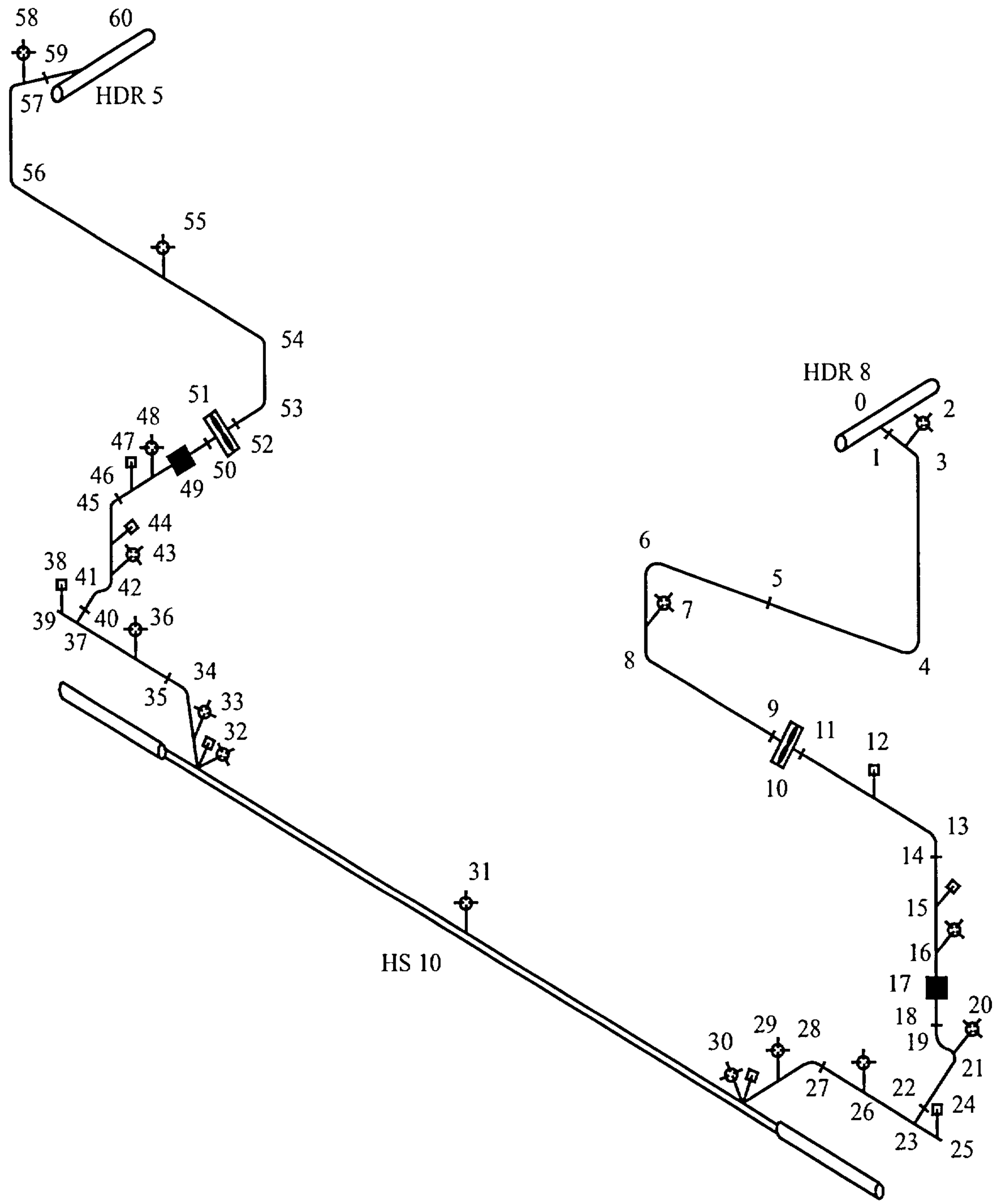

FIGURE 2.2: Elevation Diagram for Heated Section HS10 Feeders

2. PRIMARY HEAT TRANSPORT SYSTEM

FIGURE 2.2 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR8 Centreline	10.71			
			0.21	40.89	36
1	Grayloc/Reducer	10.59			
			0.25	26.64	36
2	Thermocouple (233T-D1)	10.44			
			0.26	26.64	36
3	Elbow (54°)	10.29			
			1.00	26.64	90
4	Elbow (90°)	9.29			
			1.57	26.64	0
5	Grayloc/Orifice (OR15)	9.29		15.13	
			0.50	26.64	0
6	Elbow (90°)	9.29			
			0.30	26.64	90
7	Thermocouple (233T-D2)	8.99			
			0.66	26.64	90
8	Elbow (60°)	8.33			
			0.66	26.64	30
9	Grayloc	8.00			
10	Turbine Flowmeter (187F-D1)		0.21	29.46	30
11	Grayloc	7.90			
			0.21	26.64	30
12	Standoff	7.80			
			0.21	26.64	30
13	Elbow (60°)	7.69			
			0.10	26.64	90
14	Grayloc	7.59			
			0.20	26.64	90
15	Standoff (29Q-D1/D2, 95P-D1,52Q-D1)	7.39			
			0.06	26.64	90
16	Thermocouple	7.33			
17	Void Fraction Meter (25VF)		0.43	26.64	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Grayloc	6.90			
			0.08	26.64	90
19	Elbow (38°)	6.82			
			0.05	26.64	52
20	Thermocouple (233T-D3,233T-S1)	6.78			
			0.05	26.64	52
21	Elbow (48°)	6.74			
			0.13	26.64	58
22	Grayloc/Reducer	6.64			
			0.15	26.64	58
23	End-Fitting Tee	6.51			
			0.13	76.20	0
24	Standoff (97P-D1)	6.51			
			0.08	76.20	0
25	End-Fitting Cap	6.51			
23	End-Fitting Tee	6.51			
			0.36	76.20	0
26	Thermocouple (232T-D1,281T-D1)	6.51			
			0.76	76.20	0
27	Grayloc	6.51			
			0.10	76.20	0
28	Elbow (90°)/Reducer	6.51			
			0.15	42.90	0
29	Thermocouple (261T-D1,261T-S1)	6.51			
			0.15	42.90	0
30	HS10 Inlet Tee/Standoff/ Thermocouple (95P-D2,296T-D1)	6 51			
			2.85	44.80	0
31	Thermocouple (296T-D2,296T-S1)	6.51			
			3.05	44.80	0
32	HS10 Outlet Tee/Standoff/ Thermocouple (116P-D2,296T-D3)	6.51			
			0.15	42.90	0
33	Thermocouple (262T-D1,262T-S1)	6.51			
			0.15	42.90	0
34	Elbow (90°)/Reducer	6.51			
			0.10	76.20	0
35	Grayloc	6.51			
			0.76	76.20	0
36	Thermocouple (231T-D1,282T-D1)	6.51			
			0.36	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	6.51			
			0.13	76.20	0
38	Standoff (96P-D1)	6.51			
			0.08	76.20	0
39	End-Fitting Cap	6.51			
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37	End-Fitting Tee	6.51			
			0.15	40.89	58
40	Grayloc/Reducer	6.62			
			0.12	35.05	58
41	Elbow (48°)	6.72			
			0.10	35 05	52
42	Elbow (38°)	6 80			
			0.20	35.05	90
43	Thermocouple (230T-D1,230T-S1)	7.00			
			0.20	35.05	90
44	Standoff(29Q-D1/D2,116P-D1, 42Q-D1)	7.20			
			0.40	35.05	90
45	Elbow (60°)	7.60			
			0.10	35.05	30
46	Grayloc	7.65			
			0.20	35.05	30
47	Standoff	7.75			
			0.06	35 05	30
48	Thermocouple	7.78			
49	Void Fraction Meter (26VF)		0.43	35.05	30
50	Grayloc	8.00			
51	Turbine Flowmeter (188F-D1)		0.21	33.99	30
52	Grayloc	8.10			
			0.46	35.05	30
53	Elbow (60°)	8.33			
			0.96	35.05	90
54	Elbow (90°)	9.29			
			1.00	35.05	0
55	Thermocouple (230T-D2)	9.29			
			2.85	35.05	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (90°)	9.29			
			1.00	35.05	90
57	Elbow (54°)	10.29			
			0.26	35.05	36
58	Thermocouple (230T-D3)	10.44			
			0.25	35.05	36
59	Grayloc/Reducer	10.59			
			0.21	40.89	36
60	Header HDR5 Centreline	10.71			

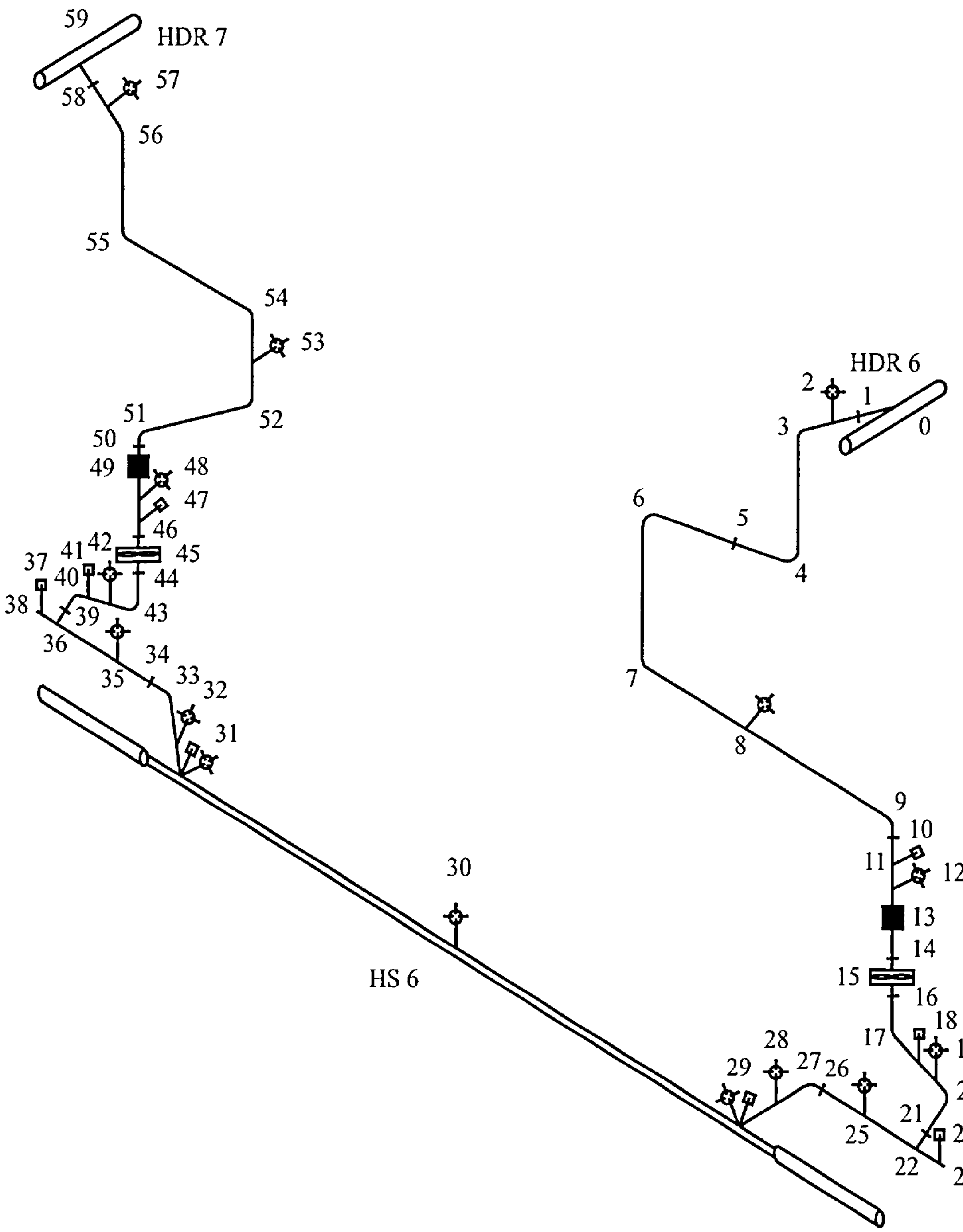

FIGURE 2.3: Elevation Diagram for Heated Section HS6 Feeders

FIGURE 2.3 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR6 Centreline	10.71			
			0.21	40.89	36
1	Grayloc/Reducer	10.59			
			0.25	26.64	36
2	Thermocouple (214T-D1)	10.44			
			0.26	26.64	36
3	Elbow (54°)	10.29			
			0.54	26.64	90
4	Elbow (90°)	9.75			
			1.32	26.64	0
5	Grayloc/Orifice (OR10)	9.75		15.64	
			0.54	26.64	0
6	Elbow (90°)	9.75			
			1.63	26.64	90
7	Elbow (60°)	8.12			
			0.65	26.64	30
8	Thermocouple (214T-D2)	7.80			
			1.05	26.64	30
9	Elbow (60°)	7.27			
			1.54	26.64	90
10	Grayloc	5.73			
			0.20	26.64	90
11	Standoff	5.53			
			0.06	26.64	90
12	Thermocouple	5.47			
13	Void Fraction Meter (17VF)		0.43	26.64	90
14	Grayloc	5.04			
15	Turbine Flowmeter (179F-D1)		0.21	29.46	90
16	Grayloc	4.83			
			0.42	26.64	90
17	Elbow (70°)	4.41			
			0.24	26.64	20

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (25Q-D1/D2, 83P-D1,38Q-D1)	4.33			
			0.24	26.64	20
19	Thermocouple (214T-D3)	4.25			
			0.24	26.64	20
20	Elbow (107°)	4.17			
			0.13	26.64	58
21	Grayloc/Reducer	4.07			
			0.15	40.89	58
22	End-Fitting Tee	3.96			
			0.13	76.20	0
23	Standoff (84P-D1)	3.96			
			0.08	76.20	0
24	End-Fitting Cap	3.96			
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22	End-Fitting Tee	3.96			
			0.36	76.20	0
25	Thermocouple (215T-D1,273T-D1)	3.96			
			0.76	76.20	0
26	Grayloc	3.96			
			0.10	76.20	0
27	Elbow (90°)/Reducer	3.96			
			0.15	42.90	0
28	Thermocouple (253T-D1)	3.96			
			0.15	42.90	0
29	HS6 Inlet Tee/Standoff/ Thermocouple (83P-D2,292T-D1)	3.96			
			2.85	44.80	0
30	Thermocouple (292T-D2)	3.96			
			3.05	44.80	0
31	HS6 Outlet Tee/Standoff/ Thermocouple (112P-D2,292T-D3)	3.96			
			0.15	42.90	0
32	Thermocouple (254T-D1)	3.96			
			0.15	42.90	0
33	Elbow (90°)/Reducer	3.96			
			0.10	76.20	0
34	Grayloc	3.96			
			0.76	76.20	0
35	Thermocouple (216T-D1,274T-D1)	3.96			
			0.36	76.20	0
36	End-Fitting Tee	3.96			
			0.13	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Standoff (85P-D1)	3.96			
			0.08	76.20	0
38	End-Fitting Cap	3.96			
36	End-Fitting Tee	3.96			
			0.15	40.89	58
39	Grayloc/Reducer	4.07			
			0.13	35.05	58
40	Elbow (107°)	4.18			
			0.24	35.05	20
41	Standoff (25Q-D1/D2, 112P-D1,48Q-D1)	4.26			
			0.24	35.05	20
42	Thermocouple (217T-D1)	4 34			
			0.24	35.05	20
43	Elbow (70°)	4.42			
			0.43	35.05	90
44	Grayloc	4.85			
45	Turbine Flowmeter (180F-D1)		0.21	33.99	90
46	Grayloc	5.06			
			0.20	35.05	90
47	Standoff	5.26			
			0.07	35.05	90
48	Thermocouple	5.33			
49	Void Fraction Meter (18VF)		0.43	35.05	90
50	Grayloc	5.76			
			1.45	35.05	90
51	Elbow (60°)	7.21			
			1.87	35.05	30
52	Elbow (60°)	8.15			
			0.40	35.05	90
53	Thermocouple (217T-D2)	8.55			
			1.20	35.05	90
54	Elbow (90°)	9.75			
			3.67	35.05	0
55	Elbow (90°)	9.75			
			0.54	35.05	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (54°)	10.29			
			0.26	35.05	36
57	Thermocouple (217T-D3)	10.44			
			0.25	35.05	36
58	Grayloc/Reducer	10.59			
			0.21	40.89	36
59	Header HDR7 Centreline	10.71			

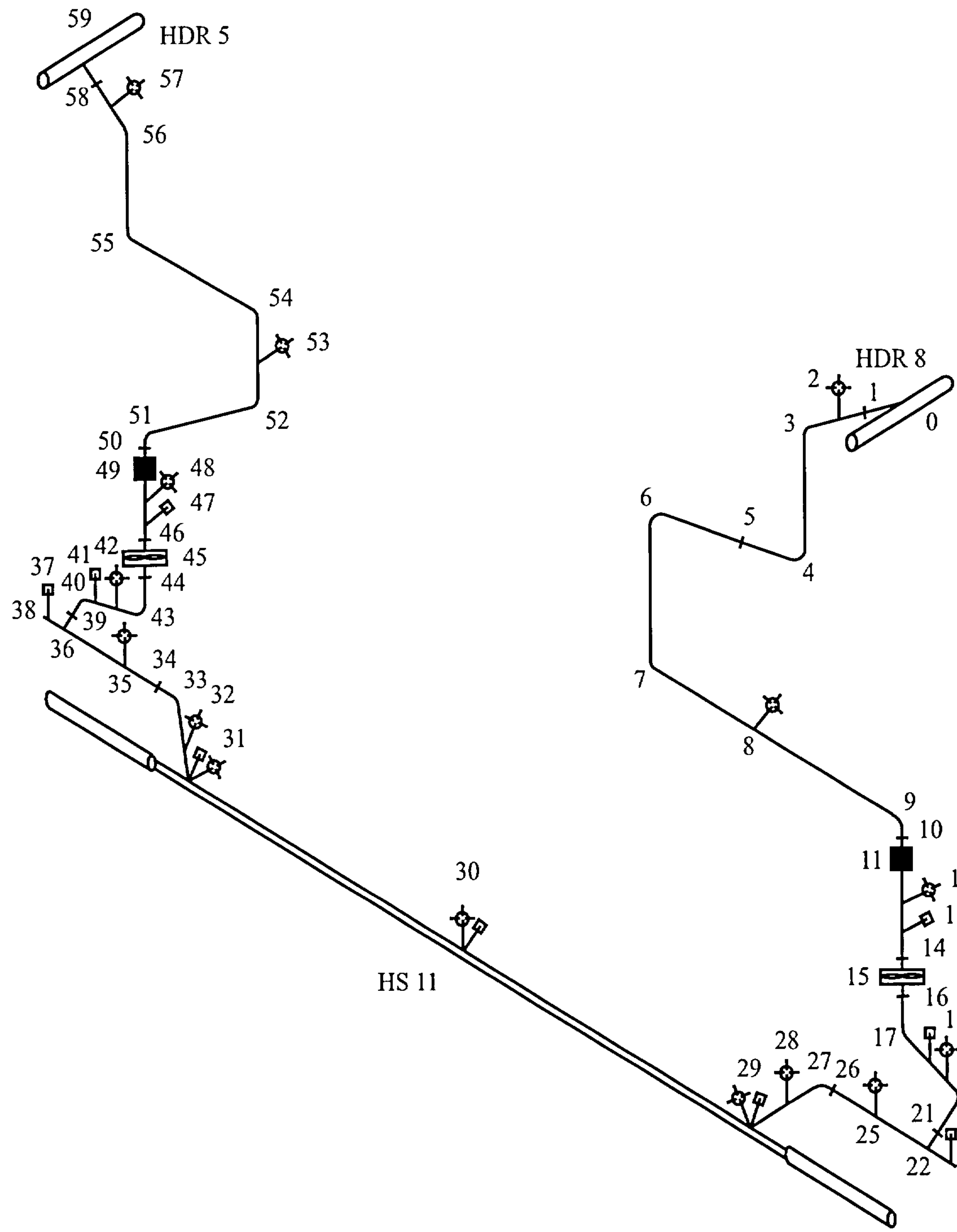

FIGURE 2.4: Elevation Diagram for Heated Section HS11 Feeders

2. PRIMARY HEAT TRANSPORT SYSTEM

FIGURE 2.4 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR8 Centreline	10.71			
			0.21	40.89	36
1	Grayloc/Reducer	10.59			
			0.25	26.64	36
2	Thermocouple (237T-D1)	10.44			
			0.26	26.64	36
3	Elbow (54°)	10.29			
			0.54	26.64	90
4	Elbow (90°)	9.75			
			1.32	26.64	0
5	Grayloc/Orifice (OR16)	9.75		15.67	
			0.54	26.64	0
6	Elbow (90°)	9.75			
			1.63	26.64	90
7	Elbow (60°)	8.12			
			0.65	26.64	30
8	Thermocouple (237T-D2)	7.80			
			1.05	26.64	30
9	Elbow (60°)	7.27			
			1.54	26.64	90
10	Grayloc	5.73			
11	Void Fraction Meter (27VF)		0.43	26.64	90
12	Thermocouple	5.30			
			0.06	26.64	90
13	Standoff	5.24			
			0.20	26.64	90
14	Grayloc	5.04			
15	Turbine Flowmeter (189F-D1)		0.21	29.46	90
16	Grayloc	4.83			
			0.42	26.64	90
17	Elbow (70°)	4.41			
			0.24	26.64	20

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (30Q-D1/D2, 98P-D1,53Q-D1)	4.33			
			0.24	26.64	20
19	Thermocouple (237T-D3)	4.25			
			0.24	26.64	20
20	Elbow (107°)	4.17			
			0.13	26.64	58
21	Grayloc/Reducer	4.07			
			0.15	40.89	58
22	End-Fitting Tee	3.96			
			0.13	76.20	0
23	Standoff (100P-D1)	3.96			
			0.08	76.20	0
24	End-Fitting Cap	3.96			
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22	End-Fitting Tee	3.96			
			0.36	76.20	0
25	Thermocouple (236T-D1,283T-D1)	3.96			
			0.76	76.20	0
26	Grayloc	3.96			
			0.10	76.20	0
27	Elbow (90°)/Reducer	3.96			
			0.15	42.90	0
28	Thermocouple (263T-D1)	3.96			
			0.15	42.90	0
29	HS11 Inlet Tee/Standoff/ Thermocouple (98P-D2,297T-D1)	3.96			
			2.85	44.80	0
30	Standoff/Thermocouple (143P-D1,297T-D2)	3.96			
			3.05	44.80	0
31	HS11 Outlet Tee/Standoff/ Thermocouple (117P-D2,297T-D3)	3.96			
			0.15	42.90	0
32	Thermocouple (264T-D1)	3.96			
			0.15	42.90	0
33	Elbow (90°)/Reducer	3.96			
			0.10	76.20	0
34	Grayloc	3.96			
			0.76	76.20	0
35	Thermocouple (235T-D1,284T-D1)	3.96			
			0.36	76.20	0
36	End-Fitting Tee	3.96			
			0.13	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Standoff (99P-D1)	3.96			
			0.08	76.20	0
38	End-Fitting Cap	3.96			
36	End-Fitting Tee	3 96			
			0.15	40.89	58
39	Grayloc/Reducer	4.07			
			0.13	35.05	58
40	Elbow (107°)	4.18			
			0.24	35.05	20
41	Standoff (30Q-D1/D2, 117P-D1,43Q-D1)	4.26			
			0.24	35.05	20
42	Thermocouple (234T-D1)	4.34			
			0.24	35.05	20
43	Elbow (70°)	4.42			
			0.43	35.05	90
44	Grayloc	4.85			
45	Turbine Flowmeter (190F-D1)		0.21	33.99	90
46	Grayloc	5.06			
			0.20	35.05	90
47	Standoff	5.26			
			0.07	35.05	90
48	Thermocouple	5.33			
49	Void Fraction Meter (28VF)		0.43	35.05	90
50	Grayloc	5.76			
			1.45	35.05	90
51	Elbow (60°)	7.21			
			1.87	35.05	30
52	Elbow (60°)	8.15			
			0.40	35.05	90
53	Thermocouple (234T-D2)	8.55			
			1.20	35.05	90
54	Elbow (90°)	9.75			
			3.67	35.05	0
55	Elbow (90°)	9.75			
			0.54	35.05	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (54°)	10.29			
			0.26	35.05	36
57	Thermocouple (234T-D3)	10.44			
			0.25	35.05	36
58	Grayloc/Reducer	10.59			
			0.21	40.89	36
59	Header HDR5 Centreline	10.71			

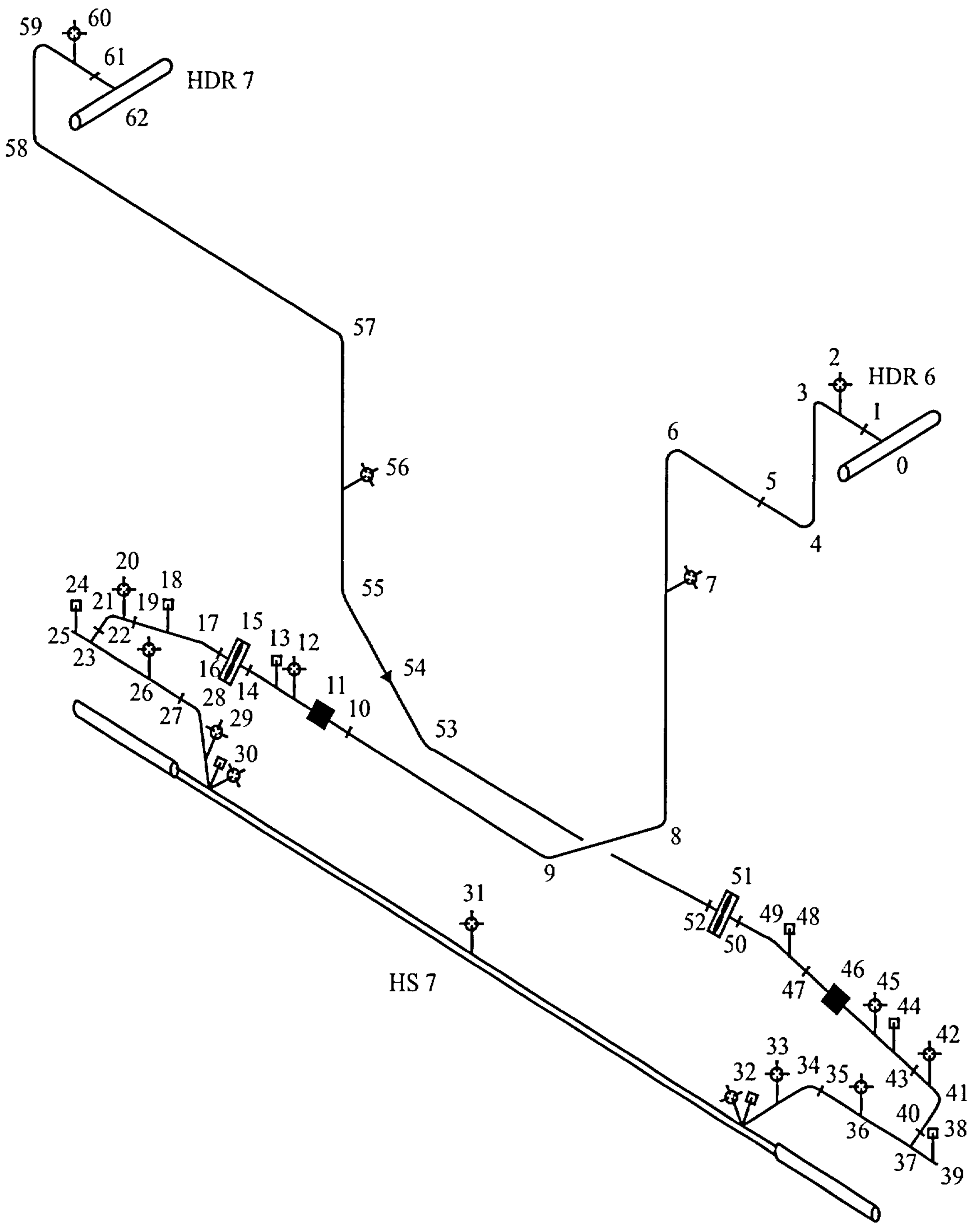

FIGURE 2.5: Elevation Diagram for Heated Section HS7 Feeders

FIGURE 2.5 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR6 Centreline	10.71			
			0.21	40.89	0
1	Grayloc/Reducer	10.71			
			0.32	35.05	0
2	Thermocouple (218T-D1)	10.71			
			0.28	35.05	0
3	Elbow (90°)	10.71			
			0.82	35.05	90
4	Elbow (90°)	9.89			
			2.08	35.05	0
5	Grayloc/Orifice (OR11)	9.89		35.05	
			1.00	35.05	0
6	Elbow (90°)	9.89			
			3.20	35.05	90
7	Thermocouple (218T-D2)	6.69			
			2.14	35.05	90
8	Elbow (55°)	4.55			
			1.30	35.05	35
9	Elbow (35°)	3.80			
			2.39	35.05	0
10	Grayloc	3.80			
11	Void Fraction Meter (19VF)	3.80	0.43	35.05	0
12	Thermocouple	3.80			
			0.06	35.05	0
13	Standoff	3.80			
			0.20	35.05	0
14	Grayloc	3.80			
15	Turbine Flowmeter (181F-D1)	3.80	0.21	33.99	0
16	Grayloc	3.80			
			0.10	35.05	0
17	Elbow (20°)	3.80			
			0.11	35.05	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (26Q-D1/D2, 86P-D1,39Q-D1)	3.80			
			0.32	35.05	0
19	Grayloc	3.80			
			0.34	35.05	0
20	Thermocouple (218T-D3)	3.80			
			0.11	35.05	0
21	Elbow (107°)	3.80			
			0.13	35.05	32
22	Grayloc/Reducer	3.72			
			0.15	40.89	32
23	End-Fitting Tee	3.66			
			0.13	76.20	0
24	Standoff (87P-D1)	3.66			
			0.08	76.20	0
25	End-Fitting Cap	3.66			
------	------	------	------	------	------
23	End-Fitting Tee	3.66			
			0.36	76.20	0
26	Thermocouple (219T-D1,275T-D1)	3.66			
			0.76	76.20	0
27	Grayloc	3.66			
			0.10	76.20	0
28	Elbow (90°)/Reducer	3.66			
			0.15	42.90	0
29	Thermocouple (255T-D1)	3.66			
			0.15	42.90	0
30	HS7 Inlet Tee/Standoff/ Thermocouple (86P-D2,293T-D1)	3.66			
			2.85	44.80	0
31	Thermocouple (293T-D2)	3.66			
			3.05	44.80	0
32	HS7 Outlet Tee/Standoff/ Thermocouple (113P-D2,293T-D3)	3.66			
			0.15	42.90	0
33	Thermocouple (256T-D1)	3.66			
			0.15	42.90	0
34	Elbow (90°)/Reducer	3.66			
			0.10	76.20	0
35	Grayloc	3.66			
			0.76	76.20	0
36	Thermocouple (220T-D1,276T-D1)	3.66			
			0.36	76.20	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	3.66			
			0.13	76.20	0
38	Standoff (88P-D1)	3.66			
			0.08	76.20	0
39	End-Fitting Cap	3.66			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	3.66			
			0.15	40.89	32
40	Grayloc/Reducer	3.74			
			0.31	35.05	32
41	Elbow (107°)	3.90			
			0.10	35.05	0
42	Thermocouple (221T-D1)	3.90			
			0.10	35.05	0
43	Grayloc	3.90			
			0.20	35.05	0
44	Standoff (26Q-D1/D2, 113P-D1,49Q-D1)	3.90			
			0.07	35.05	0
45	Thermocouple	3.90			
46	Void Fraction Meter (20VF)	3.90	0.43	35.05	0
47	Grayloc	3.90			
			0.11	35.05	0
48	Standoff	3.90			
			0.10	35.05	0
49	Elbow (20°)	3.90			
			0.43	35.05	0
50	Grayloc	3.90			
51	Turbine Flowmeter (182F-D1)	3.90	0.21	33.99	0
52	Grayloc	3.90			
			2.74	35.05	0
53	Elbow (35°)	3.90			
			0.53	35.05	35
54	Reducer	4.20			
			0.70	40.89	35
55	Elbow (55°)	4.60			
			3.56	40.89	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Thermocouple (221T-D2)	8.16			
			1.84	40.89	90
57	Elbow (90°)	10.00			
			5.97	40.89	0
58	Elbow (90°)	10.00			
			0.71	40.89	90
59	Elbow (90°)	10.71			
			0.38	40.89	0
60	Thermocouple (221T-D3)	10.71			
			0.22	40.89	0
61	Grayloc	10.71			
			0.21	40.89	0
62	Header HDR7 Centreline	10.71			

2. PRIMARY HEAT TRANSPORT SYSTEM

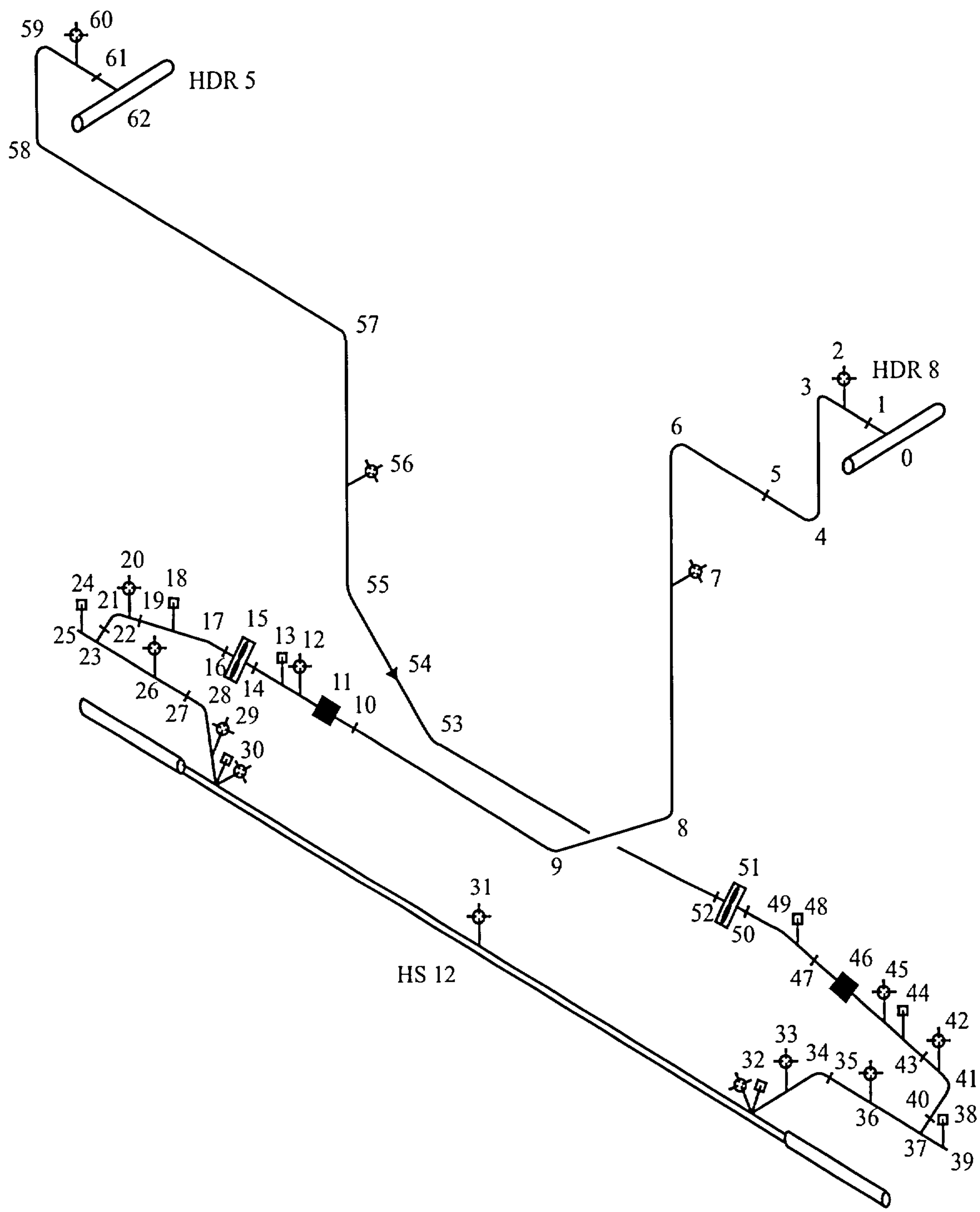

FIGURE 2.6: Elevation Diagram for Heated Section HS12 Feeders

FIGURE 2.6 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR8 Centreline	10.71			
			0.21	40.89	0
1	Grayloc/Reducer	10.71			
			0.32	35.05	0
2	Thermocouple (241T-D1)	10.71			
			0.28	35.05	0
3	Elbow (90°)	10.71			
			0.82	35.05	90
4	Elbow (90°)	9.89			
			2.08	35.05	0
5	Grayloc/Orifice (OR17)	9.89		35.05	
			1.00	35.05	0
6	Elbow (90°)	9.89			
			3.20	35.05	90
7	Thermocouple (241T-D2)	6.69			
			2.14	35.05	90
8	Elbow (55°)	4.55			
			1.30	35.05	35
9	Elbow (35°)	3.80			
			2.39	35.05	0
10	Grayloc	3.80			
11	Void Fraction Meter (29VF)	3.80	0.43	35.05	0
12	Thermocouple	3.80			
			0.06	35.05	0
13	Standoff	3.80			
			0.20	35.05	0
14	Grayloc	3.80			
15	Turbine Flowmeter (191F-D1)	3.80	0.21	33.99	0
16	Grayloc	3.80			
			0.10	35.05	0
17	Elbow (20°)	3.80			
			0.11	35.05	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (31Q-D1/D2, 101P-D1,54Q-D1,71Q-D1)	3.80			
			0.32	35.05	0
19	Grayloc	3.80			
			0.34	35.05	0
20	Thermocouple (241T-D3)	3.80			
			0.11	35.05	0
21	Elbow (107°)	3.80			
			0.13	35.05	32
22	Grayloc/Reducer	3.72			
			0.15	40.89	32
23	End-Fitting Tee	3.66			
			0.13	76.20	0
24	Standoff (103P-D1)	3.66			
			0.08	76.20	0
25	End-Fitting Cap	3.66			
23	End-Fitting Tee	3.66			
			0.36	76.20	0
26	Thermocouple (240T-D1,285T-D1)	3.66			
			0.76	76.20	0
27	Grayloc	3.66			
			0.10	76.20	0
28	Elbow (90°)/Reducer	3.66			
			0.15	42.90	0
29	Thermocouple (265T-D1)	3.66			
			0.15	42.90	0
30	HS12 Inlet Tee/Standoff/Thermocouple (101P-D2,71Q-D1,298T-D1)	3.66			
			2.85	44.80	0
31	Thermocouple (298T-D2)	3.66			
			3.05	44.80	0
32	HS12 Outlet Tee/Standoff/Thermocouple (118P-D2,72Q-D1,298T-D3)	3.66			
			0.15	42.90	0
33	Thermocouple (266T-D1)	3.66			
			0.15	42.90	0
34	Elbow (90°)/Reducer	3.66			
			0.10	76.20	0
35	Grayloc	3.66			
			0.76	76.20	0
36	Thermocouple (239T-D1,286T-D1)	3.66			
			0.36	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	3.66			
			0.13	76.20	0
38	Standoff (102P-D1)	3.66			
			0.08	76.20	0
39	End-Fitting Cap	3.66			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	3.66			
			0.15	40.89	32
40	Grayloc/Reducer	3.74			
			0.31	35.05	32
41	Elbow (107°)	3.90			
			0.10	35 05	0
42	Thermocouple (238T-D1)	3.90			
			0.10	35.05	0
43	Grayloc	3.90			
			0.20	35.05	0
44	Standoff (31Q-D1/D2, 118P-D1,44Q-D1,72Q-D1)	3.90			
			0.07	35.05	0
45	Thermocouple	3.90			
46	Void Fraction Meter (30VF)	3.90	0.43	35.05	0
47	Grayloc	3.90			
			0.11	35.05	0
48	Standoff	3.90			
			0.10	35.05	0
49	Elbow (20°)	3.90			
			0.43	35.05	0
50	Grayloc	3.90			
51	Turbine Flowmeter (192F-D1)	3.90	0.21	33.99	0
52	Grayloc	3.90			
			2.74	35.05	0
53	Elbow (35°)	3.90			
			0.53	35.05	35
54	Reducer	4.20			
			0.70	40.89	35
55	Elbow (55°)	4.60			
			3.56	40.89	90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Thermocouple (238T-D2)	8.16			
			1.84	40.89	90
57	Elbow (90°)	10.00			
			5.97	40.89	0
58	Elbow (90°)	10.00			
			0.71	40.89	90
59	Elbow (90°)	10.71			
			0.38	40.89	0
60	Thermocouple (238T-D3)	10.71			
			0.22	40.89	0
61	Grayloc	10.71			
			0.21	40.89	0
62	Header HDR5 Centreline	10.71			

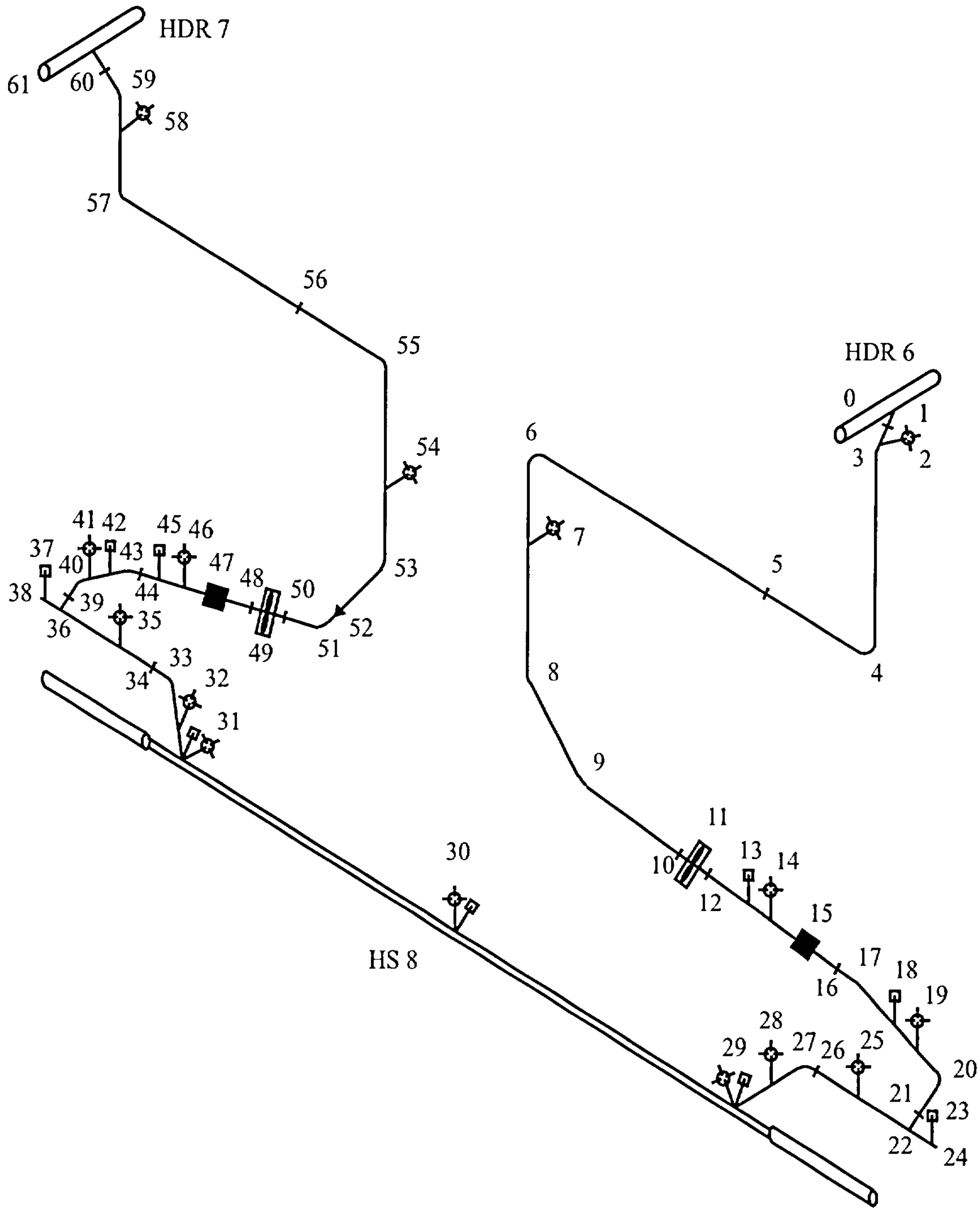

FIGURE 2.7: Elevation Diagram for Heated Section HS8 Feeders

FIGURE 2.7 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR6 Centreline	10.71			
			0.21	40.89	72
1	Grayloc/Reducer	10.51			
			0.32	35.05	72
2	Thermocouple (222T-D1)	10.20			
			0.13	35.05	72
3	Elbow (18°)	10.08			
			0.64	35.05	90
4	Elbow (90°)	9.44			
			2.83	35.05	0
5	Grayloc/Orifice (OR12)	9.44		23.50	
			0.50	35.05	0
6	Elbow (90°)	9.44			
			2.50	35.05	90
7	Thermocouple (222T-D2)	6.94			
			2.49	35.05	90
8	Elbow (55°)	4.45			
			2.10	35.05	35
9	Elbow (35°)	3.24			
			0.73	35.05	0
10	Grayloc	3.24			
11	Turbine Flowmeter (183F-D1)	3.24	0.21	33.99	0
12	Grayloc	3.24			
			0.20	35.05	0
13	Standoff	3.24			
			0.06	35.05	0
14	Thermocouple	3.24			
15	Void Fraction Meter (21VF)	3.24	0.43	35.05	0
16	Grayloc	3.24			
			0.10	35.05	0
17	Elbow (20°)	3.24			
			0.11	35.05	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (27Q-D1/D2, 89P-D1,40Q-D1,69Q-D1)	3.24			
			0.11	35.05	0
19	Thermocouple (222T-D3)	3.24			
			0.11	35 05	0
20	Elbow (107°)	3.24			
			0.12	35.05	32
21	Grayloc/Reducer	3.18			
			0.15	40.89	32
22	End-Fitting Tee	3.11			
			0.13	76.20	0
23	Standoff (90P-D1)	3.11			
			0.08	76.20	0
24	End-Fitting Cap	3.11			

22	End-Fitting Tee	3.11			
			0.36	76.20	0
25	Thermocouple (223T-D1,277T-D1)	3.11			
			0.76	76.20	0
26	Grayloc	3.11			
			0.10	76.20	0
27	Elbow (90°)/Reducer	3.11			
			0.15	42.90	0
28	Thermocouple (257T-D1)	3.11			
			0.15	42.90	0
29	HS8 Inlet Tee/Standoff/Thermocouple (89P-D2,69Q-D1,294T-D1)	3.11			
			2.85	44.80	0
30	Standoff/Thermocouple (145P-D1,294T-D2)	3.11			
			3.05	44.80	0
31	HS8 Outlet Tee/Standoff/Thermocouple (114P-D2,70Q-D1,294T-D3)	3.11			
			0.15	42.90	0
32	Thermocouple (258T-D1)	3.11			
			0.15	42.90	0
33	Elbow (90°)/Reducer	3.11			
			0.10	76.20	0
34	Grayloc	3.11			
			0.76	76.20	0
35	Thermocouple (224T-D1,278T-D1)	3.11			
			0.36	76.20	0
36	End-Fitting Tee	3.11			
			0.13	76.20	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Standoff (91P-D1)	3.11			
			0.08	76.20	0
38	End-Fitting Cap	3.11			
----	----	----	----	----	----
36	End-Fitting Tee	3.11			
			0.15	40.89	32
39	Grayloc/Reducer	3.18			
			0.10	35.05	32
40	Elbow (107°)	3.24			
			0.11	35.05	0
41	Thermocouple (225T-D1)	3.24			
			0.12	35.05	0
42	Standoff (27Q-D1/D2, 114P-D1,50Q-D1,70Q-D1)	3.24			
			0.10	35.05	0
43	Elbow (20°)	3 24			
			0.10	35.05	0
44	Grayloc	3.24			
			0.20	35.05	0
45	Standoff	3.24			
			0 07	35.05	0
46	Thermocouple	3.24			
47	Void Fraction Meter (22VF)	3.24	0.43	35.05	0
48	Grayloc	3.24			
49	Turbine Flowmeter (184F-D1)	3.24	0.21	33.99	0
50	Grayloc	3.24			
			0.92	35.05	0
51	Elbow (35°)	3.24			
			0.53	35.05	35
52	Reducer	3.55			
			1.51	40.89	35
53	Elbow (55°)	4.41			
			3.83	40.89	90
54	Thermocouple (225T-D2)	8.24			
			1.20	40.89	90
55	Elbow (90°)	9.44			
			4.72	40.89	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Grayloc/Orifice (OR14)	9.44		40.89	
			1.45	40.89	0
57	Elbow (90°)	9.44			
			0.38	40.89	90
58	Thermocouple (225T-D3)	9.82			
			0.26	40.89	90
59	Elbow (18°)	10.08			
			0.45	40.89	72
60	Grayloc	10.51			
			0.21	40.89	72
61	Header HDR7 Centreline	10.71			

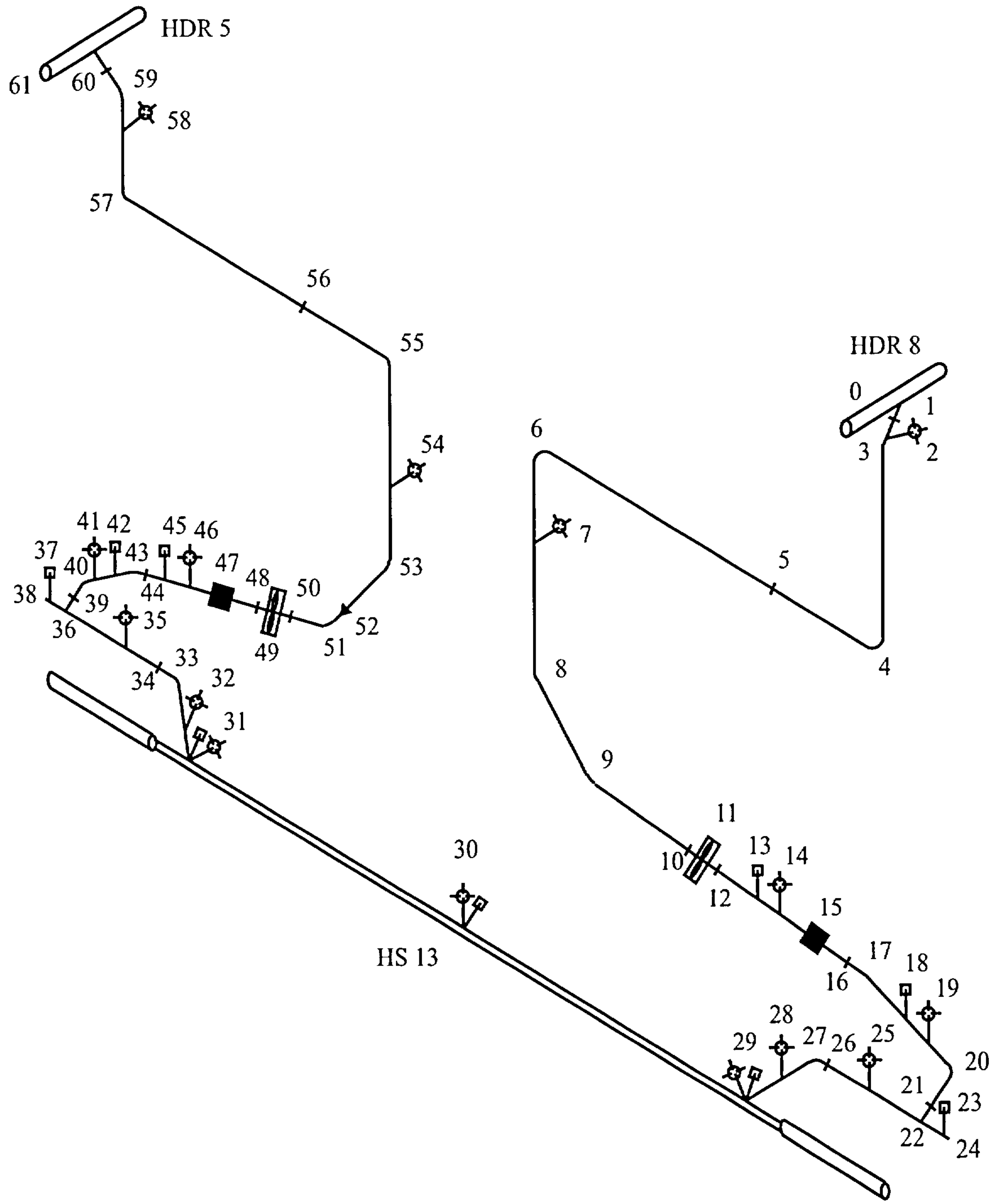

FIGURE 2.8: Elevation Diagram for Heated Section HS13 Feeders

FIGURE 2.8 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR8 Centreline	10.71			
			0.21	40.89	72
1	Grayloc/Reducer	10.51			
			0.32	35.05	72
2	Thermocouple (245T-D1)	10.20			
			0.13	35.05	72
3	Elbow (18°)	10.08			
			0.64	35.05	90
4	Elbow (90°)	9.44			
			2.83	35.05	0
5	Grayloc/Orifice (OR18)	9.44		23.46	
			0.50	35.05	0
6	Elbow (90°)	9.44			
			2.50	35 05	90
7	Thermocouple (245T-D2)	6.94			
			2.49	35.05	90
8	Elbow (55°)	4.45			
			2.10	35.05	35
9	Elbow (35°)	3.24			
			0.73	35.05	0
10	Grayloc	3.24			
11	Turbine Flowmeter (193F-D1)	3.24	0.21	33.99	0
12	Grayloc	3.24			
			0.20	35.05	0
13	Standoff (DP1-D1,DP1-D2)	3.24			
			0.06	35.05	0
14	Thermocouple	3.24			
15	Void Fraction Meter (31VF)	3.24	0.43	35.05	0
16	Grayloc	3.24			
			0.10	35.05	0
17	Elbow (20°)	3.24			
			0.11	35.05	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Standoff (32Q-D1/D2, 104P-D1,55Q-D1)	3.24			
			0.11	35.05	0
19	Thermocouple (245T-D3)	3.24			
			0.11	35.05	0
20	Elbow (107°)	3.24			
			0.12	35.05	32
21	Grayloc/Reducer	3.18			
			0.15	40.89	32
22	End-Fitting Tee	3.11			
			0.13	76.20	0
23	Standoff (106P-D1)	3.11			
			0.08	76 20	0
24	End-Fitting Cap	3.11			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
22	End-Fitting Tee	3.11			
			0.36	76.20	0
25	Thermocouple (244T-D1,287T-D1)	3.11			
			0.76	76.20	0
26	Grayloc	3.11			
			0.10	76.20	0
27	Elbow (90°)/Reducer	3.11			
			0.15	42.90	0
28	Thermocouple (267T-D1)	3.11			
			0 15	42.90	0
29	HS13 Inlet Tee/Standoff/ Thermocouple (104P-D2,299T-D1)	3.11			
			2.85	44.80	0
30	Standoff/Thermocouple (HS13-P, DP1-D1/D2,DP2-D1/D2,299T-D2)	3.11			
			3.05	44.80	0
31	HS13 Outlet Tee/Standoff/ Thermocouple (119P-D2,299T-D3)	3.11			
			0.15	42.90	0
32	Thermocouple (268T-D1)	3.11			
			0.15	42.90	0
33	Elbow (90°)/Reducer	3.11			
			0.10	76.20	0
34	Grayloc	3.11			
			0.76	76.20	0
35	Thermocouple (243T-D1,288T-D1)	3.11			
			0.36	76.20	0
36	End-Fitting Tee	3.11			
			0.13	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Standoff (105P-D1)	3.11			
			0.08	76.20	0
38	End-Fitting Cap	3.11			
36	End-Fitting Tee	3.11			
			0.15	40.89	32
39	Grayloc/Reducer	3.18			
			0.10	35.05	32
40	Elbow (107°)	3.24			
			0.11	35.05	0
41	Thermocouple (242T-D1)	3.24			
			0.12	35 05	0
42	Standoff (32Q-D1/D2, 119P-D1,45Q-D1)	3.24			
			0.10	35.05	0
43	Elbow (20°)	3.24			
			0.10	35.05	0
44	Grayloc	3.24			
			0.20	35.05	0
45	Standoff (DP2-D1,DP2-D2)	3.24			
			0.07	35.05	0
46	Thermocouple	3.24			
47	Void Fraction Meter (32VF)	3.24	0.43	35.05	0
48	Grayloc	3.24			
49	Turbine Flowmeter (194F-D1)	3.24	0.21	33.99	0
50	Grayloc	3.24			
			0.92	35.05	0
51	Elbow (35°)	3.24			
			0.53	35.05	35
52	Reducer	3.55			
			1.51	40.89	35
53	Elbow (55°)	4.41			
			3.83	40.89	90
54	Thermocouple (242T-D2)	8.24			
			1.20	40.89	90
55	Elbow (90°)	9 44			
			4.72	40.89	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Grayloc/Orifice (OR20)	9.44		40.89	
			1.45	40.89	0
57	Elbow (90°)	9.44			
			0.38	40.89	90
58	Thermocouple (242T-D3)	9.82			
			0.26	40.89	90
59	Elbow (18°)	10.08			
			0.45	40.89	72
60	Grayloc	10.51			
			0.21	40.89	72
61	Header HDR5 Centreline	10.71			

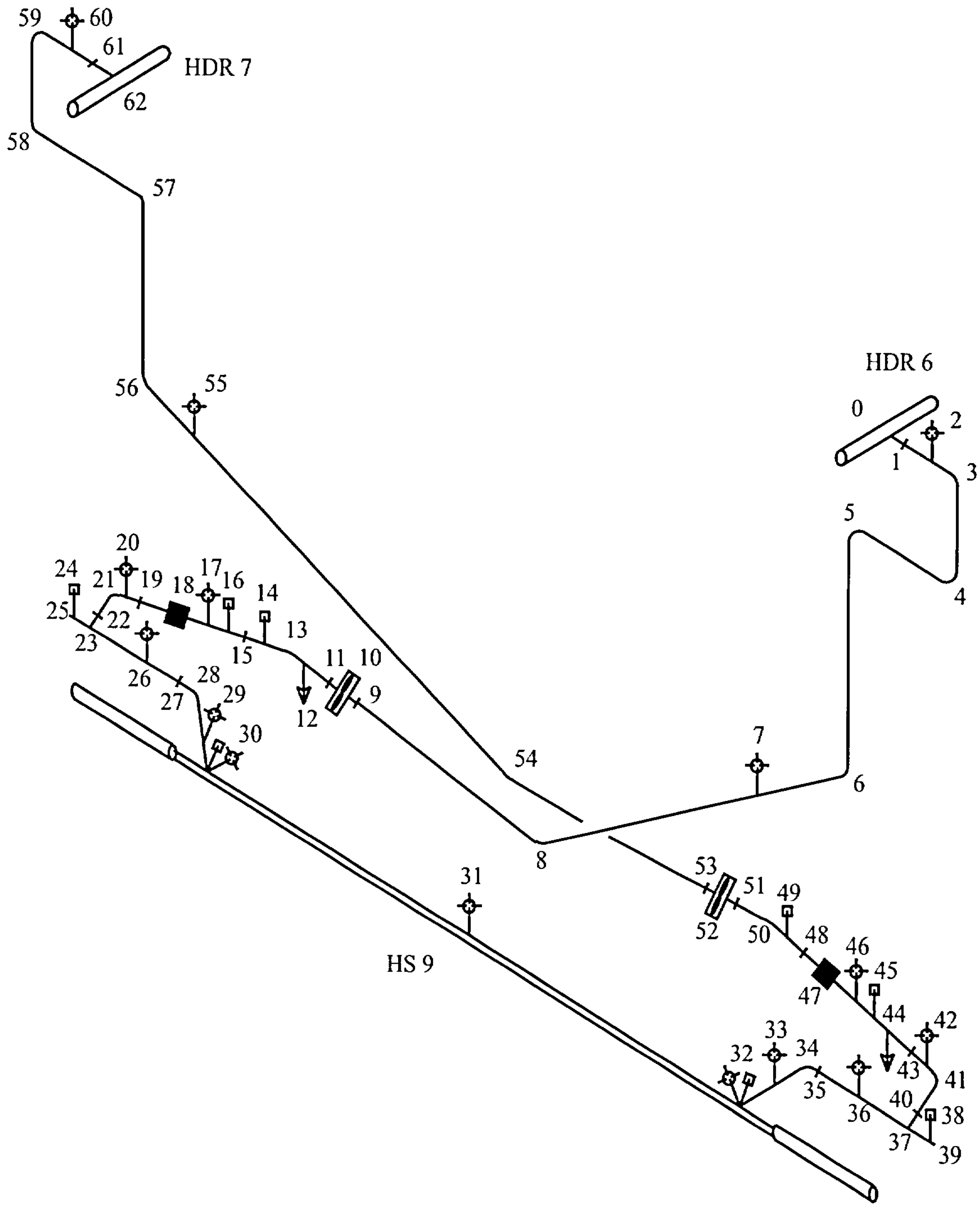

FIGURE 2.9: Elevation Diagram for Heated Section HS9 Feeders

FIGURE 2.9 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR6 Centreline	10.71			
			0.21	40.89	0
1	Grayloc/Reducer/Orifice (OR13)	10.71			
			0.25	26.64	0
2	Thermocouple (226T-D1)	10.71			
			0.35	26.64	0
3	Elbow (90°)	10.71			
			0.81	26.64	90
4	Elbow (90°)	9.89			
			0.97	26.64	0
5	Elbow (90°)	9.89			
			5.95	26.64	90
6	Elbow (55°)	3.91			
			0.95	26.64	35
7	Thermocouple (226T-D2)	3.37			
			4.80	26.64	35
8	Elbow (35°)	0.62			
			2.83	26.64	0
9	Grayloc	0.62			
10	Turbine Flowmeter (185F-D1)	0.62	0.21	29.46	0
11	Grayloc	0.62			
			0.23	26.64	0
12	Drain Line to Tank TK3	0.62			
			0.19	26.64	0
13	Elbow (20°)	0.62			
			0.10	26.64	0
14	Standoff	0.62			
			0.11	26.64	0
15	Grayloc	0.62			
			0.20	26.64	0
16	Standoff (28Q-D1/D2, 92P-D1,41Q-D1)	0 62			
			0.06	26.64	0
17	Thermocouple	0.62			

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Void Fraction Meter (23VF)	0.62	0.43	26.64	0
19	Grayloc	0.62			
			0.09	26.64	0
20	Thermocouple (226T-D3)	0.62			
			0.11	26.64	0
21	Elbow (107°)	0.62			
			0.13	26.64	32
22	Grayloc/Reducer	0.56			
			0.15	40.89	32
23	End-Fitting Tee	0.48			
			0.13	76.20	0
24	Standoff (93P-D1)	0.48			
			0.08	76.20	0
25	End-Fitting Cap	0.48			
------	------	------	------	------	------
23	End-Fitting Tee	0 48			
			0.36	76.20	0
26	Thermocouple (227T-D1,279T-D1)	0.48			
			0.76	76.20	0
27	Grayloc	0.48			
			0.10	76.20	0
28	Elbow (90°)/Reducer	0.48			
			0.15	42.90	0
29	Thermocouple (259T-D1)	0.48			
			0.15	42.90	0
30	HS9 Inlet Tee/Standoff/ Thermocouple (92P-D2,295T-D1)	0.48			
			2.85	44.80	0
31	Thermocouple (295T-D2)	0.48			
			3.05	44.80	0
32	HS9 Outlet Tee/Standoff/ Thermocouple (115P-D2,295T-D3)	0.48			
			0.15	42.90	0
33	Thermocouple (260T-D1)	0 48			
			0.15	42.90	0
34	Elbow (90°)/Reducer	0.48			
			0.10	76.20	0
35	Grayloc	0.48			
			0.76	76.20	0
36	Thermocouple (228T-D1,280T-D1)	0.48			
			0.36	76.20	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	0.48			
			0.13	76.20	0
38	Standoff (94P-D1)	0.48			
			0.08	76.20	0
39	End-Fitting Cap	0.48			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	0 48			
			0.15	40.89	32
40	Grayloc/Reducer	0.55			
			0.31	35.05	32
41	Elbow (107°)	0.72			
			0.10	35.05	0
42	Thermocouple (229T-D1)	0.72			
			0.10	35.05	0
43	Grayloc	0.72			
			0.14	35.05	0
44	Drain Line to Tank TK3	0.72			
			0.06	35.05	0
45	Standoff (28Q-D1/D2, 115P-D1,51Q-D1)	0.72	0.07	35 05	0
46	Thermocouple	0.72			
47	Void Fraction Meter (24VF)	0.72	0.43	35.05	0
48	Grayloc	0.72			
			0.11	35.05	0
49	Standoff	0.72			
			0.10	35.05	0
50	Elbow (20°)	0.72			
			0.43	35.05	0
51	Grayloc	0.72			
52	Turbine Flowmeter (186F-D1)	0.72	0.21	33.99	0
53	Grayloc	0.72			
			3.03	35.05	0
54	Elbow (35°)	0.72			
			4.26	35.05	35
55	Thermocouple (229T-D2)	3.20			
			1.40	35.05	35

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (55°)	4.00			
			5.99	35.05	90
57	Elbow (90°)	10.00			
			1.87	35.05	0
58	Elbow (90°)	10.00			
			0.71	35.05	90
59	Elbow (90°)	10.71			
			0.38	35.05	0
60	Thermocouple (229T-D3)	10.71			
			0.22	35.05	0
61	Grayloc	10.71			
			0.21	35.05	0
62	Header HDR7 Centreline	10.71			

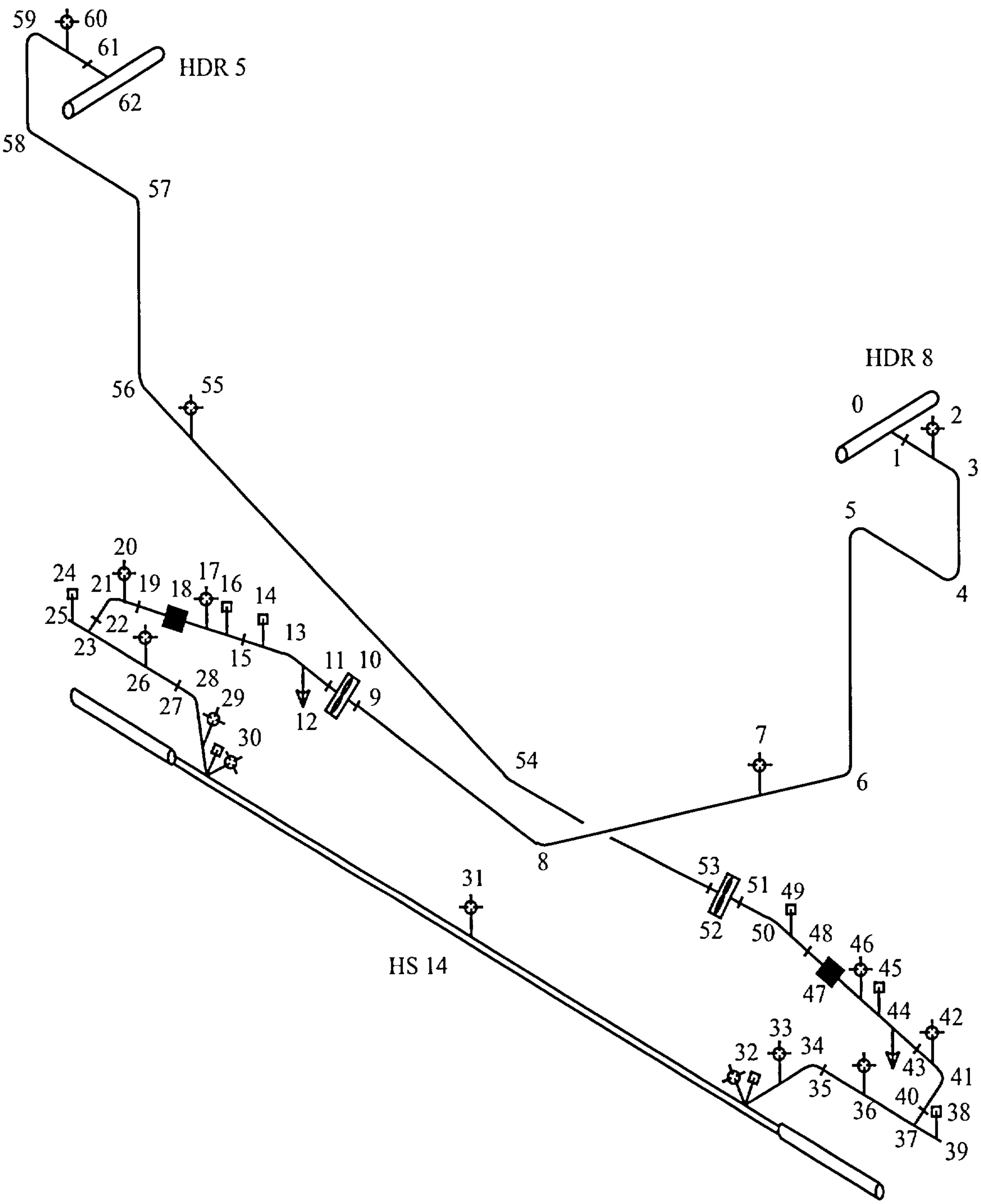

FIGURE 2.10: Elevation Diagram for Heated Section HS14 Feeders

FIGURE 2.10 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR8 Centreline	10.71			
			0.21	40.89	0
1	Grayloc/Reducer/Orifice (OR19)	10.71			
			0.25	26.64	0
2	Thermocouple (247T-D1)	10.71			
			0.35	26.64	0
3	Elbow (90°)	10.71			
			0.81	26.64	90
4	Elbow (90°)	9.89			
			0.97	26.64	0
5	Elbow (90°)	9.89			
			5.95	26.64	90
6	Elbow (55°)	3.91			
			0.95	26.64	35
7	Thermocouple (247T-D2)	3.37			
			4.80	26.64	35
8	Elbow (35°)	0.62			
			2.83	26.64	0
9	Grayloc	0 62			
10	Turbine Flowmeter (195F-D1)	0.62	0.21	29.46	0
11	Grayloc	0.62			
			0.23	26.64	0
12	Drain Line to Tank TK3	0.62			
			0.19	26.64	0
13	Elbow (20°)	0.62			
			0.10	26.64	0
14	Standoff	0.62			
			0.11	26.64	0
15	Grayloc	0.62			
			0.20	26.64	0
16	Standoff (33Q-D1/D2, 107P-D1,56Q-D1)	0.62			
			0.06	26.64	0
17	Thermocouple	0.62			

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Void Fraction Meter (33VF)	0.62	0.43	26.64	0
19	Grayloc	0.62			
			0.09	26.64	0
20	Thermocouple (247T-D3)	0.62			
			0.11	26.64	0
21	Elbow (107°)	0.62			
			0.13	26.64	32
22	Grayloc/Reducer	0.56			
			0.15	40.89	32
23	End-Fitting Tee	0.48			
			0.13	76.20	0
24	Standoff (109P-D1)	0.48			
			0.08	76.20	0
25	End-Fitting Cap	0.48			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
23	End-Fitting Tee	0.48			
			0.36	76.20	0
26	Thermocouple (246T-D1,289T-D1)	0.48			
			0.76	76.20	0
27	Grayloc	0.48			
			0.10	76.20	0
28	Elbow (90°)/Reducer	0.48			
			0.15	42.90	0
29	Thermocouple (269T-D1)	0.48			
			0.15	42.90	0
30	HS14 Inlet Tee/Standoff/ Thermocouple (107P-D2,300T-D1)	0.48			
			2.85	44.80	0
31	Thermocouple (300T-D2)	0.48			
			3.05	44.80	0
32	HS14 Outlet Tee/Standoff/ Thermocouple (120P-D2,300T-D3)	0.48			
			0.15	42.90	0
33	Thermocouple (270T-D1)	0.48			
			0.15	42.90	0
34	Elbow (90°)/Reducer	0.48			
			0.10	76.20	0
35	Grayloc	0.48			
			0.76	76.20	0
36	Thermocouple (248T-D1,290T-D1)	0.48			
			0.36	76.20	0

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	End-Fitting Tee	0.48			
			0.13	76.20	0
38	Standoff (108P-D1)	0.48			
			0.08	76.20	0
39	End-Fitting Cap	0.48			
37	End-Fitting Tee	0.48			
			0.15	40.89	32
40	Grayloc/Reducer	0.55			
			0.31	35.05	32
41	Elbow (107°)	0.72			
			0.10	35.05	0
42	Thermocouple (249T-D1)	0.72			
			0.10	35.05	0
43	Grayloc	0.72			
			0.14	35.05	0
44	Drain Line to Tank TK3	0.72			
			0.06	35.05	0
45	Standoff (33Q-D1/D2, 120P-D1,46Q-D1)	0.72			
			0.07	35.05	0
46	Thermocouple	0.72			
47	Void Fraction Meter (34VF)	0.72	0.43	35.05	0
48	Grayloc	0.72			
			0.11	35.05	0
49	Standoff	0.72			
			0.10	35.05	0
50	Elbow (20°)	0.72			
			0.43	35.05	0
51	Grayloc	0.72			
52	Turbine Flowmeter (196F-D1)	0.72	0.21	33.99	0
53	Grayloc	0.72			
			3.03	35.05	0
54	Elbow (35°)	0.72			
			4.26	35.05	35
55	Thermocouple (249T-D2)	3.20			
			1.40	35.05	35

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Elbow (55°)	4.00			
			5.99	35.05	90
57	Elbow (90°)	10.00			
			1.87	35.05	0
58	Elbow (90°)	10.00			
			0.71	35.05	90
59	Elbow (90°)	10.71			
			0.38	35.05	0
60	Thermocouple (249T-D3)	10.71			
			0.22	35.05	0
61	Grayloc	10.71			
			0.21	35.05	0
62	Header HDR5 Centreline	10.71			

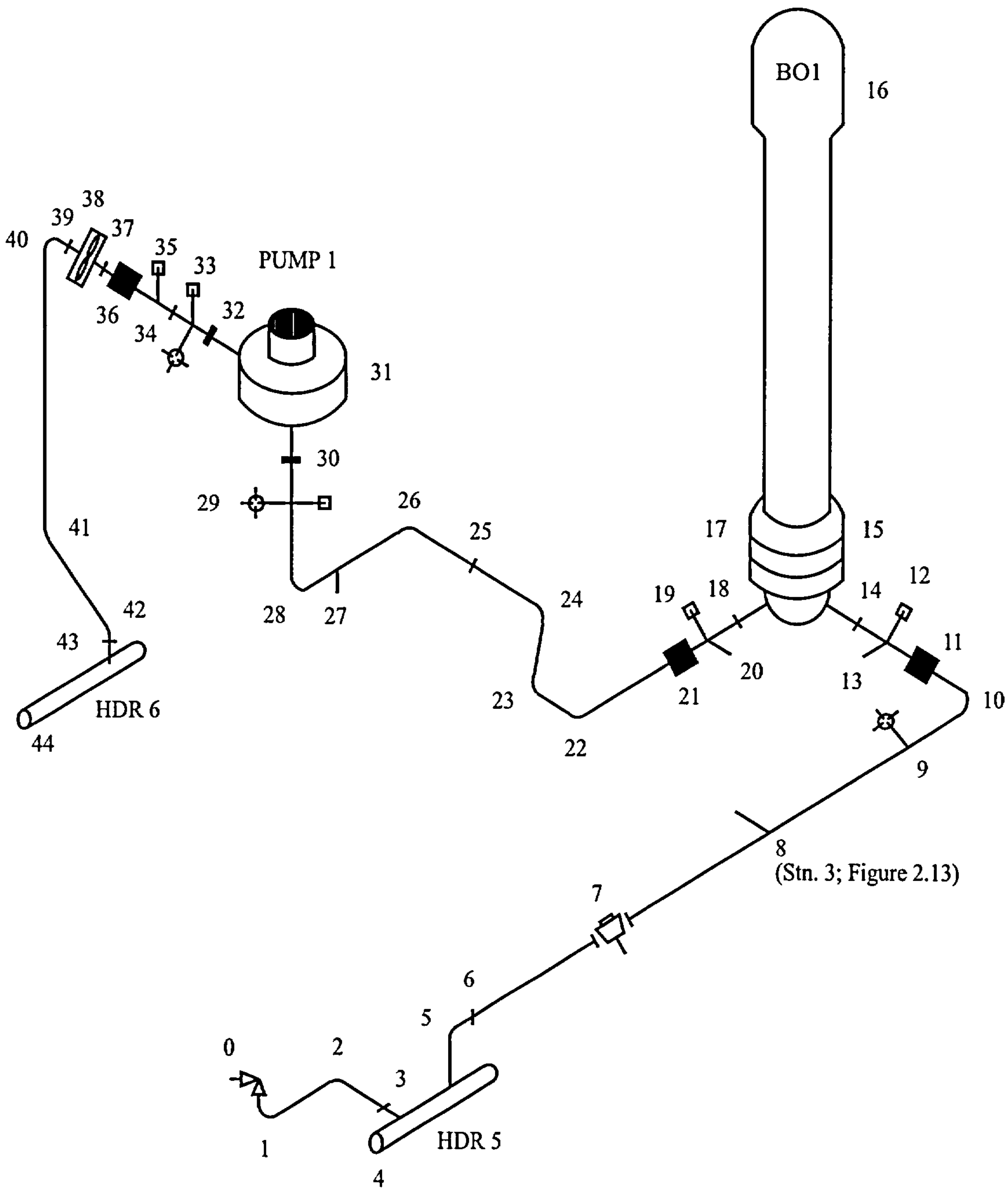

FIGURE 2.11: Elevation Diagram for Primary Circuit Above Headers HDR5 and HDR6

FIGURE 2.11 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Relief Valve (RV5) Bottom	11.00			
			0.18	49.25	90
1	Elbow (90°)	10.82			
			1.12	49.25	0
2	Elbow (90°)	10.82			
			0.19	49.25	15
3	Grayloc/Reducer	10.77			
			0.25	97.18	15
4	Header HDR5	10.71			
4	Header HDR5	10.71			
			0.27	97.18	90
5	Elbow (75°)	10.98			
			0.21	97.18	15
6	Grayloc	11.03			
			0.70	97.18	15
7	Strainer/Drain	11.21			
			0.87	97.18	15
8	Tee (Interconnect Takeoff; same as Stn. 3, Fig. 2.14)	11.44			
				97.18	15
9	Surface Thermocouple (98T)		0.70		
				97.18	15
10	Elbow (90°)	11.62			
			0.55	97.18	75
11	Void Fraction Meter (11VF-DT1,11VF-DT2)	12.15			
			0.32	97.18	75
12	Standoff (16Q-D1,3Q-D1)	12.46			
				97.18	75
13	Piezo Electric Tap (123P)		0.15		
				97.18	75
14	Steam Generator BO1 Inlet	12.61			
			0.70		90
15	Steam Generator BO1 Tube Sheet	13.31			
			9.46		90
16	Steam Generator BO1 Top	22.77			
			9.46		90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
17	Steam Generator BO1 Tube Sheet	13.31			
			0.70		90
18	Steam Generator BO1 Outlet	12.61			
			0.15	97.18	75
19	Standoff (3Q-D1,4Q-D1)	12.46			
				97.18	75
20	Piezo Electric Tap (124P)		0.26		
				97.18	75
21	Void Fraction Meter (11VF-DT3,11VF-DT4)	12.21			
			0.59	97.18	75
22	Elbow (45°)	11.64			
			0.33	97.18	45
23	Elbow (45°)	11.41			
			0.33	97.18	0
24	Elbow (90°)	11.41			
			0.74	97.18	0
25	Grayloc	11.41			
			0.52	97.18	0
26	Elbow (90°)	11.41			
			0.37	97.18	0
27	Drain (0.5 inch)	11.41			
			0.18	97.18	0
28	Elbow (90°)	11.41			
			0.75	97.18	90
29	Standoff/Thermocouple (4Q-D1, 5Q-D1/D2,124T)	12.16			
			0.15	97.18	90
30	Pump P1 Inlet Flange	12.31			
31	Pump P1				
32	Pump P1 Outlet Flange	12.65			
			0.11	77.92	0
33	Standoff/Thermocouple (133P-D1, 5Q-D1/D2,6Q-D1,125T)	12.65			
			0.10	77.92	0
34	Grayloc	12.65			
			0.13	77.92	0
35	Standoff/Vent	12.65			
			0.32	77.92	0
36	Void Fraction Meter (1VF)	12.65			
			0.22	77.92	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Grayloc	12.65			
38	Turbine Flowmeter (1F)		0.33	76.20	0
39	Grayloc	12.65			
			0.46	77.92	0
40	Elbow (90°)	12.65			
			0.67	77.92	90
41	Elbow (45°)	11.98			
			1.23	77.92	45
42	Elbow (45°)	11.11			
			0.16	77.92	90
43	Grayloc	10.95			
			0.24	77.92	90
44	Header HDR6	10.71			

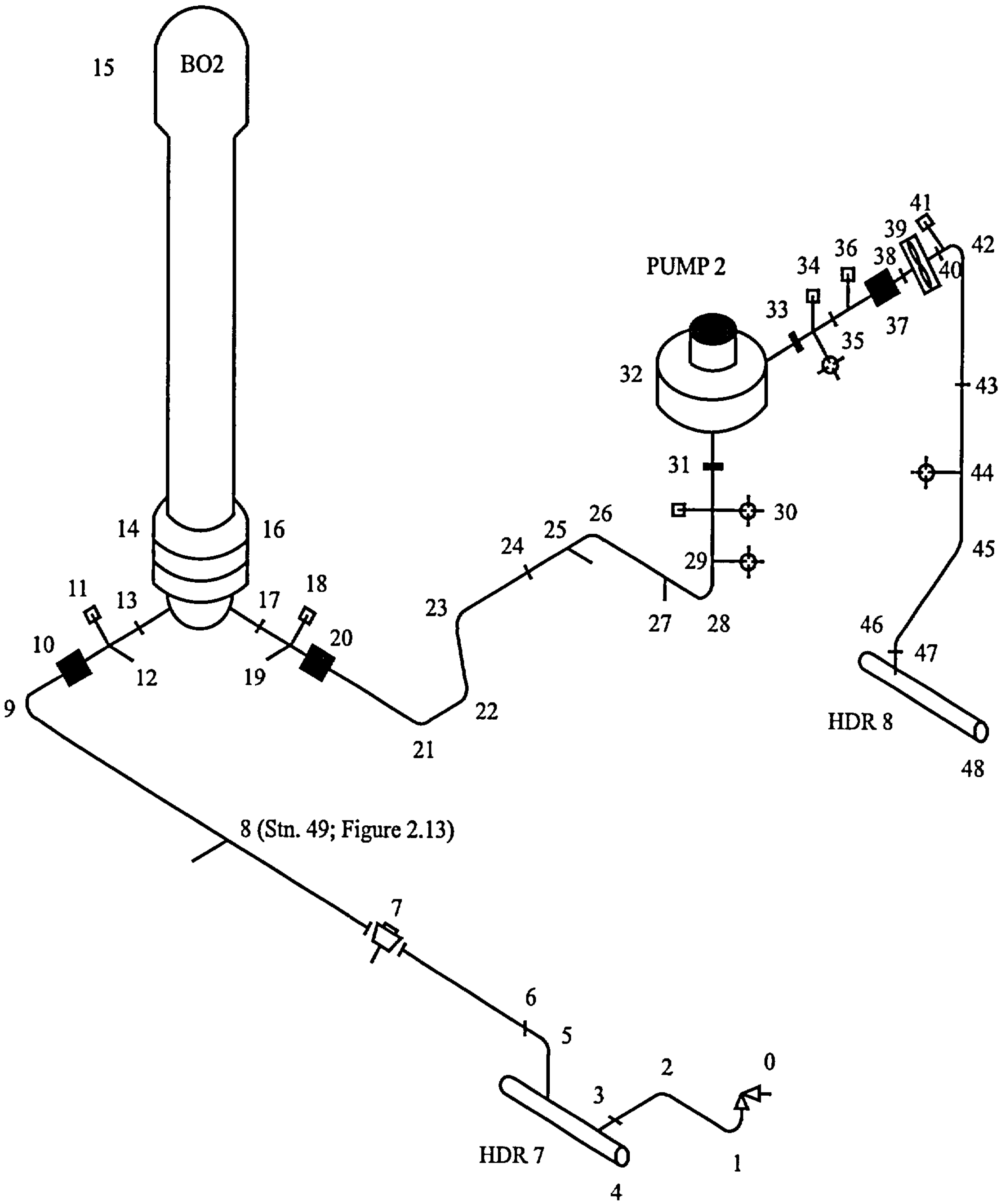

FIGURE 2.12: Elevation Diagram for Primary Circuit Above Headers HDR7 and HDR8

FIGURE 2.12 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Relief Valve (RV6) Bottom	11.00			
			0.18	49.25	90
1	Elbow (90°)	10.82			
			1.12	49.25	0
2	Elbow (90°)	10.82			
			0.19	49.25	15
3	Grayloc/Reducer	10.77			
			0.25	97.18	15
4	Header HDR7	10.71			
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4	Header HDR7	10.71			
			0.27	97.18	90
5	Elbow (75°)	10.98			
			0.21	97.18	15
6	Grayloc	11.03			
			0.70	97.18	15
7	Strainer/Drain	11.21			
			0.87	97.18	15
8	Tee (Interconnect Takeoff; same as Stn. 49, Fig. 2.14)	11.44			
			0.70	97.18	15
9	Elbow (90°)	11.62			
			0.55	97.18	75
10	Void Fraction Meter (12VF-DT3,12VF-DT4)	12.15			
			0.32	97.18	75
11	Standoff (9Q-D1,10Q-D1)	12.46			
				97.18	75
12	Piezo Electric Tap (125P)		0.15		
				97.18	75
13	Steam Generator BO2 Inlet	12.61			
			0.70		90
14	Steam Generator BO2 Tube Sheet	13.31			
			9.46		90
15	Steam Generator BO2 Top	22.77			
			9.46		90
16	Steam Generator BO2 Tube Sheet	13.31			
			0.70		90

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
17	Steam Generator BO2 Outlet	12.61			
			0.15	97.18	75
18	Standoff (10Q-D1,11Q-D1)	12.46			
				97.18	75
19	Piezo Electric Tap (126P)		0.26		
				97.18	75
20	Void Fraction Meter	12.21			
	(12VF-DT1,12VF-DT2)		0.59	97.18	75
21	Elbow (45°)	11.64			
			0.33	97.18	45
22	Elbow (45°)	11.41			
			0.33	97.18	0
23	Elbow (90°)	11.41			
			0.74	97.18	0
24	Grayloc	11.41			
			0.45	97.18	0
25	Distilled H_20 Addition	11.41			
			0.07	97.18	0
26	Elbow (90°)	11.41			
			0.37	97.18	0
27	Drain (0.5 inch)	11.41			
			0.18	97.18	0
28	Elbow (90°)	11.41			
				97.18	90
29	Surface Thermocouple (90T)		0.75		
				97.18	90
30	Standoff/Thermocouple (11Q-D1,	12.16			
	12Q-D1/D2,122T)		0.15	97.18	90
31	Pump P2 Inlet Flange	12.31			
32	Pump P2				
33	Pump P2 Outlet Flange	12.65			
			0.11	77.92	0
34	Standoff/Thermocouple (12Q-D1/D2,	12.65			
	13Q-D1,123T,134P-D1)		0.10	77.92	0
35	Grayloc	12.65			
			0.13	77.92	0
36	Standoff/Vent (2F-DP)	12.65			
			0.32	77.92	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
37	Void Fraction Meter (4VF)	12.65			
			0.22	77.92	0
38	Grayloc	12.65			
39	Turbine Flowmeter (2F)	12.65	0.33	76.20	0
40	Grayloc	12.65			
			0.07	77.92	0
41	Standoff (2F-DP)	12.65			
			0.39	77.92	0
42	Elbow (90°)	12.65			
			0.30	77.92	90
43	Grayloc	12.35			
				77.92	90
44	Surface Thermocouple (91T)		0.37		
				77.92	90
45	Elbow (45°)	11.98			
			1.13	77.92	45
46	Elbow (45°)	11.18			
			0.23	77.92	90
47	Grayloc	10.95			
			0.24	77.92	90
48	Header HDR8	10.71			

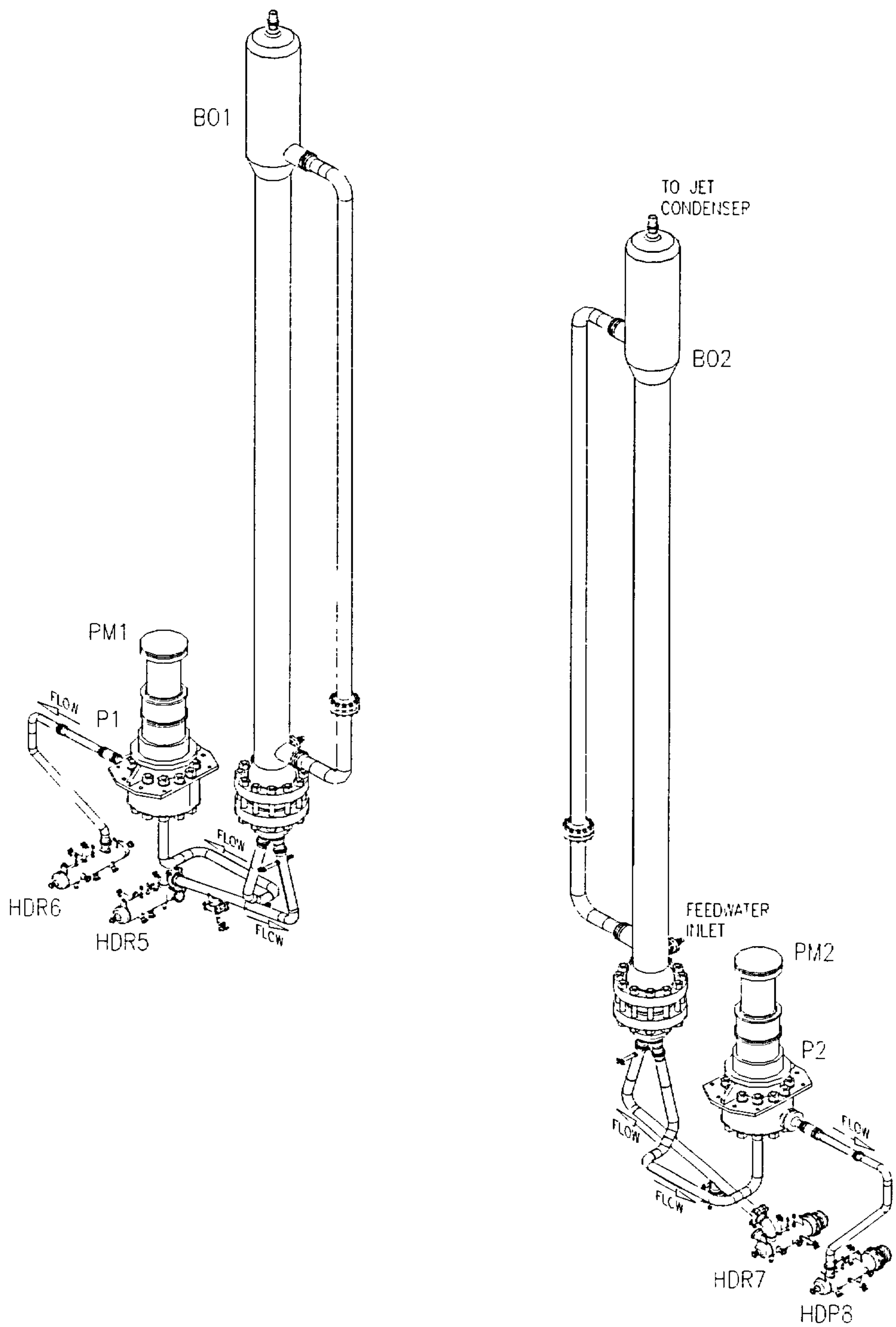


FIGURE 2.13: Above Header Schematic

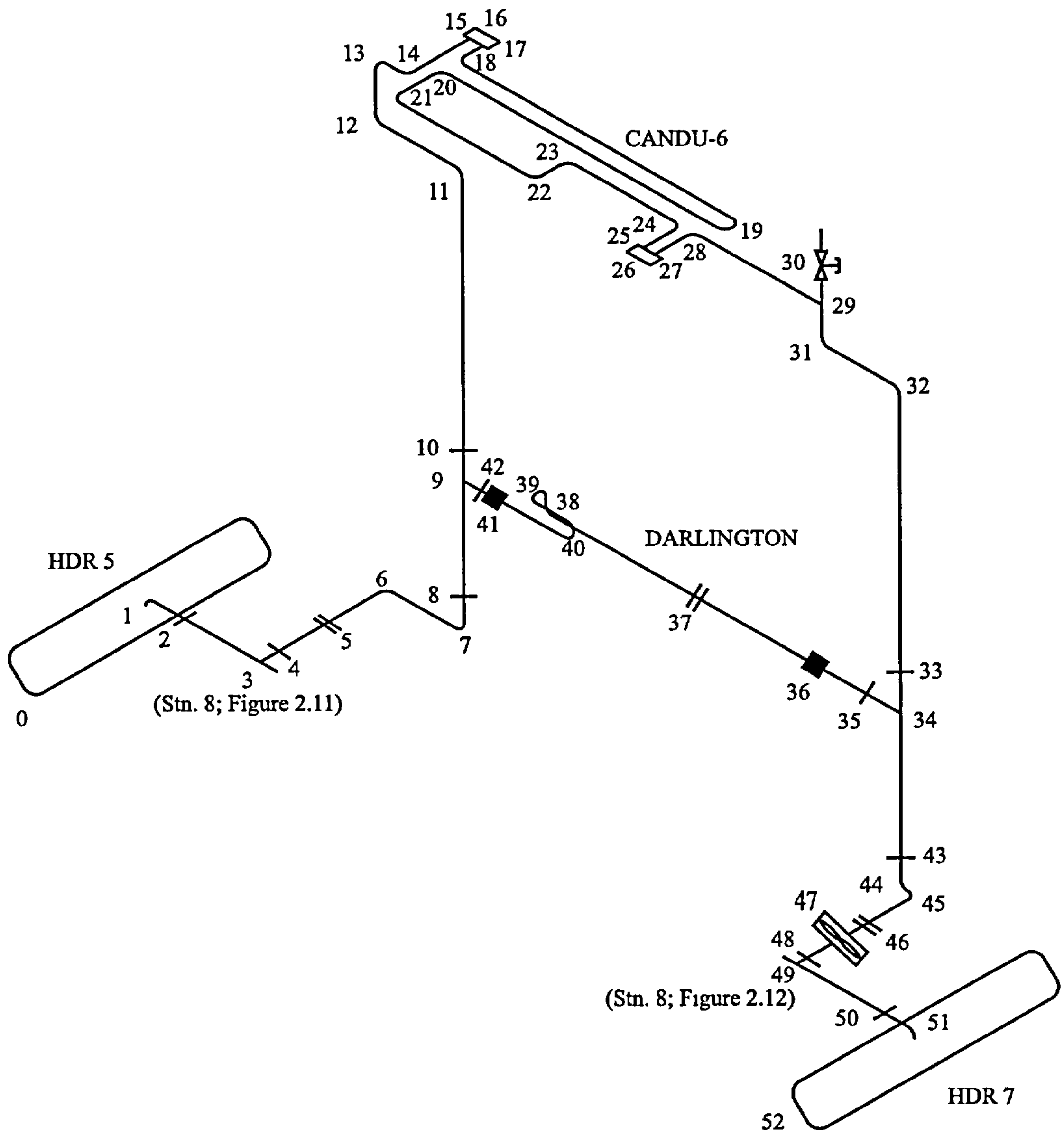


FIGURE 2.14: Elevation Diagram for Outlet Header Interconnects

FIGURE 2.14 Legend

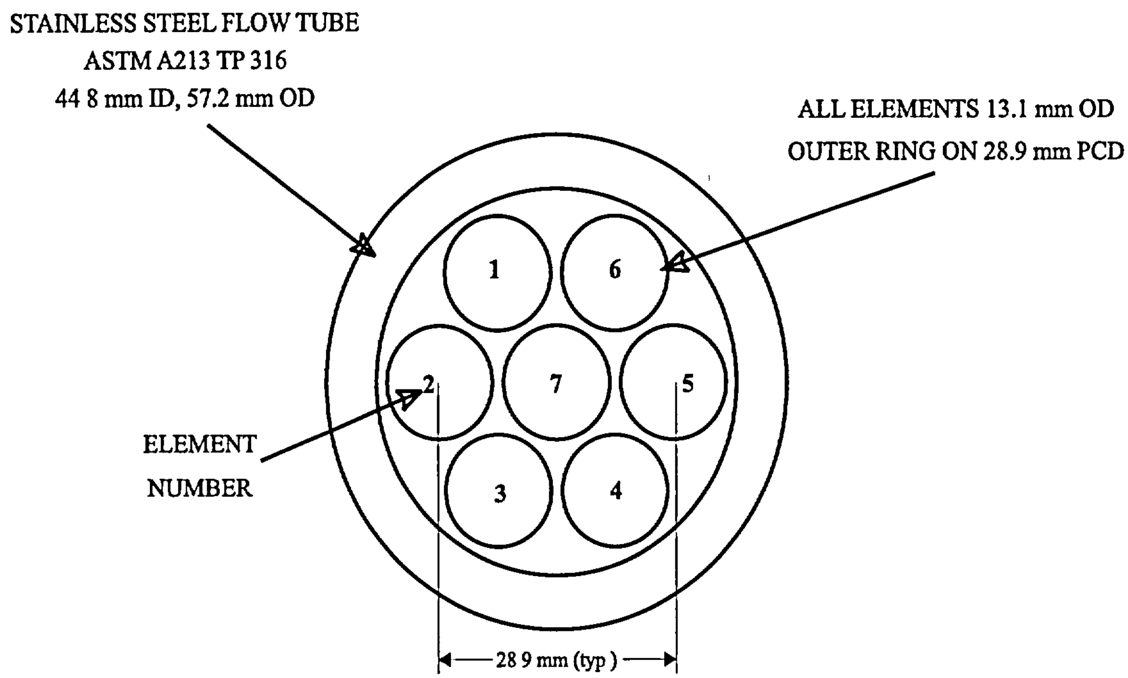
STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
0	Header HDR5	10.71			
			0.27	97.18	90
1	Elbow (75°)	10.98			
			0.21	97.18	15
2	Grayloc	11.03			
			1.57	97.18	15
3	Tee (Interconnect Takeoff;	11.44			
	same as Stn. 8, Fig. 2.11)		0.06	24.31	0
4	Grayloc	11.44			
			0.92	24.31	0
5	Grayloc/Orifice Flowmeter	11.44		8.50	
	(200F-D1)		1.23	24.31	0
6	Elbow (97.5°)	11.44			
			0.62	24.31	0
7	Elbow (90°)	11.44			
			0.08	24.31	90
8	Grayloc	11.52			
			0.86	24.31	90
9	Tee	12.38			
			0.08	24.31	90
10	Grayloc/Reducer	12.46			
			1.79	13.87	90
11	Elbow (45°)	14.25			
			1.42	13.87	45
12	Elbow (45°)	15.25			
			0.93	13.87	90
13	Elbow (90°)	16.18			
			0.70	13.87	0
14	Elbow (90°)	16.18			
			0.50	13.87	0
15	Tee	16.18			
16	Void Fraction Meter (37VF)	16.18	0.05	13.87	0
17	Tee	16.18			
			0.34	13.87	0

2. PRIMARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Elbow (90°)	16.18			
			4.00	13.87	0
19	Elbow (90°) (South)	16.18			
			0.10	13.87	0
19	Elbow (90°) (North)	16.18			
			3.90	13.87	0
20	Elbow (90°)	16.18			
			0.75	13.87	0
21	Elbow (90°)	16.18			
			3.20	13.87	0
22	Elbow (90°)	16.18			
			0.64	13.87	0
23	Elbow (90°)	16.18			
			0.98	13.87	0
24	Elbow (90°)	16.18			
			0.50	13.87	0
25	Tee	16.18			
26	Void Fraction Meter (38VF)	16.18	0.05	13.87	0
27	Tee	16.18			
			0.50	13.87	0
28	Elbow (90°)	16.18			
			0.50	13.87	0
29	Tee	16.18			
			0.12	13.87	90
30	Manual Vent Valve (V446)	16.30			
29	Tee	16.18			
			0.83	13.87	90
31	Elbow (45°)	15.35			
			1.55	13.87	45
32	Elbow (45°)	14.25			
			1.79	13.87	90
33	Grayloc/Reducer	12.46			
			0.08	24.31	90
34	Tee	12.38			
			0.86	24.31	90
43	Grayloc	11.52			
			0.08	24.31	90

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
44	Elbow (90°)	11.44			
			0.09	24.31	0
45	Elbow (88.3°)	11.44			
			1.15	24.31	0
46	Grayloc/Orifice Flowmeter (230F-D1)	11.44		8.50	
			0.46	24.31	0
47	Turbine Flowmeter (246F-D1)	11.44			
			0.46	24.31	0
48	Grayloc	11.44			
			0.06	24.31	0
49	Tee (Interconnect Takeoff; see Stn. 8, Fig. 2.12)	11.44			
			1.57	97.18	15
50	Header Outlet Grayloc	11.06			
			0.21	97.18	15
51	Elbow (75°)	10.98			
			0.27	97.18	90
52	Header HDR7	10.71			

34	Tee	12.38			
			0.08	24.31	0
35	Grayloc	12.38			
			0.24	24.31	0
36	Void Fraction Meter (36VF)	12.38			
			3.21	24.31	0
37	Grayloc/Orifice Flowmeter (201F-D1)	12.38		9.70	
			1.44	24.31	0
38	Elbow (90°) (Bottom)	12.38			
			0.07	24.31	90
38	Elbow (90°) (Top)	12.45			
			0.10	24.31	0
39	Elbow (90°)	12.45			
			1.14	24.31	0
40	Elbow (90°) (Top)	12.45			
			0.07	24.31	90
40	Elbow (90°) (Bottom)	12.38			
			1.38	24.31	0
41	Void Fraction Meter (35VF)	12.38			
			0.16	24.31	0
42	Grayloc	12.38			
			0.08	24.31	0
9	Tee	12.38			



(VIEW FROM INLET END)

NOTE: ELEMENTS 5 AND 6 ARE INSTRUMENTED
ELEMENTS 1, 4, AND 7 ARE INSTRUMENTED
ELEMENTS 2 AND 3 ARE UNINSTRUMENTED

FIGURE 2.15: Seven-Element Heater Cross Section

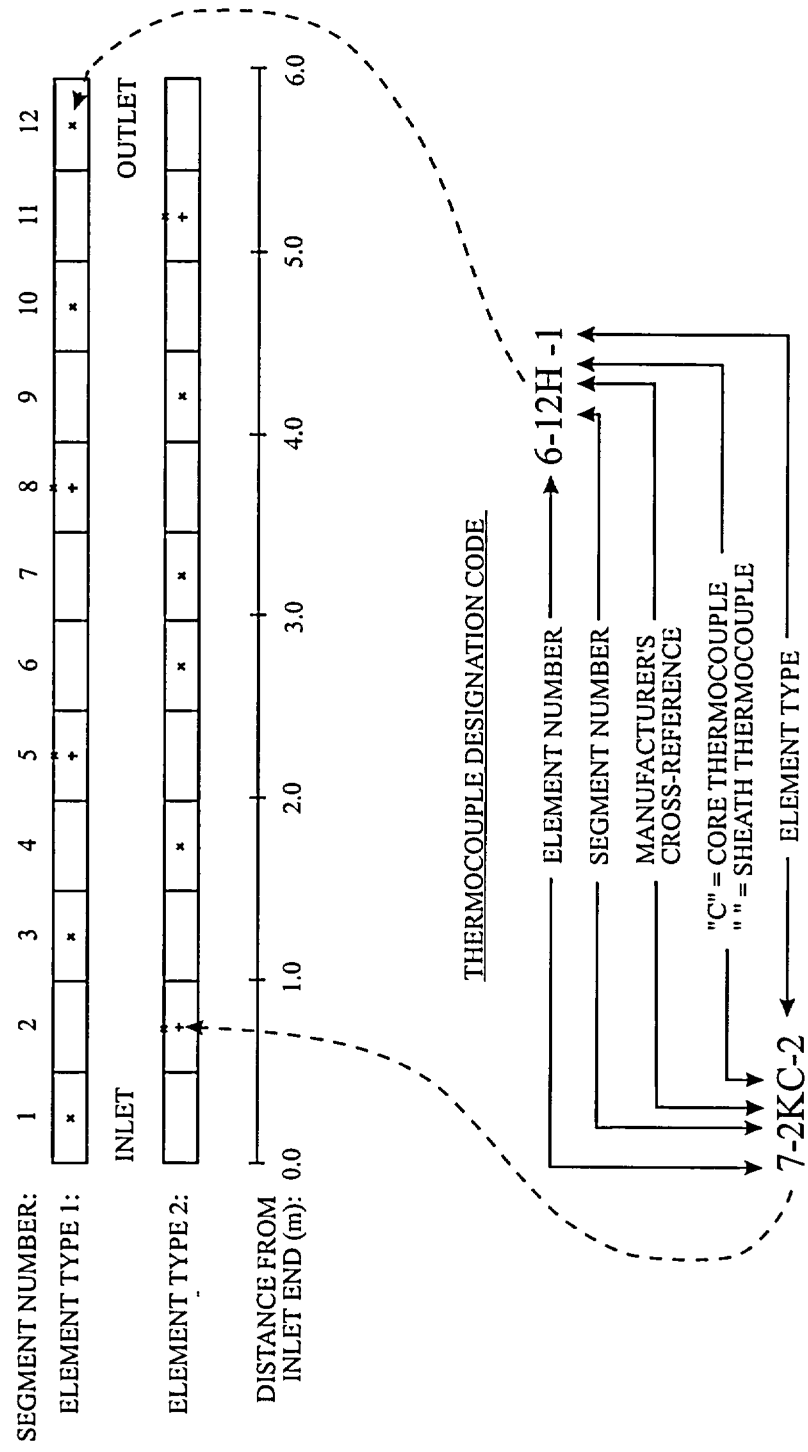
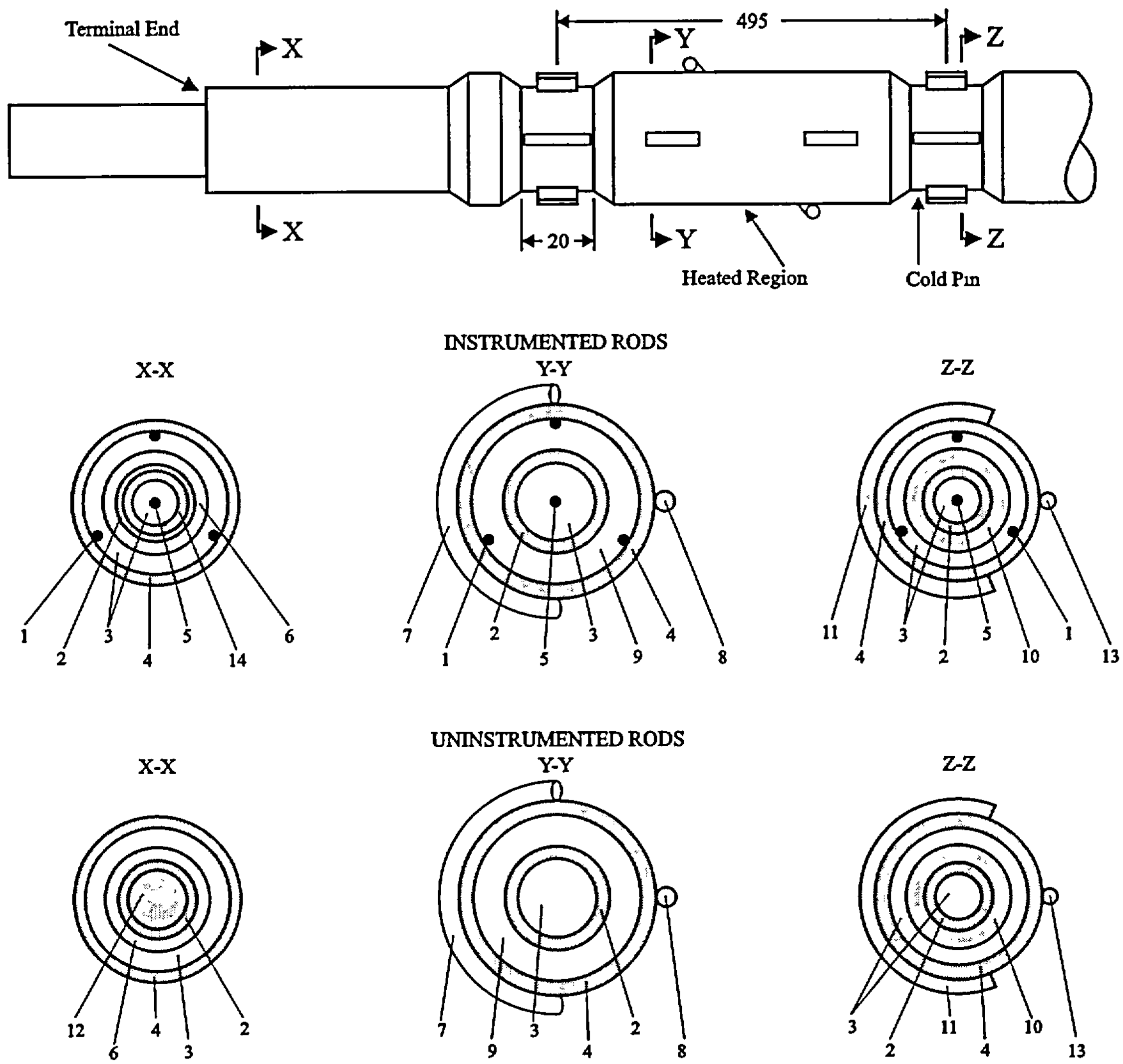


FIGURE 2.16: Nominal Thermocouple Locations and Identification Guide



1. Sheath Thermocouple
2. Inconel 625 Heater Tube
3. MgO
4. 304 Stainless Steel Sheath
5. Core Thermocouple
6. Nickel 200 Terminal End Oversleeve
7. Spiral Spacer Wire
8. Bundle Bearing Pad (outer elements only)
9. Boron Nitride
10. Nickel 200 Cold Pin Oversleeve
11. Bundle Retaining Clip
12. Solid Copper Terminal End
13. Cold Pin Spacer Wire
14. Copper Tube Terminal End

FIGURE 2.17: Fuel Element Simulator (FES) Construction Details

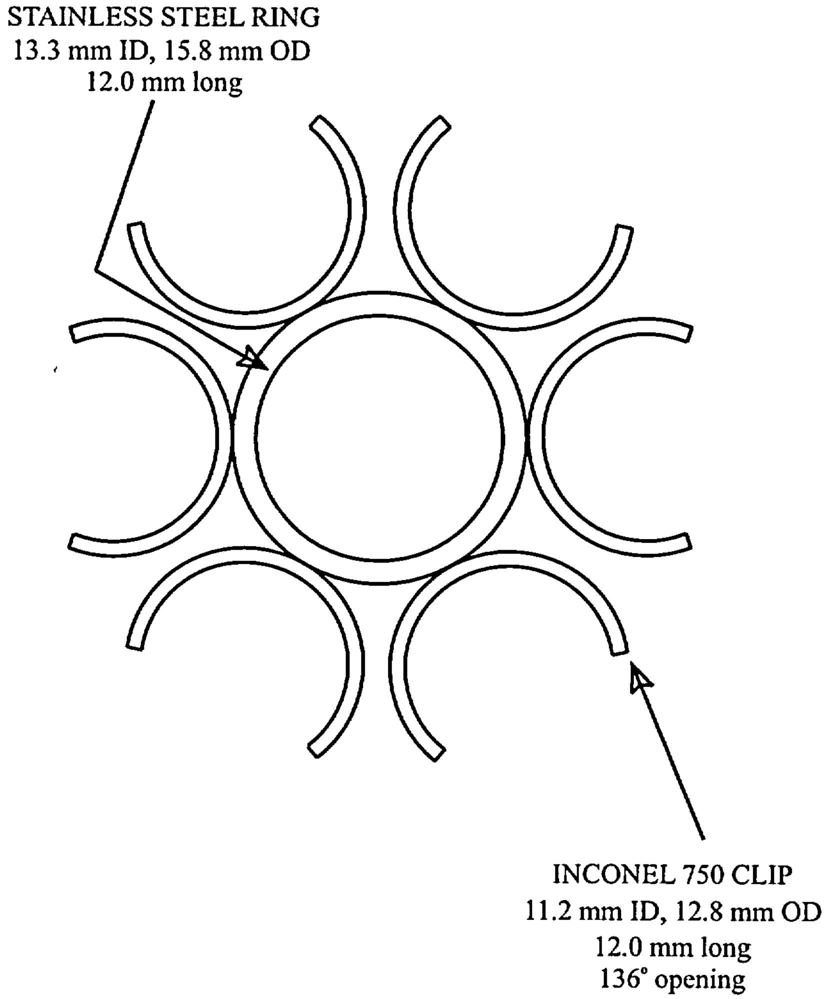


FIGURE 2.18: Bundle Retainer Assembly

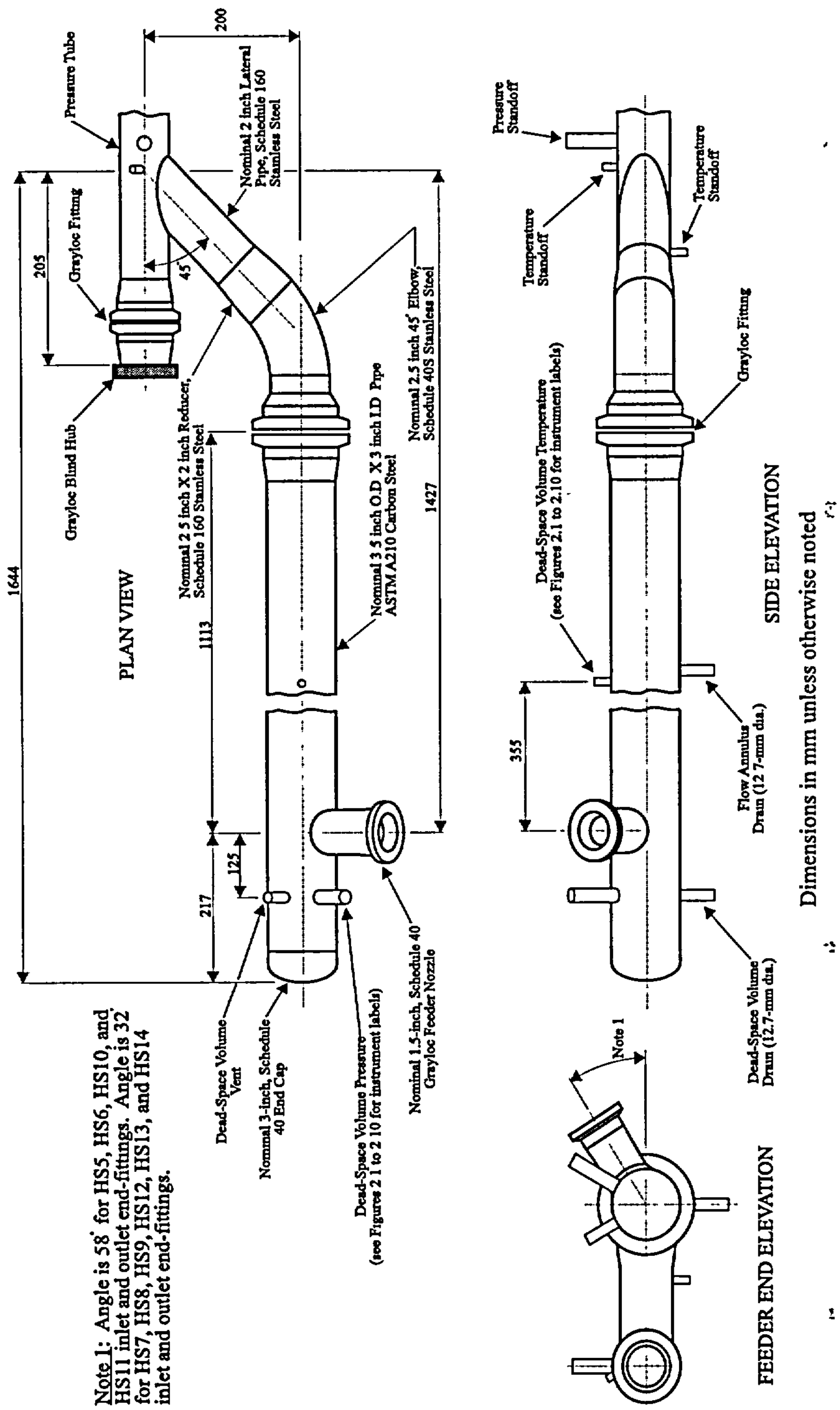


FIGURE 2.19: End-Fitting Simulator Overall Construction

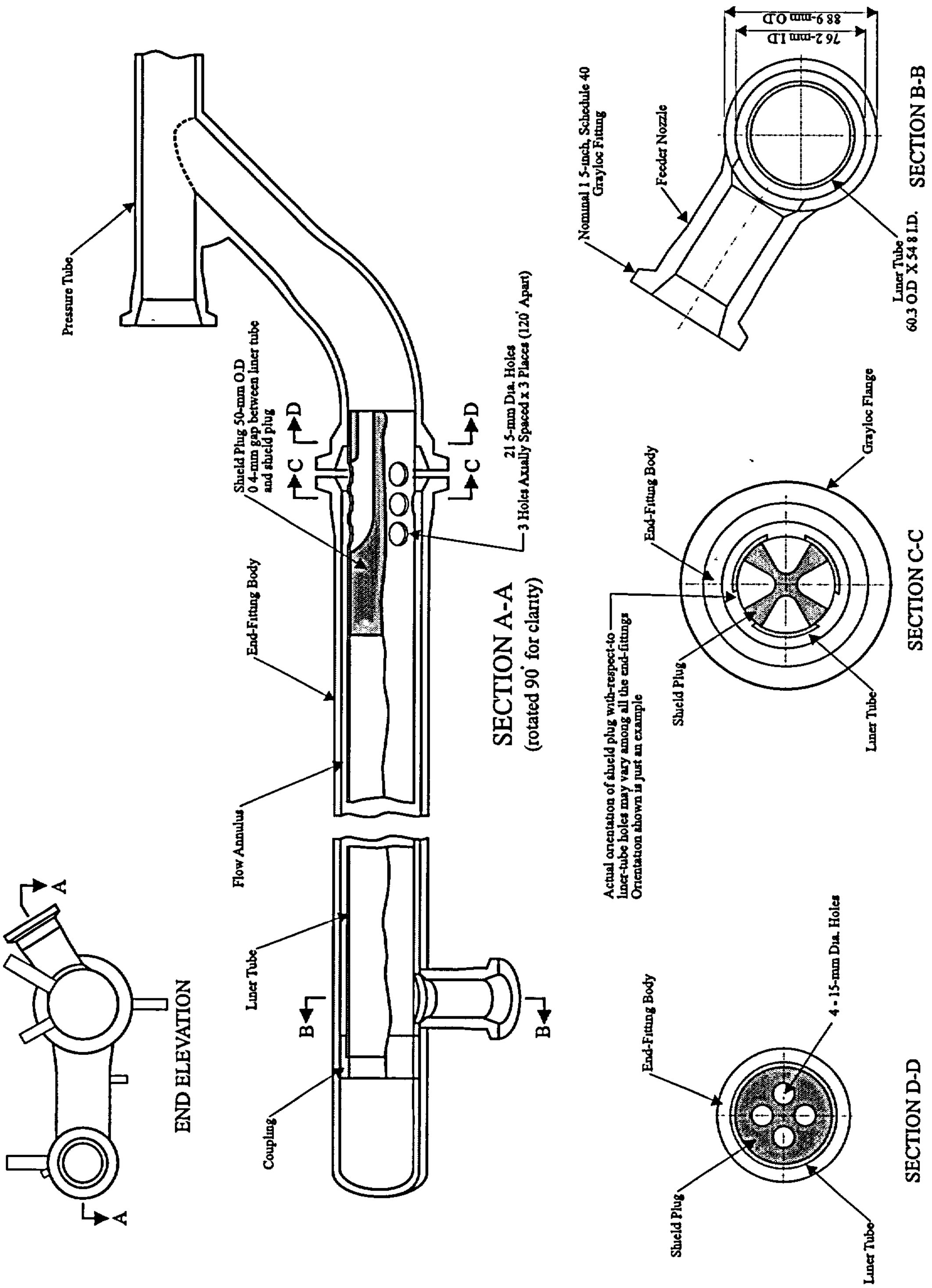


FIGURE 2.20: End-Fitting Simulator Details

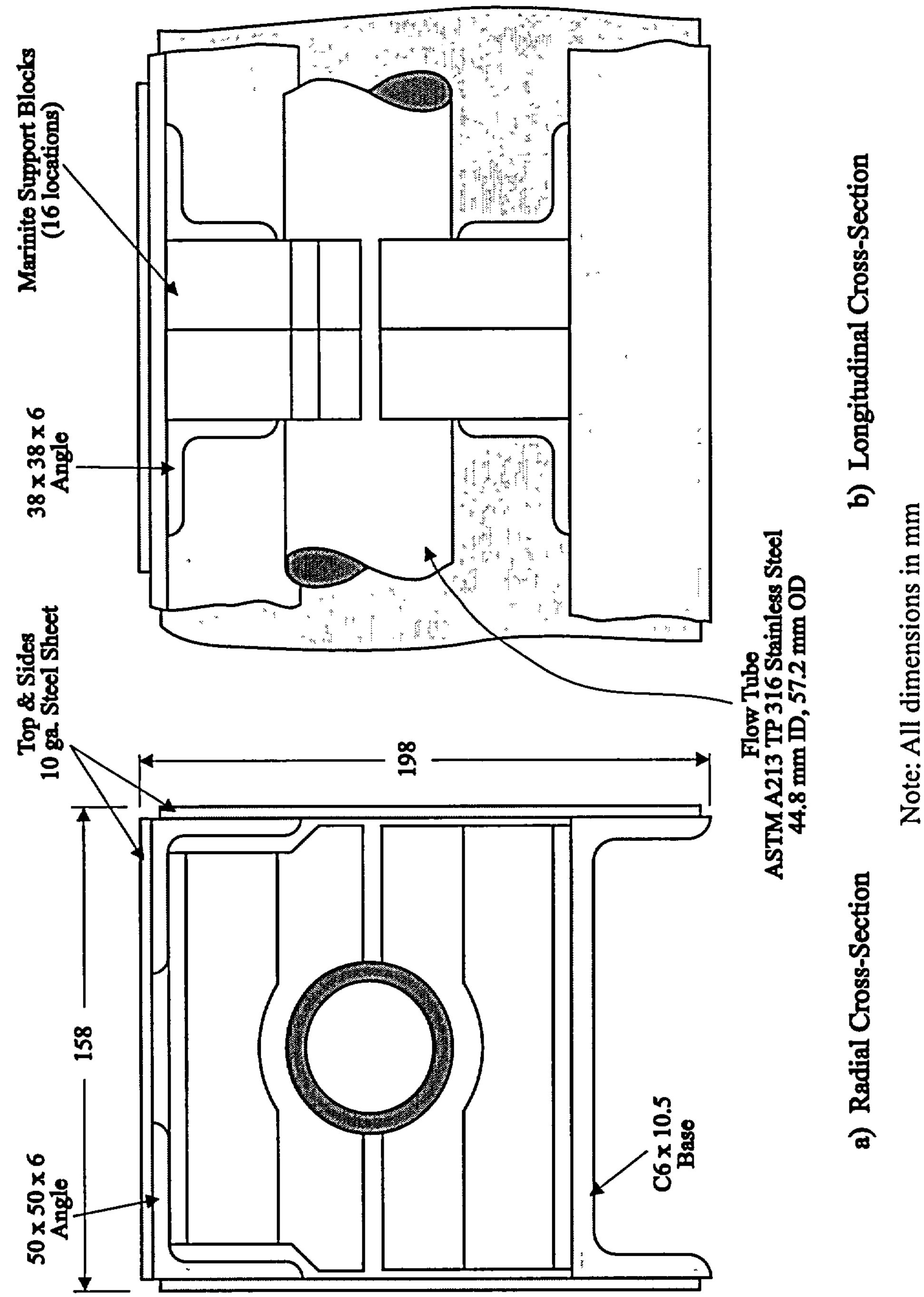
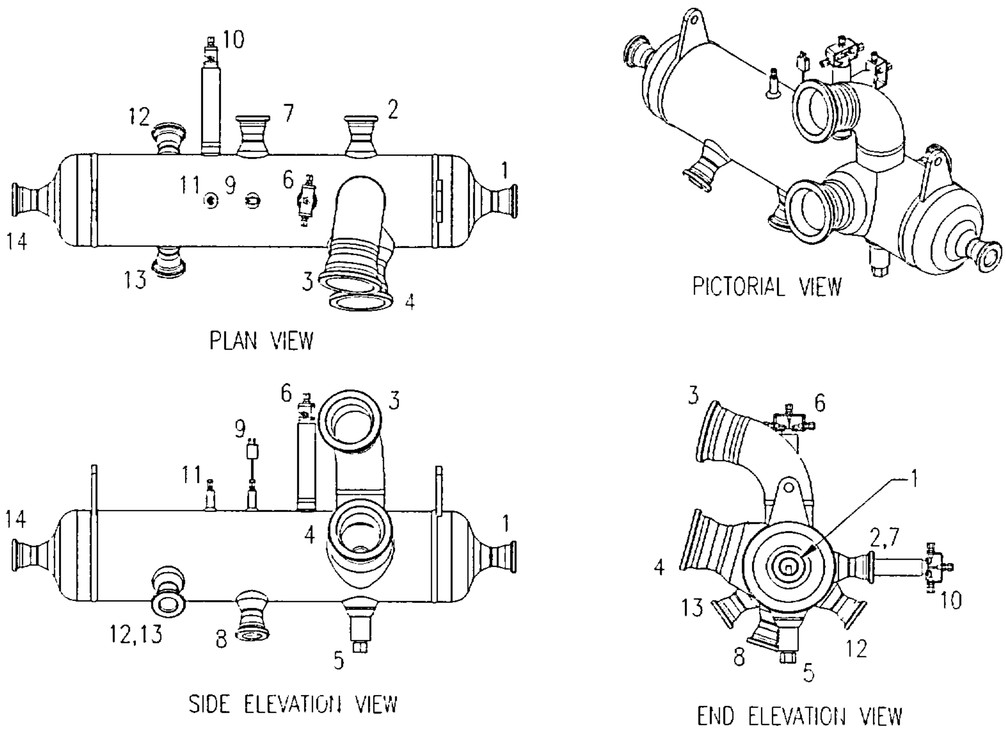


FIGURE 2.21: Heated-Section Strongback Details

2. PRIMARY HEAT TRANSPORT SYSTEM



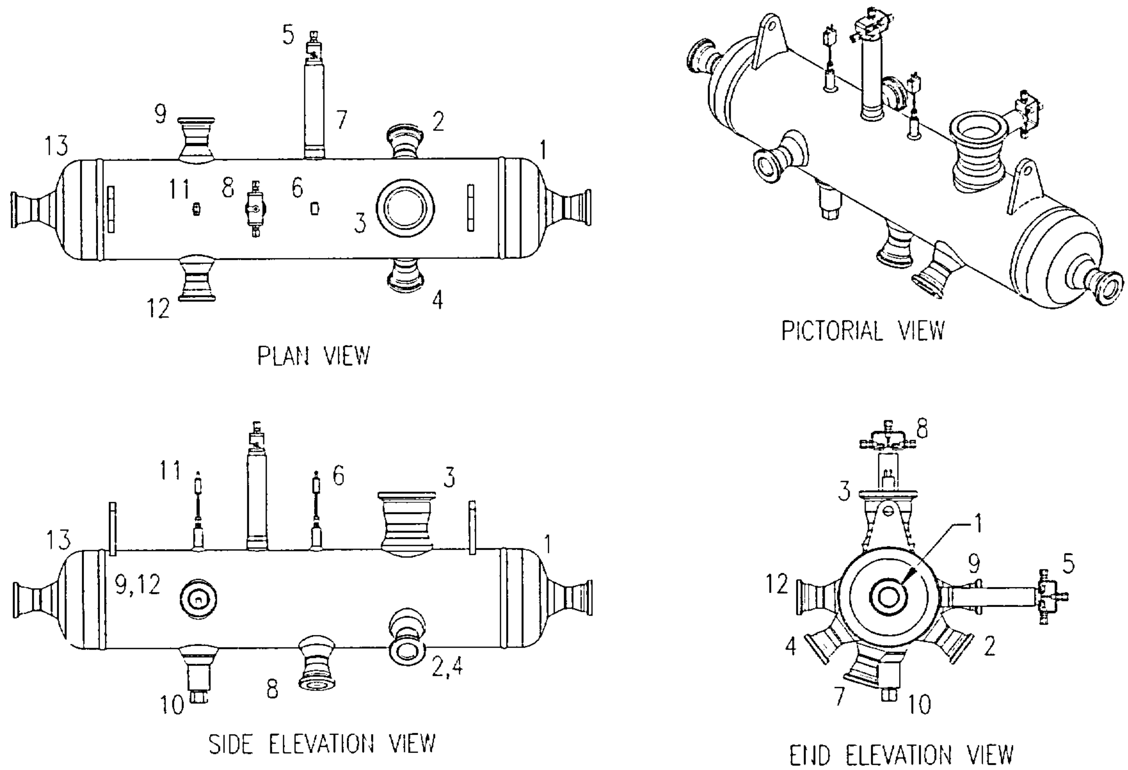
Station Number	Description	Axial Distance From ECI End (mm)	Radial Orientation*
1	ECI Nozzle	0	n/a
2	HS14 Outlet Feeder Nozzle	279	90°
3	Outlet Nozzle (BO1 Inlet)	279	0°
4	Outlet Nozzle (RV5)	279	285°
5	RTD Thermowell (24T)	279	180°
6	Pressure Tap**	409	0°
7	HS12 Outlet Feeder Nozzle	539	90°
8	HS13 Outlet Feeder Nozzle	539	198°
9	Thermocouple Tap (23T-D2) (thermocouple extends to header centreline)	539	0°
10	Pressure Tap	639	90°
11	Thermocouple Tap (23T-D1)	639	0°
12	HS10 Outlet Feeder Nozzle	739	126°
13	HS11 Outlet Feeder Nozzle	739	234°
14	Surge Tank Nozzle	1019	n/a

* - 0° = top, 90° = east, 180° = bottom, 270° = west

** - tap is connected to 12P-D1/D2, 13P-D1/D2, 16Q-D1, 35Q-D1/D2, 42Q-D1, 43Q-D1, 44Q-D1, 45Q-D1, 46Q-D1, 57Q-D1, 64Q-D1, 73Q-D1, ECI DP1

FIGURE 2.22: Outlet Header HDR5

2. PRIMARY HEAT TRANSPORT SYSTEM

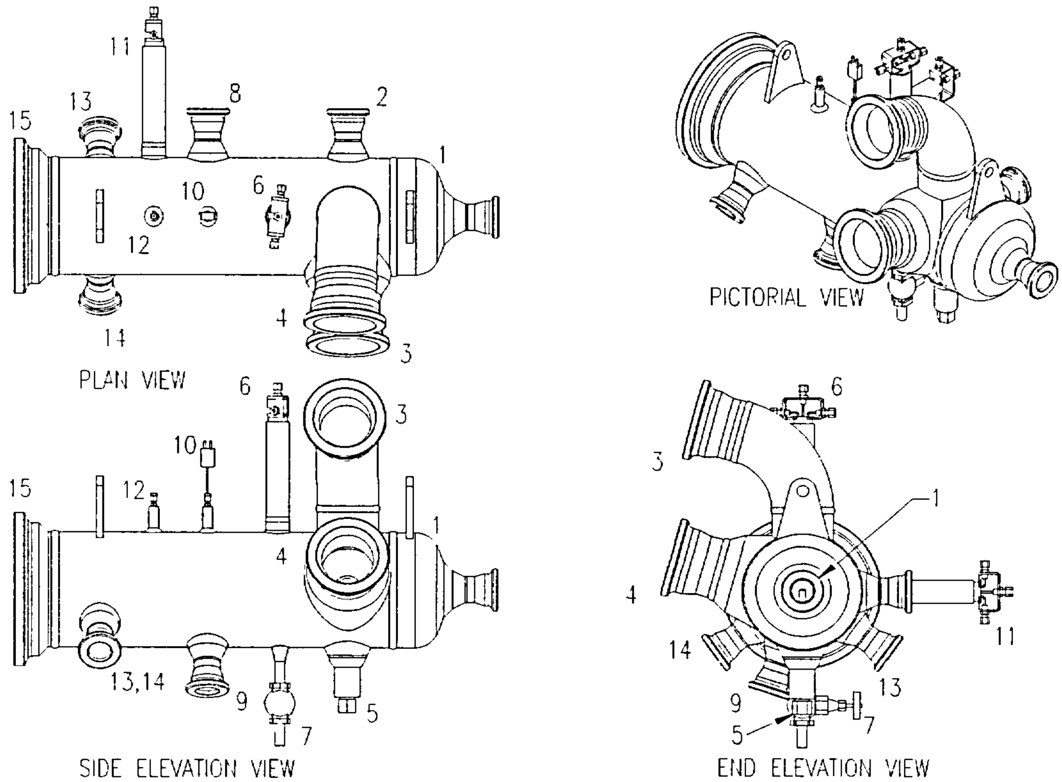


Station Number	Description	Axial Distance From ECI End (mm)	Radial Orientation*
1	ECI Nozzle	0	n/a
2	HS5 Inlet Feeder Nozzle	315	126°
3	Inlet Nozzle (P1 Discharge)	315	0°
4	HS6 Inlet Feeder Nozzle	315	234°
5	Pressure Tap	515	90°
6	Thermocouple Tap (5T-D1)	515	0°
7	HS8 Inlet Feeder Nozzle	515	198°
8	Pressure Tap**	645	0°
9	HS9 Inlet Feeder Nozzle	775	90°
10	RTD Thermowell (6T)	775	180°
11	Thermocouple Tap (5T-D2) (thermocouple extends to header centreline)	775	0°
12	HS7 Inlet Feeder Nozzle	775	270°
13	Degas Tank Nozzle	1090	n/a

* - 0° = top, 90° = east, 180° = bottom, 270° = west

** - tap is connected to 4P-D1/D2, 5P-D1/D2, 6Q-D1, 36Q-D1/D2, 37Q-D1, 38Q-D1, 39Q-D1, 40Q-D1, 41Q-D1, 57Q-D1, ECI DP2

FIGURE 2.23: Inlet Header HDR6

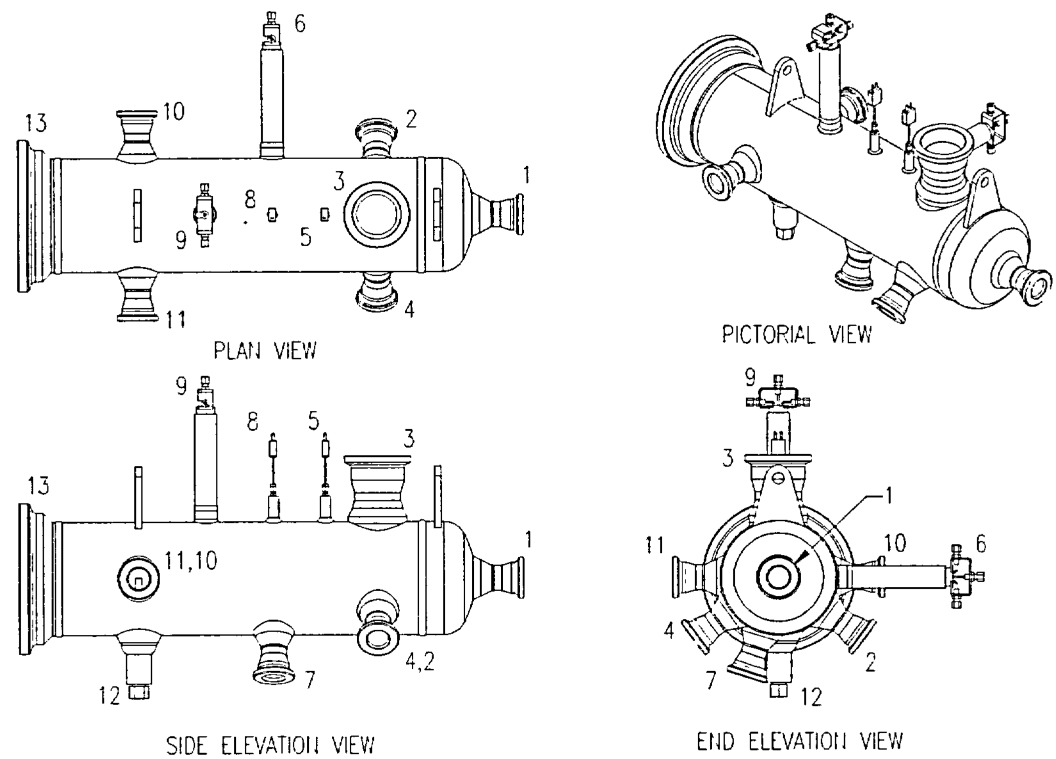


Station Number	Description	Axial Distance From ECI End (mm)	Radial Orientation*
1	ECI Nozzle	0	n/a
2	HS9 Outlet Feeder Nozzle	186	90°
3	Outlet Nozzle (BO2 Inlet)	186	0°
4	Outlet Nozzle (RV6)	186	285°
5	RTD Thermowell (12T)	186	180°
6	Pressure Tap**	316	0°
7	Drain Connection to Tank TK3	316	180°
8	HS7 Outlet Feeder Nozzle	446	90°
9	HS8 Outlet Feeder Nozzle	446	198°
10	Thermocouple Tap (11T-D1)	446	0°
11	Pressure Tap	546	90°
12	Thermocouple Tap (11T-D2) (thermocouple extends to header centreline)	546	0°
13	HS5 Outlet Feeder Nozzle	646	126°
14	HS6 Outlet Feeder Nozzle	646	234°
15	8" Grayloc Hub (connect to MV8 or end cap)	807	n/a

* - 0° = top, 90° = east, 180° = bottom, 270° = west

** - tap is connected to 6P-D1, 7P-D1/D2, 9Q-D1, 36Q-D1/D2, 47Q-D1, 48Q-D1, 49Q-D1, 50Q-D1, 51Q-D1, 58Q-D1, 73Q-D1, ECI DP3

FIGURE 2.24: Outlet Header HDR7



Station Number	Description	Axial Distance From ECI End (mm)	Radial Orientation*
1	ECI Nozzle	0	n/a
2	HS10 Inlet Feeder Nozzle	187	126°
3	Inlet Nozzle (P2 Discharge)	187	0°
4	HS11 Inlet Feeder Nozzle	187	234°
5	Thermocouple Tap (17T-D1)	287	0°
6	Pressure Tap	387	90°
7	HS13 Inlet Feeder Nozzle	387	198°
8	Thermocouple Tap (17T-D2) (thermocouple extends to header centreline)	387	0°
9	Pressure Tap**	517	0°
10	HS12 Inlet Feeder Nozzle	447	90°
11	HS14 Inlet Feeder Nozzle	447	270°
12	RTD Thermowell (18T)	447	180°
13	8" Grayloc Hub (connect to MV8 or end cap)	877	n/a

* - 0° = top, 90° = east, 180° = bottom, 270° = west

** - tap is connected to 10P-D1/D2, 11P-D1/D2, 13Q-D1, 35Q-D1/D2, 52Q-D1, 53Q-D1, 54Q-D1, 55Q-D1, 56Q-D1, 58Q-D1, ECI DP4

FIGURE 2.25: Inlet Header HDR8

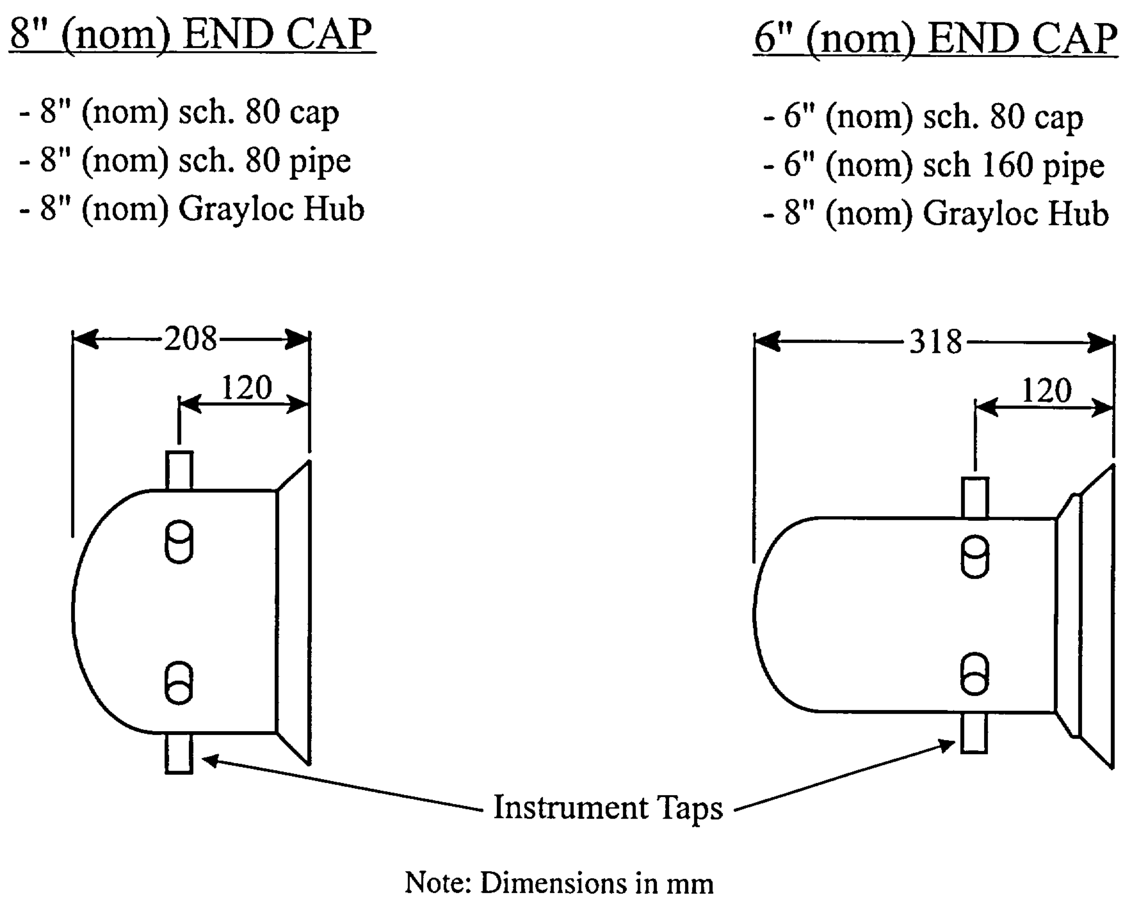
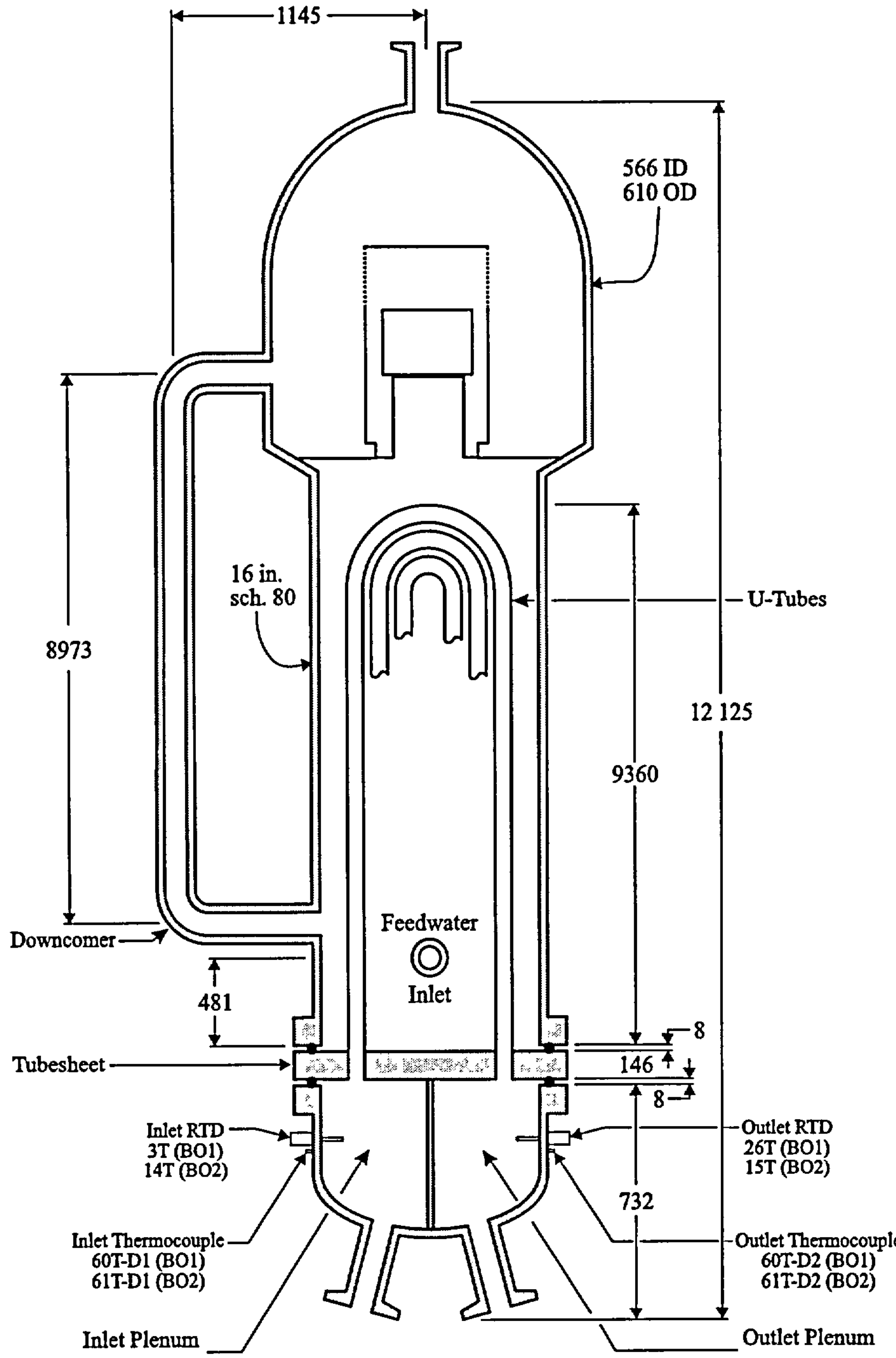


FIGURE 2.26: Header HDR7 and HDR8 End Caps



Note: Dimensions in mm

FIGURE 2.27: Schematic of Steam Generators (BO1, BO2) With Primary-Side Instrumentation

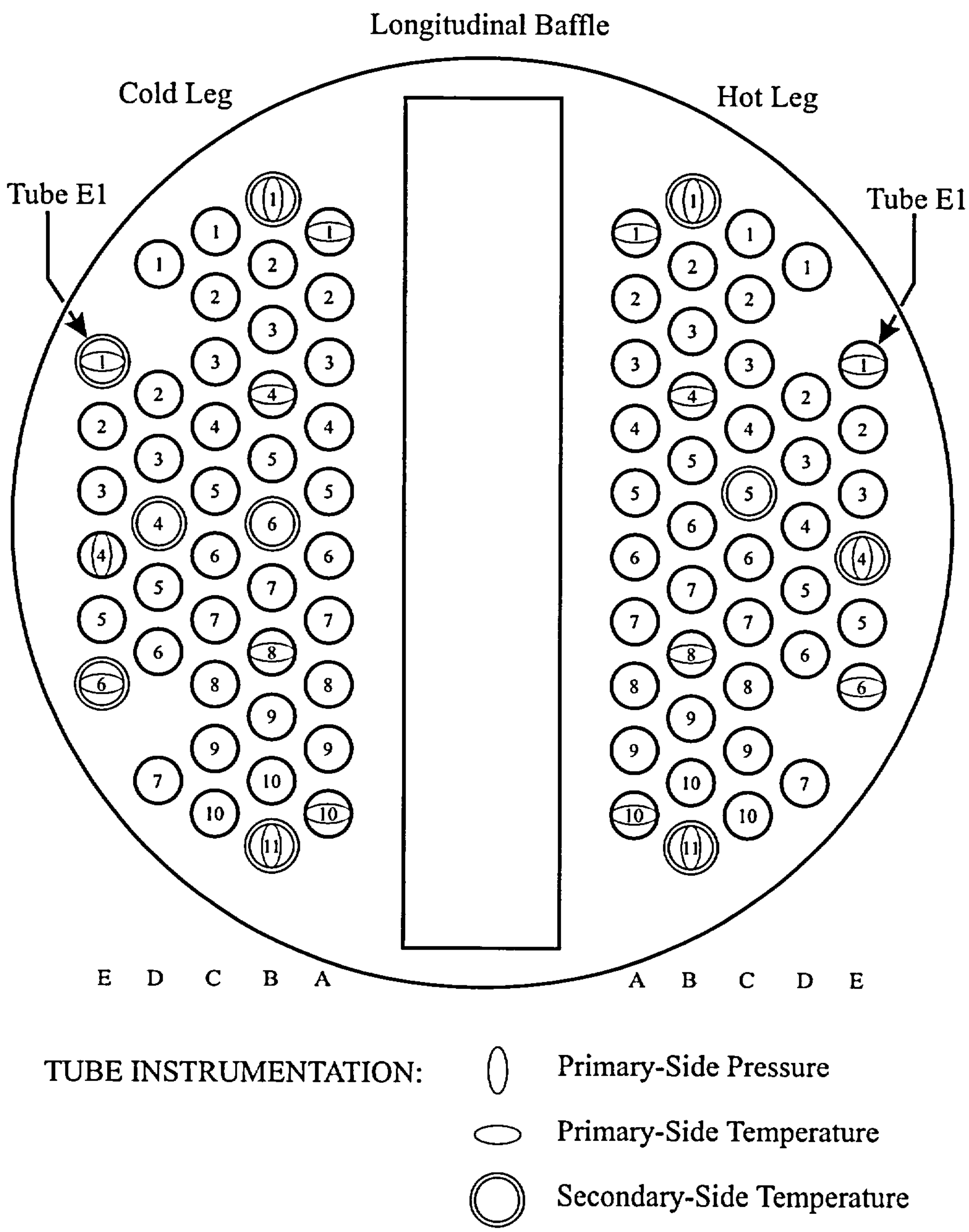
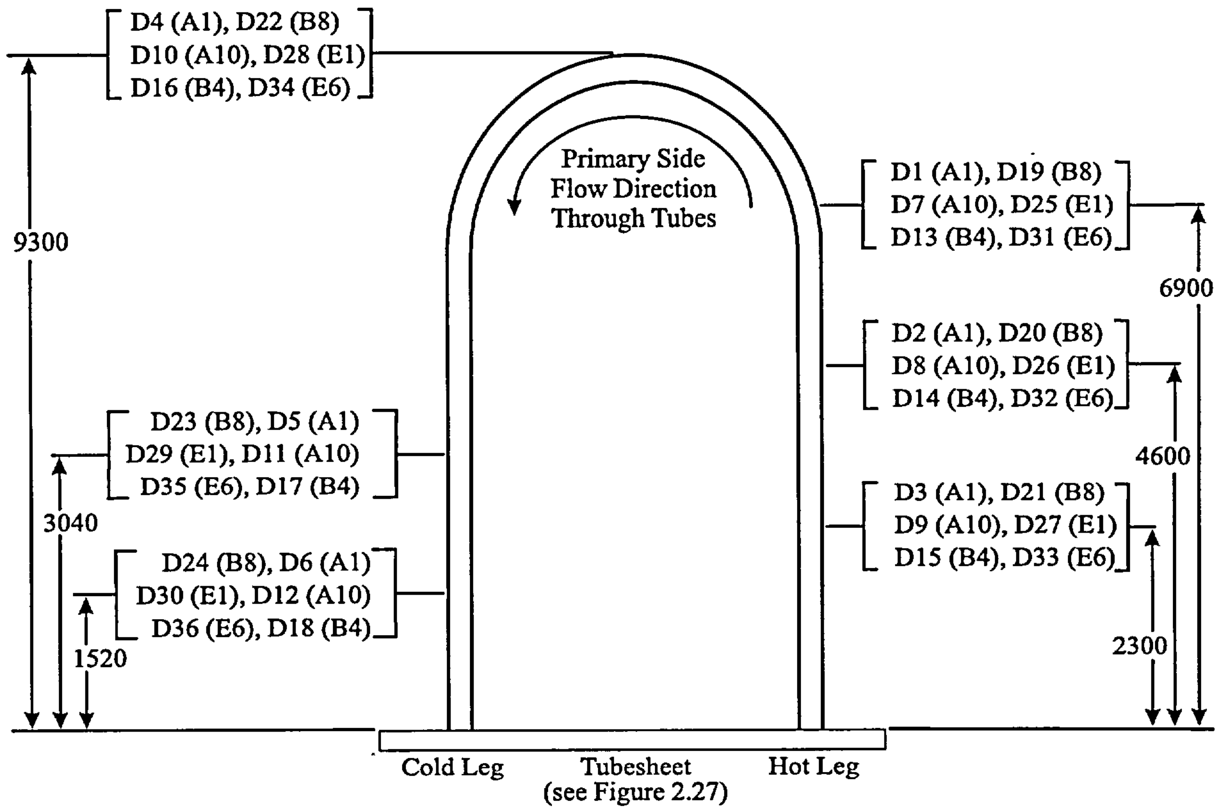
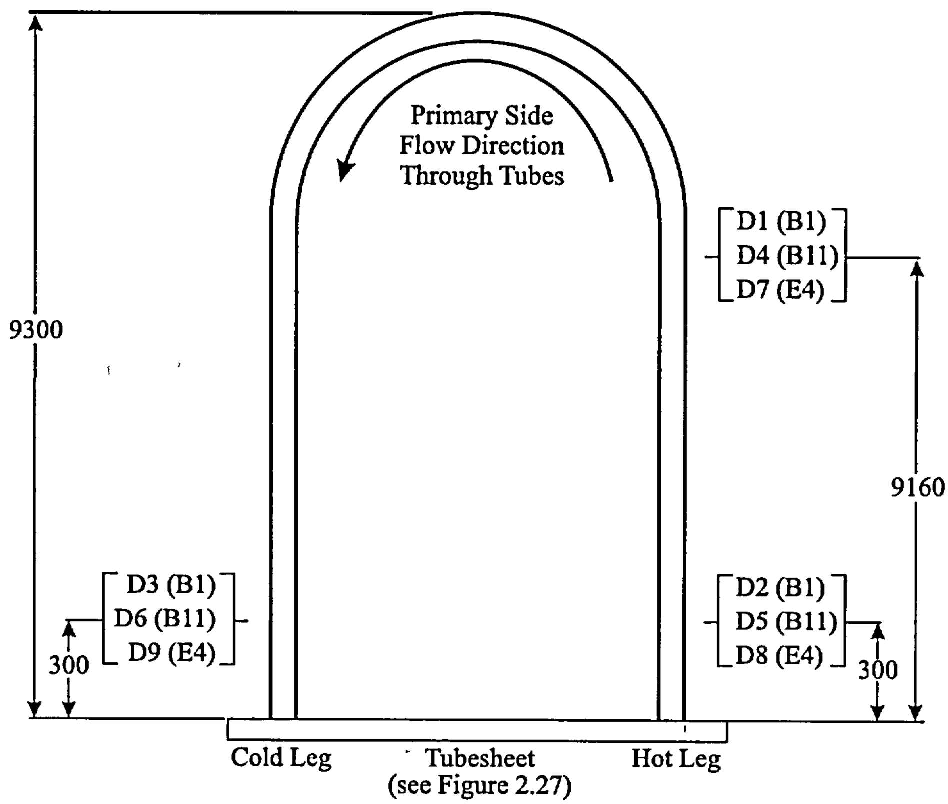


FIGURE 2.28: Steam Generator (BO1, BO2) Tube Details



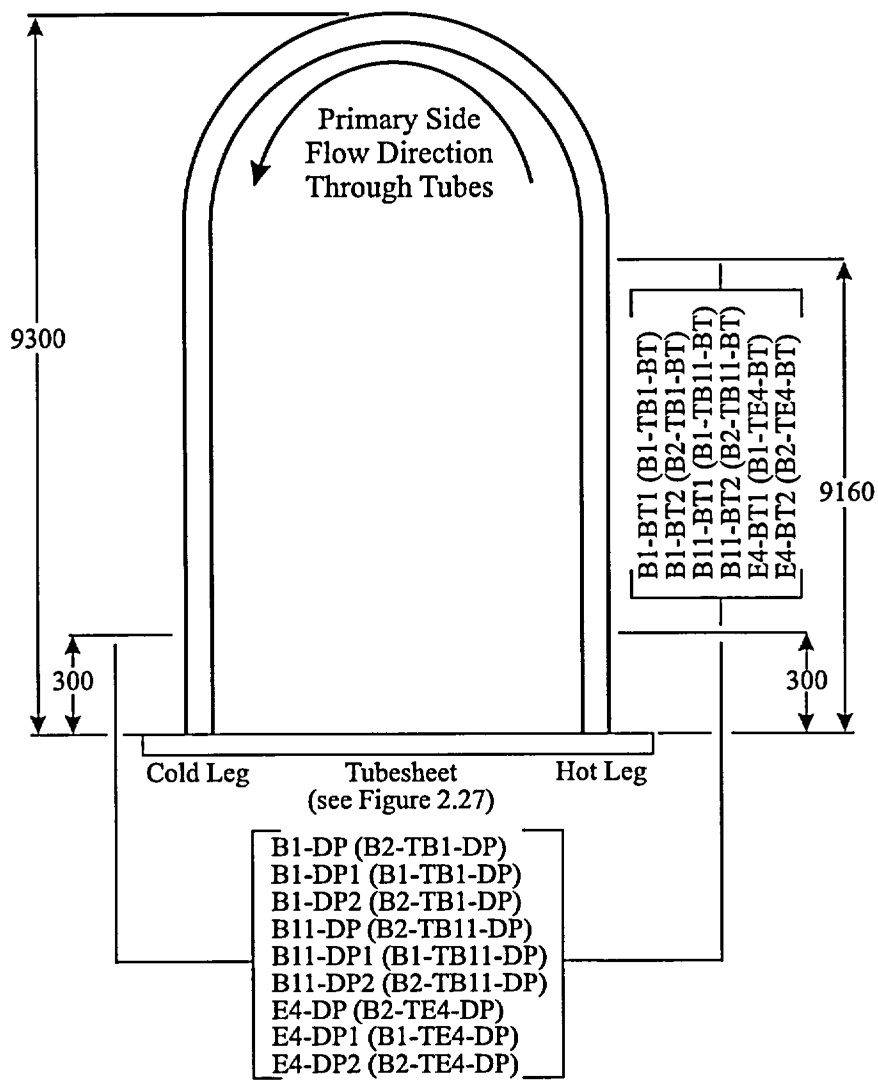
Notes: Device Codes are 1T-nn for BO1 and 2T-nn for BO2, followed by tube number (see Table 6.1)
Dimensions in mm

FIGURE 2.29: Steam Generator Primary-Side Thermocouple Locations



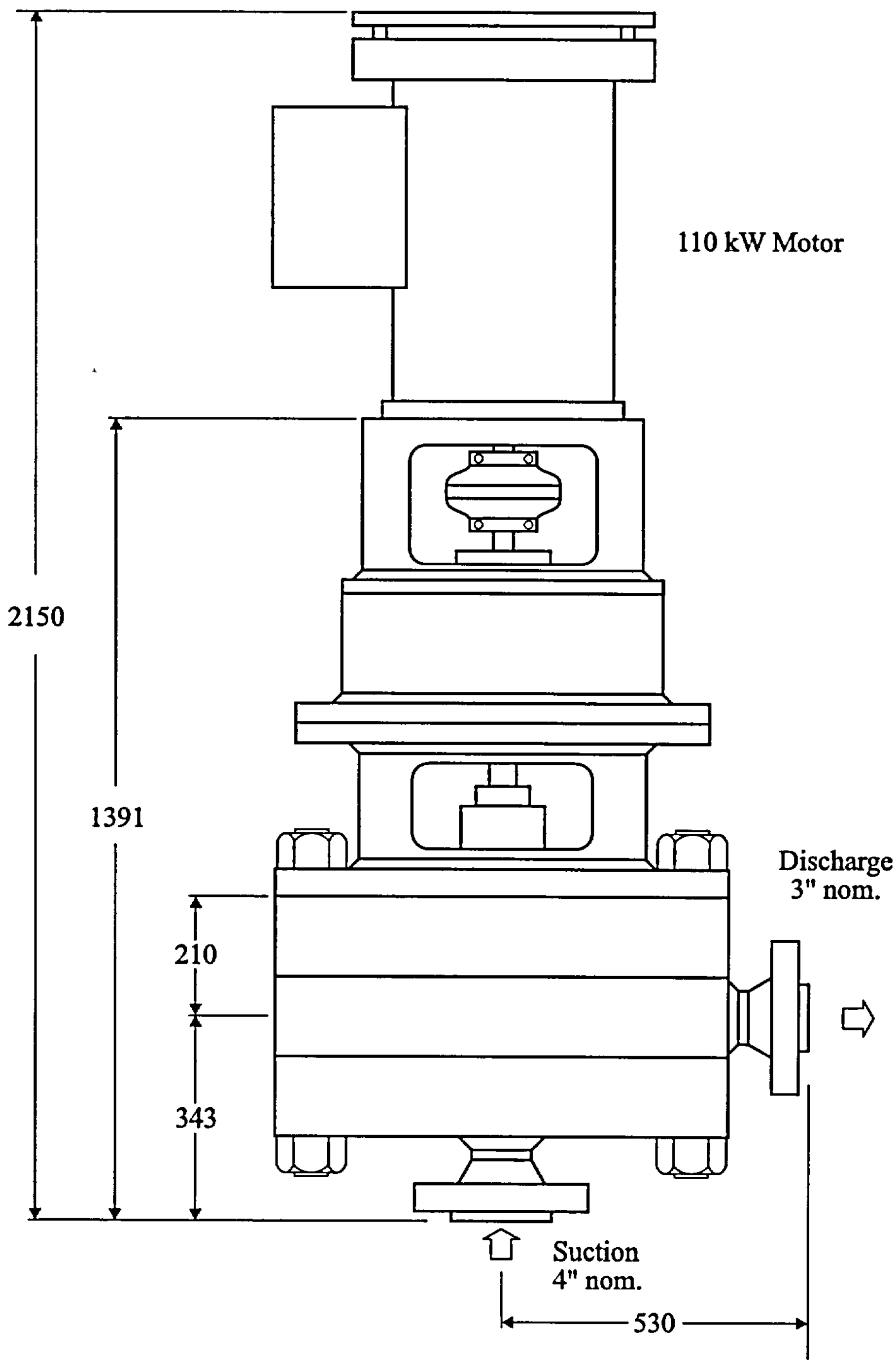
Notes: Device Codes are 38P-nn for BO1 and 39P-nn for BO2, followed by tube number (see Table 6.1)
Dimensions in mm

FIGURE 2.30: Steam Generator Tube Primary-Side Pressure Tap Locations



Note: Dimensions in mm

FIGURE 2.31: Steam Generator Tube Primary-Side Differential Pressure Tap Locations



Note: Dimensions in mm

FIGURE 2.32: Primary Pump (P1, P2) Schematic

3. SECONDARY HEAT TRANSPORT SYSTEM

In RD-14M, the primary heat transport system is cooled by heat exchange with a separate transport system, referred to as the secondary heat transport system. In the secondary system, distilled water is pumped through a circuit consisting of two steam generators, a jet condenser, a heat exchanger, and the associated piping and controls. Secondary feedwater enters the steam generators on the shell side and removes heat from the hot primary fluid flowing in the steam generator tubes. Boiling of the feedwater occurs, and the steam produced is carried to a jet condenser where it is condensed back to liquid when contacted with a cooler jet spray of circulating secondary fluid. Sensible heat is removed from hot condensate coming out of the jet condenser in a secondary heat exchanger that is cooled with firewater. The cooled condensate out of the heat exchanger is then returned to the secondary piping system and recirculates as cool spray for the jet condenser and feedwater for the steam generators.

The RD-14M secondary heat transport system presently consists of two separate circuits: the high power secondary circuit, designed for high power operating conditions of 250 kW to 5.5 MW per steam generator (500kW to 11 MW total power); and the low power secondary circuit, designed for operating conditions of less than 250 kW per steam generator (less than 500 kW total power). Both secondary circuits are shown schematically in Figure 3.1.

Other than the steam generators, there has been no attempt to scale secondary-side components to those of a reactor. The thermalhydraulic capacity of the RD-14M secondary circuits is based entirely on operational considerations (i.e., to remove up to 11 MW of heat from the steam generators in the high power configuration, or up to 500 kW in the low power configuration).

The low power secondary circuit was constructed and commissioned in 1991 after an operational need was identified for more sensitive control of the secondary system under low power conditions. The original RD-14M secondary system was designed to remove 11 MW of energy from the primary system. Under low power operation, where less than 500 kW of energy had to be removed from the primary side, the operation of the secondary control system was found to be unstable. The low power secondary circuit has been used for all low power experiments conducted since 1992 February 06.

The major components of the secondary heat transport system are described in more detail in the sections to follow.

3.100 SECONDARY SYSTEM PIPING

All secondary-circuit piping is ASTM A106, Grade B carbon steel pipe. Pipe sizes vary from 0.5-inch (nominal), schedule-80 to 6-inch (nominal), schedule-80. All secondary system piping is pressure rated to 7.4 MPa (g) at 343°C. Socket-welded joints are used for piping up to 2 inches in diameter. For piping 2.5 inches or larger, butt welds are used. All butt welds are radiographically inspected.

3. SECONDARY HEAT TRANSPORT SYSTEM

An elevation diagram of the secondary system, configured for high power operation, is shown in Figure 3.2. An elevation diagram of the additional piping and heat exchanger for the low power piping configuration is shown in Figure 3.3.

3.200 STEAM GENERATORS

The two RD-14M steam generators, BO1 and BO2, shown schematically in Figure 3.4, are designed to remove 5.5 MW of heat each (11 MW total) from the primary system. Secondary feedwater enters the steam generator near the bottom of the shell at the feedwater inlet, as shown in Figures 3.4 and 3.5.

Details of the secondary-side of the steam generators, from the tubesheet to the top of the U-tubes, is shown in Figure 3.5, including the preheater baffle arrangement. Figure 3.6 shows a simplified schematic of this region, and Figure 3.7 is a three-dimensional view.

Under normal full-power conditions, the feedwater flow rate for each steam generator is 2.7 kg/s and the temperature is 187°C. The feedwater flows through a duct to the bottom of the longitudinal baffle where it enters the preheater. Hot primary fluid flowing through the U-tubes then heats the secondary fluid to the saturation temperature (the fluid exiting the preheater section is near saturation). The hot secondary begins to boil and travels upward through the vertical boiling section of the steam generator to a steam drum at the top. In the steam drum, steam and liquid are separated, aided by a cyclone separator shown in Figure 3.8. Saturated steam discharges from the top of the steam generator, with water recirculating to the bottom of the shell via an external downcomer. An orifice plate located in the downcomer measures the recirculated flow rate.

The RD-14M steam generators were manufactured by Versatile Vickers. Each vessel consists of a vertical carbon-steel shell approximately 12 m in overall length. The main shell is made from nominal 16-inch, schedule-80 carbon-steel pipe in the lower boiling section, and nominal 24-inch carbon-steel pipe in the upper steam drum section. The primary side plenums are separated from the main shell by a tubesheet, and attached to the main shell with bolted flanges. Figure 3.9 shows the U-tube layout and indicates which tubes are instrumented.

The exact locations of the thermocouples on the secondary side of the steam generator tubes are shown in Figure 3.10 (primary-side steam generator thermocouple, gauge pressure, and differential pressure transducer locations are shown in Figures 2.29 to 2.31).

The design heat transport removal capacity of each steam generator is 5.5 MW at a primary-side flow rate of 24 kg/s. Shell side design pressure is 6.89 MPa at a temperature of 343°C. Tube-side design pressure is 16.5 MPa (g) at 343°C, however tubes are limited to the external design pressure of the shell of 6.89 MPa. The tube-side operating pressure is 10 MPa at an inlet fluid temperature of 309°C.

3. SECONDARY HEAT TRANSPORT SYSTEM

3.300 JET CONDENSER

Jet condenser CD1, shown in Figure 3.11, is used to condense the steam produced in the steam generators. This type of condenser was chosen for use in RD-14M for its quick response to changes in steam production. The vessel has a carbon-steel shell (ASME SA 516 Gr-70) with a Grayloc closure on top, in which two type-303 stainless-steel spray nozzles are located. The larger flow nozzle is a 2.5 inch × 30° fulljet, while the smaller flow nozzle is a 2 inch × 30° fulljet. The jet condenser is provided with a degas line to atmosphere, regulated by a solenoid valve, to enable degassing of the secondary system fluid.

Nominal full-power conditions are 5.5 kg/s steam at 260°C, and 12.7 kg/s spray water at 100°C, producing 18.2 kg/s condensate at 260°C. The jet condenser has a design pressure of 7.4 MPa (g) at 343°C.

The empty vessel mass is 4725 kg, and the capacity is 1.985 m^3.

The liquid level in the jet condenser is determined by measuring the pressure difference between two taps provided near the top and bottom of the vessel, as shown in Figure 3.11. Fluid temperatures, pressures, and flows to and from the jet condenser, are measured in connecting piping, as shown in Figures 3.2 and 3.3. This and other secondary-side instrumentation is listed in Table 6.2.

3.400 PUMPS

The two secondary-system circulating pumps P6 and P7, shown in Figure 3.12, are horizontal, single-stage Bingham centrifugal pumps. The shaft of each pump extends through the pump case on both sides of the impeller and is supported by bearings on both ends. The shaft is sealed at both ends by mechanical seals that are cooled by pumping secondary process fluid through an external heat exchanger cooled with firewater. The pumps are driven by 75 kW, variable-speed DC motors with a maximum speed of 3600 rpm. The pumps have high-head/low-flow characteristics (see Section 8.520).

3.500 HEAT EXCHANGER FOR HIGH-POWER OPERATION (HX2)

A U-tube inside of shell 11 MW heat exchanger, HX2, shown in Figure 3.13, is used to remove the heat load in the secondary circuit. This heat exchanger was used in all experiments involving the secondary system up to 1992 February 06, when the low-power secondary circuit was installed. HX2 is currently used for high power tests only, where input power is greater than 500 kW.

The large heat exchanger has a heat transfer area of 46.25 m^2. The shell and tube sheet are carbon steel while the tubes are stainless steel. The heat exchanger contains 113 U-tubes, with an outside diameter of 19.05 mm, and 1803-mm long.

The shell-side design pressure is 1.03 MPa (g) at 177°C. The operating inlet and outlet temperatures are 23°C and 61°C at a flow of 69.2 kg/s.

The tube-side design pressure is 7.4 MPa (g) at 343°C. The operating inlet and outlet temperatures are 187°C and 100°C at a flow of 29.5 kg/s. The tube side is a four-pass design.

The empty unit mass is 2585 kg; when filled with water the mass is 3402 kg.

3.600 HEAT EXCHANGER FOR LOW-POWER OPERATION (HX5)

A U-tube inside shell 500 kW heat exchanger, HX5, shown in Figure 3.14, is used to remove the heat load in the secondary system under low power operating conditions (input power less than 500 kW). This heat exchanger has been used in all low power experiments (input power less than 500 kW) conducted after 1992 February 06. The unit has a heat transfer area of 1.0 m^2. The shell and tube sheet are carbon steel while the tubes are stainless steel. The heat exchanger contains 11 U-tubes, each 19.05 mm (OD) and 1562 mm long.

The shell-side design pressure is 1.03 MPa (g) at 177°C. The operating inlet and outlet temperatures are 23°C and 58.3°C at a flow of 3.38 kg/s. The shell side operates single pass.

The tube-side design pressure is 7.4 MPa (g) at 343°C. The operating inlet and outlet temperatures are 260°C and 187°C at a flow of 1.47 kg/s.

3.700 OPERATION AND CONTROL

3.710 High-Power Operation

As stated previously, the high-power secondary circuit was used for all RD-14M tests prior to 1992 February 06, and all tests after this date conducted at an input power greater than 500 kW.

Under high power conditions, the low-power circuit is isolated by opening manual valve V476 and closing V469 (see Figure 3.1 or Station 42, Figure 3.2 and Station 5, Figure 3.3, respectively). Condensed fluid from the jet condenser, CD1, passes through secondary pumps P6 and P7 to the 11 MW heat exchanger, HX2, via a 6-inch (nominal) line. Three-way valve 43T-CV1 controls the outlet temperature from the heat exchanger by controlling the amount of secondary flow allowed to bypass the heat exchanger.

The temperature of feedwater returned to the steam generators is controlled by valve 34T-CV1, which mixes cooled fluid from the heat exchanger outlet with hot fluid from the jet condenser outlet. Feedwater is returned to the steam generators via a 1.5-inch (nominal) line. The water level in steam generators BO1 and BO2 is controlled by throttling the feedwater flow through respective control valves 2H-CV1 and 3H-CV1.

3. SECONDARY HEAT TRANSPORT SYSTEM

The control systems used to regulate secondary system conditions during high power operation are discussed below. Figure 3.1 illustrates the approximate location of these controls. Exact control locations can be found on the elevation diagram in Figure 3.2.

3.711 Pressure Control

The secondary-system pressure is controlled by varying the flow rate of water to the jet condenser spray nozzles through control valves 31P-CV1 and 31P-CV2. The set-point range of controller 31P-C1 is 0-8 MPa (g). A linear ramp generator, 31P-M1, can be connected to the pressure controller remote set-point, to allow controlled changes to the secondary-side pressure.

The secondary system is protected on high pressure by interlock switch 31P-K1, with the set-point at 7.0 MPa (g). When this set-point is exceeded, the "CD1 Secondary Pressure High" annunciator alarms, all power supplies are shut down, and the secondary-system make-up/addition pump, P5, is shut down.

Bursting disks are also installed to protect against high pressure in the secondary side. Bursting disks BD6, BD7, BD12 and BD13 located on the steam lines rupture at 6.89 MPa (g), while disks BD8 and BD9, located at the pump outlets, rupture at 7.4 MPa (g).

When the secondary-system pressure falls below the set-point in interlock switch 31P-K2, the "CD1 Secondary Pressure Low" annunciator alarms, and the secondary pump motors P6 and P7 are shut down. The set-point for this switch is set to 0 MPa (g) (guards against vacuum conditions which could damage the pumps).

3.712 Feedwater Temperature Control

The steam generator feedwater temperature is controlled through valve 34T-CV1. Valve 34T-CV1 throttles a flow of relatively cold water from the outlet of secondary-side heat exchanger HX2 to mix with hot condensate from the outlet of the jet condenser, via a signal from controller 34T-C1 and measurement from thermocouple 34T. The controller set-point range is 0 to 300 °C. This control system is disabled when the low-power secondary circuit is in use.

3.713 Jet Condenser Level Control

The jet condenser is filled by make-up/addition pump P5. The normal operating level on CD1 is about 30% with no steam generation in the steam generators, and an indicated steam generator level of about 55% in the drums.

The jet condenser is protected on high level by interlock switch 4H-K1. When the set-point of 90% is exceeded, the "CD1 Level High" annunciator alarms, all power supplies are shut down, and pump P5 is shut off.

When the jet condenser level falls below the 5% set-point on the 4H-K2 interlock switch, the "CD1 Level Low" annunciator alarms, all power supplies trip, and the secondary circulating pumps P6 and P7 are shut off.

The jet condenser level is controlled manually. A high level is lowered by dumping fluid through the boilers to a drain. A low level is raised by using make-up/addition pump P5.

3.714 Jet Condenser Spray Temperature Control

The jet condenser spray flow temperature is controlled by three-way control valve 43T-CV1. This valve adjusts the throughput/bypass ratio to secondary heat exchanger HX2. Control may be either manual or automatic on controller 43T-C1. In automatic control, a temperature signal is taken from thermocouple 43T, downstream of the heat exchanger. The set-point range is 0 to 300°C.

3.715 Steam Generator Level Control

The liquid level in each steam generator drum is controlled independently by feedwater flow control valves 2H-CV1 and 3H-CV1, for steam generators BO1 and BO2, respectively. A level controller adjusts the feedwater valve to maintain the steam generator drum level at a set-point of approximately 55%, ensuring that boiler tubes are completely submerged in feedwater at all times during operation of the secondary system.

3.720 <u>Low-Power Operation</u>

To achieve better control of secondary-side operating conditions during experiments conducted at input powers much lower than the 11 MW design power of the original secondary system, the low-power secondary circuit was installed and put into operation in 1992 February.

Under low-power conditions, the high-power circuit is isolated by closing manual valve V476 and opening V469 (see Figure 3.1 or Station 42, Figure 3.2 and Station 5, Figure 3.3, respectively). Condensate from the jet condenser, CD1, is directed through secondary pumps P6 and P7 and into the low-power heat exchanger HX5. Steam generator feedwater flow and jet condenser spray flow are returned to the circuit at the same temperature. This temperature is controlled by diverting a portion of the flow around HX5 using valves 43T-CV2 and 43T-CV3.

Feedwater is returned to the steam generators via ½-inch (nominal) lines. Control valves 2H-CV2 and 3H-CV2 regulate feedwater flow to maintain the liquid-level set-point of 55% in the steam generator drums.

3. SECONDARY HEAT TRANSPORT SYSTEM

The control systems used to regulate secondary-circuit conditions during low-power operation are discussed below. Figure 3.1 illustrates the approximate location of these controls. For exact control locations refer to the elevation diagram in Figure 3.3.

3.721 Pressure Control

The pressure control for low-power operation is the same as for high-power operation (see Section 3.711).

3.722 Feedwater Temperature Control

The steam generator feedwater temperature is controlled by valves 43T-CV2 and 43T-CV3, on the inlet of HX5. Fluid temperature is controlled by regulating the flow directed through HX5 via 43T-CV2, along with the flow allowed to bypass the heat exchanger via 43T-CV3. The two flows mix at the outlet of HX5, where the temperature is measured by thermocouple 43T. While the signal from thermocouple 43T is used to control 43T-CV1 when the high-power secondary circuit is in use, for the low-power secondary configuration, 43T is relocated in piping downstream of the high-power location and used to control 43T-CV2 and 43T-CV3. The controller set-point range is 0 to 300°C. The feedwater temperature control system used for the high-power secondary configuration, described in Section 3.712, is disabled in the low-power secondary configuration.

3.723 Jet Condenser Level Control

The jet condenser control for low-power operation is the same as for high-power operation (see Section 3.713).

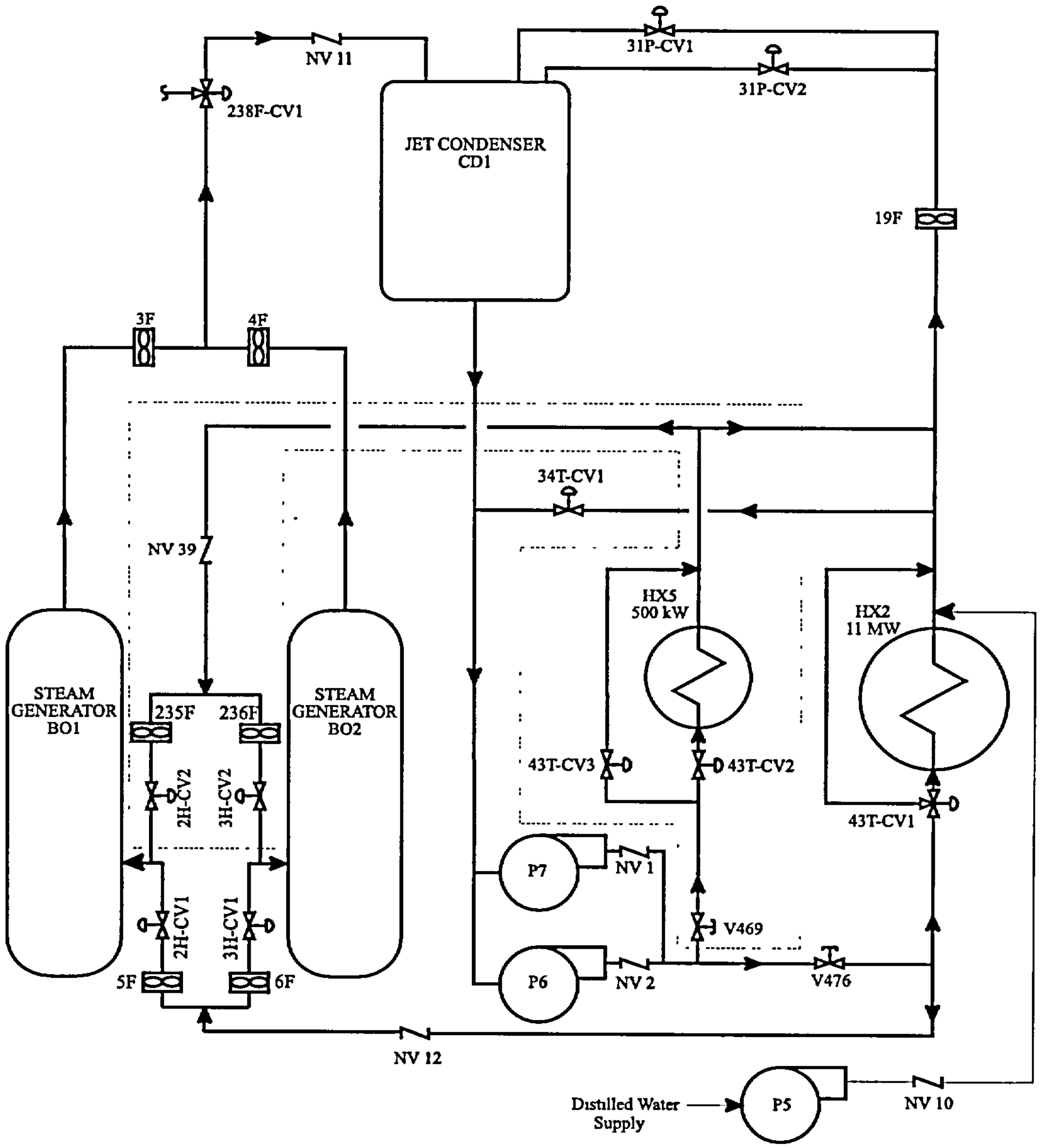
3.724 Jet Condenser Spray Temperature Control

Under low-power operating conditions, jet condenser spray flow temperature is controlled by two valves, 43T-CV2 and 43T-CV3. These valves regulate the throughput/bypass ratio to HX5. Control is either manual or automatic on controller 43T-C1. In automatic control, a temperature signal is taken from thermocouple 43T downstream of the heat exchanger. The set-point range is 0 to 300°C.

3.725 Steam Generator Level Control

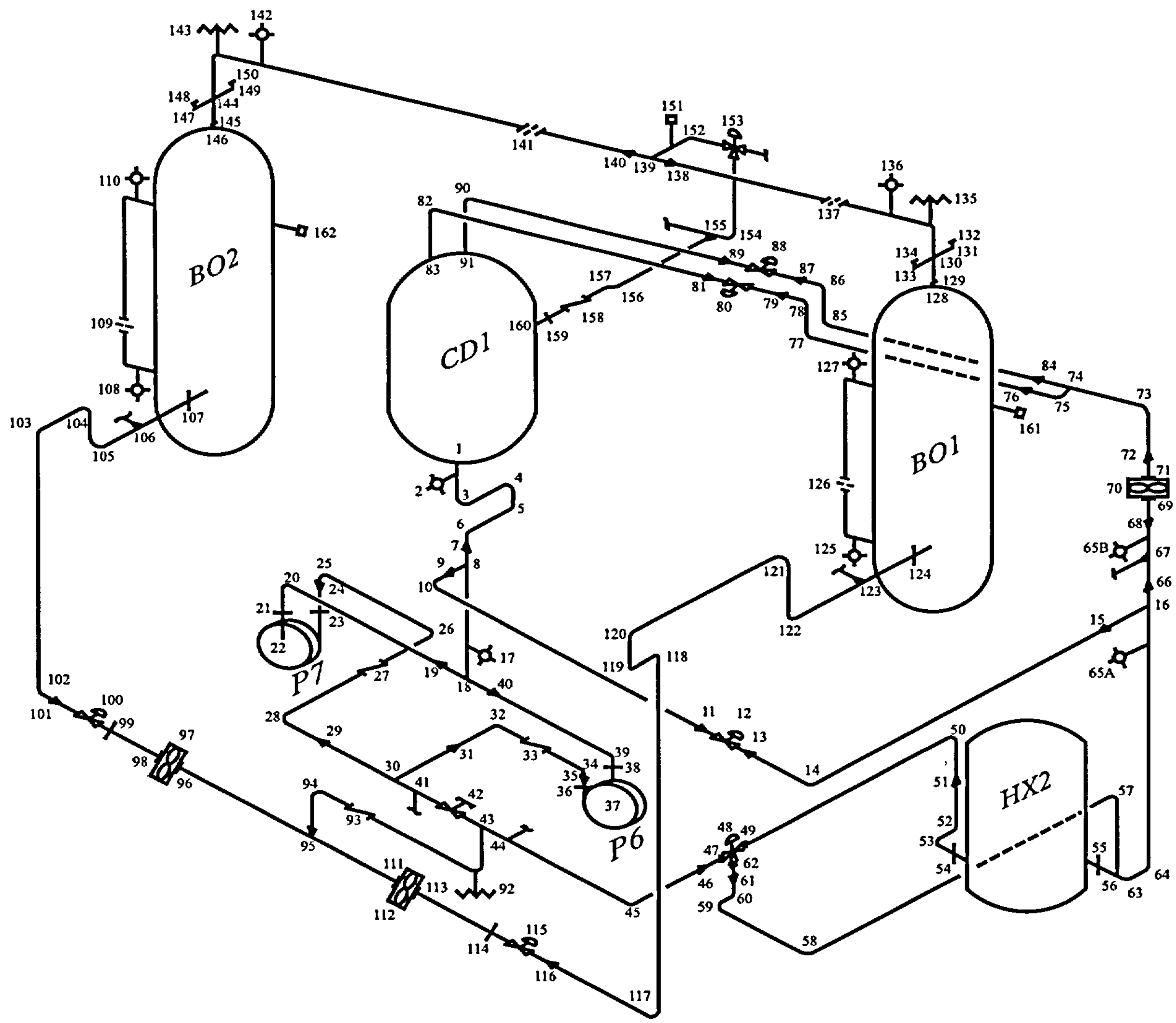
The steam generator level control for low-power operation is the same as for high-power operation (see Section 3.715).

3. SECONDARY HEAT TRANSPORT SYSTEM



Notes: Detailed elevation diagram of high-power configuration shown in Figure 3.2
Detailed elevation diagram of low-power addition (dotted line portion) shown in Figure 3.3

FIGURE 3.1: Secondary-System Schematic



Note: See Figure 3.3 and elevation legends for low-power secondary tie-in locations

FIGURE 3.2: Elevation Diagram for Secondary System in High-Power Configuration

FIGURE 3.2 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
1	Jet Condenser CD1 Bottom	22.07			
			0.35	102.26	90
2	Thermocouple (33T-D1)	21.72			
			1.60	102.26	90
3	Elbow (90°)	20.12			
			1.10	102.26	0
4	Elbow (90°)	20.12			
			1.07	102.26	90
5	Elbow (90°)	19.05			
			1.10	102.26	0
6	Elbow (90°)	19.05			
			0.56	102.26	90
7	Reducer	18.49			
			0.22	146.33	90
8	Tee	18.27			
			0.22	146.33	0
9	Reducer	18.27			
			0.33	102.26	0
10	Elbow (90°)	18.27			
			4.81	102.26	0
11	Reducer	18.27			
12	Control Valve (34T-CV1)	18.27	0.43		0
13	Reducer	18.27			
			0.36	102.26	0
14	Elbow (90°)	18.27			
			0.24	102.26	0
15	Reducer	18.27			
			0.22	146.33	0
16	Tee	18.27			
8	Tee	18.27			
			3.44	146.33	90
17	Thermocouple (34T)	14.83			
			0.50	146.33	90

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Tee	14.33			
			0.20	146.33	0
19	Reducer	14.33			
			0.79	73.66	0
20	Elbow (90°)	14.33			
			1.46	73.66	90
21	Pump P7 Inlet Flange	12.87			
22	Pump P7 (at impeller)	12.51			
23	Pump P7 Outlet Flange	12.87			
			0.18	49.25	90
24	Reducer	13.05			
			1.05	102.26	90
25	Elbow (90°)	14.10			
			0.50	102.26	0
26	Elbow (90°)	14.10			
			0.82	102.26	0
27	Check Valve (NV1)	14.10			
			0.36	102.26	0
28	Elbow (90°)	14.10			
			0.56	102.26	0
29	Reducer	14.10			
			0.20	146.33	0
30	Tee	14.10			
			0.20	146.33	0
31	Reducer	14.10			
			0.40	102.26	0
32	Elbow (90°)	14.10			
			0.36	102.26	0
33	Check Valve (NV2)	14.10			
			0.36	102.26	0
34	Elbow (90°)	14.10			
			1.06	102.26	90
35	Reducer	13.04			
			0.18	49.25	90
36	Pump P6 Outlet Flange	12.86			
37	Pump P6 (at impeller)	12.50			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
38	Pump P6 Inlet Flange	12.86			
			1.48	73.66	90
39	Elbow (90°)	14.34			
			0.79	73.66	0
40	Reducer	14.34			
			0.20	146.33	0
18	Tee	14.34			
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30	Tee	14.10			
			1.15	146.33	0
41	Tee (tie-in to low-power secondary; same as Stn. 1, Fig. 3.3)	14.10			
			0.56	146.33	0
42	Gate Valve (V476)	14.10			
			0.68	146.33	0
43	Tee Reducer	14.10			
			0.17	146.33	0
44	Tee	14.10			
			0.64	146.33	0
45	Elbow (90°)	14.10			
			0.29	146.33	0
46	Reducer	14.10			
			0.19	97.18	0
47	Flange	14.10			
48	Control Valve (43T-CV1)	14.10	0.40		0
49	Flange	14.10			
			0.26	97.18	0
50	Elbow (90°)	14.10			
			0.23	97.18	90
51	Reducer	13.87			
			1.03	146.33	90
52	Elbow (90°)	12.84			
			0.62	146.33	0
53	Elbow (90°)	12.84			
			0.36	146.33	0
54	Heat Exchanger HX2 Inlet	12.84			
55	Heat Exchanger HX2 Outlet	12.84			
			0.30	146.33	0

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
56	Tee Reducer	12.84			
			0.36	38.10	90
57	Elbow (90°)	13.20			
			0.63	38.10	0
58	Elbow (90°)	13.20			
			1.68	38.10	0
59	Elbow (90°)	13.20			
			0.77	38.10	0
60	Elbow (90°)	13.20			
			0.41	38.10	90
61	Reducer	13.61			
			0.16	97.18	90
62	Flange	13.77			
			0.33		90
48	Control Valve (43T-CV1)	14.10			
56	Tee Reducer	12.84			
			0.19	146.33	0
63	Elbow (45°)	12.84			
			0.36	146.33	0
64	Elbow (90°)	12.84			
			4.83	146.33	90
65A	Thermocouple (43T)	17.67			
	(for high-power configuration)		0.60	146.33	90
16	Tee	18.27			
			0.20	146.33	90
66	Reducer	18.47			
			3.03	73.66	90
67	Tee Reducer	21.50			
	(tie-in from low-power secondary; same as Stn. 19, Fig. 3.3)		0.75	73.66	90
65B	Alternate location for 43T (for low-power configuration; same as Stn. 20, Fig. 3.3)	22.25			
			0.71	73.66	90
68	Reducer	22.96			
			0.12	49.25	90
69	Grayloc	23.08			
70	Turbine Flowmeter (19F)	23.19	0.22	42.90	90

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
71	Grayloc	23.30			
			0.12	49.25	90
72	Reducer	23.42			
			0.63	73.66	90
73	Elbow (90°)	24.05			
			1.86	73.66	0
74	Tee	24.05			
			0.16	73.66	0
75	Elbow (90°)	24.05			
			0.11	73.66	0
76	Reducer	24.05			
			2.20	49.25	0
77	Elbow (90°)	24.05			
			1.35	49.25	90
78	Elbow (90°)	25.40			
			0.90	49.25	0
79	Reducer	25.40			
80	Control Valve (31P-CV2)	25.40	0.30		0
81	Reducer	25.40			
			0.28	49.25	0
82	Elbow (90°)	25.40			
			0.46	49.25	90
83	Jet Condenser CD1 Inlet	24.94			
74	Tee	24.05			
			0.73	73.66	0
84	Reducer	24.05			
			1.59	59.00	0
85	Elbow (90°)	24.05			
			1.35	59.00	90
86	Elbow (90°)	25.40			
			0.13	59.00	0
87	Reducer	25.40			
88	Control Valve (31P-CV1)	25.40	0.35		0
89	Reducer	25.40			
			1.06	59.00	0

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
90	Elbow (90°)	25.40			
			0.46	59.00	90
91	Jet Condenser CD1 Inlet	24.94			
43	Tee Reducer	14.10			
			0.43	49.25	90
92	Elbow (90°)/RTD (37T)	13.67			
			2.42	49.25	0
93	Check Valve (NV12)	13.67			
			0.23	49.25	0
94	Elbow (90°)	13.67			
			1.45	49.25	90
95	Tee Reducer	12.22			
			1.93	38.10	0
96	Grayloc	12.22			
97	Turbine Flowmeter (6F)		0.22	20.70	0
98	Grayloc	12.22			
			0.40	38.10	0
99	Grayloc/Reducer	12.22			
100	Control Valve (3H-CV1)	12.22	0.32		0
101	Reducer	12.22			
			0.14	38.10	0
102	Elbow (90°)	12.22			
			2.31	38.10	90
103	Elbow (90°)	14.53			
			1.55	38.10	0
104	Elbow (90°)	14.53			
			0.51	38.10	90
105	Elbow (90°)	14.02			
			0.28	38.10	0
106	Tee Reducer (from low-power secondary; same as Stn. 36, Fig. 3.3)	14.02			
			0.40	38.10	0
107	Steam Generator BO2 Inlet	14.02			

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
108	BO2 Downcomer Thermocouple (137T-D2)	14.17			
			1.15		90
109	BO2 Downcomer Orifice 135F	15.32			
			7.82		90
110	BO2 Downcomer Thermocouple (137T-D1)	23.14			
162	BO2 Pressure Tap (2P)	23.25			
95	Tee Reducer	12.22			
			1.92	38.10	0
111	Grayloc	12.22			
112	Turbine Flowmeter (5F)		0.22	20.70	0
113	Grayloc	12.22			
			0.36	38.10	0
114	Grayloc/Reducer	12.22			
115	Control Valve (2H-CV1)	12.22	0.32		0
116	Reducer	12.22			
			0.14	38.10	0
117	Elbow (90°)	12.22			
			1.70	38.10	90
118	Elbow (90°)	13.92			
			0.35	38.10	0
119	Elbow (90°)	13.92			
			0.61	38.10	90
120	Elbow (90°)	14.53			
			1.85	38.10	0
121	Elbow (90°)	14.53			
			0.51	38.10	90
122	Elbow (90°)	14.02			
			0.28	38.10	0
123	Tee Reducer	14.02			
	(tie-in from low-power secondary; same as Stn. 47, Fig. 3.3)		0.40	38.10	0
124	Steam Generator BO1 Inlet	14.02			

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
125	BO1 Downcomer Thermocouple (136T-D2)	14.17			
			1.15		90
126	BO1 Downcomer Orifice 135F	15.32			
			7.82		90
127	BO1 Downcomer Thermocouple (136T-D1)	23.14			
161	BO1 Pressure Tap (1P)	23.25			
128	Steam Generator BO1 Top	24.65			
			0.17	73.66	90
129	Grayloc	24.82			
			0.21	73.66	90
130	Cross Fitting	25.03			
			0.20	73.66	0
131	Elbow (90°)/Reducer	25.03			
			0.20	49.25	90
132	Bursting Disc BD7	25.23			
130	Cross Fitting	25.03			
			0.20	73.66	0
133	Elbow (90°)/Reducer	25.03			
			0.20	49.25	90
134	Bursting Disc BD13	25.23			
130	Cross Fitting	25.03			
			0.20	73.66	90
135	Elbow (90°)/RTD (30T)	25.23			
			0.15	73.66	0
136	Thermocouple (29T)	25.23			
			2.42	73.66	0
137	Flow Orifice (3F)	25.23		61.42	
			0.30	73.66	0
138	Reducer	25.23			
			0.14	97.18	0
139	Tee Reducer	25.23			
			0.14	97.18	0
140	Reducer	25.23			
			0.30	73.66	0

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
141	Flow Orifice (4F)	25.23		61.42	
			2.42	73.66	0
142	Thermocouple (31T-D1)	25.33			
			0.15	73.66	0
143	Elbow (90°)/RTD (32T)	25.23			
			0.20	73.66	90
144	Cross Fitting	25.03			
			0.21	73.66	90
145	Grayloc	24.82			
			0.17	73.66	90
146	Steam Generator BO2 Top	24.65			
144	Cross Fitting	25.03			
			0.20	73.66	0
147	Elbow (90°)/Reducer	25.03			
			0.20	49.25	90
148	Bursting Disc BD6	25.23			
144	Cross Fitting	25.03			
			0.20	73.66	0
149	Elbow (90°)/Reducer	25.03			
			0.20	49.25	90
150	Bursting Disc BD12	25.23			
139	Tee Reducer	25.23			
			0.60	102.26	0
151	Standoff (31P-D1)	25.23			
			0.40	102.26	0
152	Elbow (90°)	25.23			
			0.86	102.26	0
153	Control Valve (238F-CV1)	25.23			
			1.00	102.26	90
154	Elbow (90°)	24.23			
			0.86	102.26	0
155	Tee Reducer	24.23			
			0.92	97.18	0
156	Elbow (45°)	24.23			
			0.15	97.18	12
157	Elbow (45°)	24.26			
			0.30	97.18	0

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
158	Check Valve (NV11)	24.26			
			0.60	97.18	0
159	Grayloc	24.26			
			0.40	97.18	0
160	Jet Condenser CD1 Inlet	24.26			

3. SECONDARY HEAT TRANSPORT SYSTEM

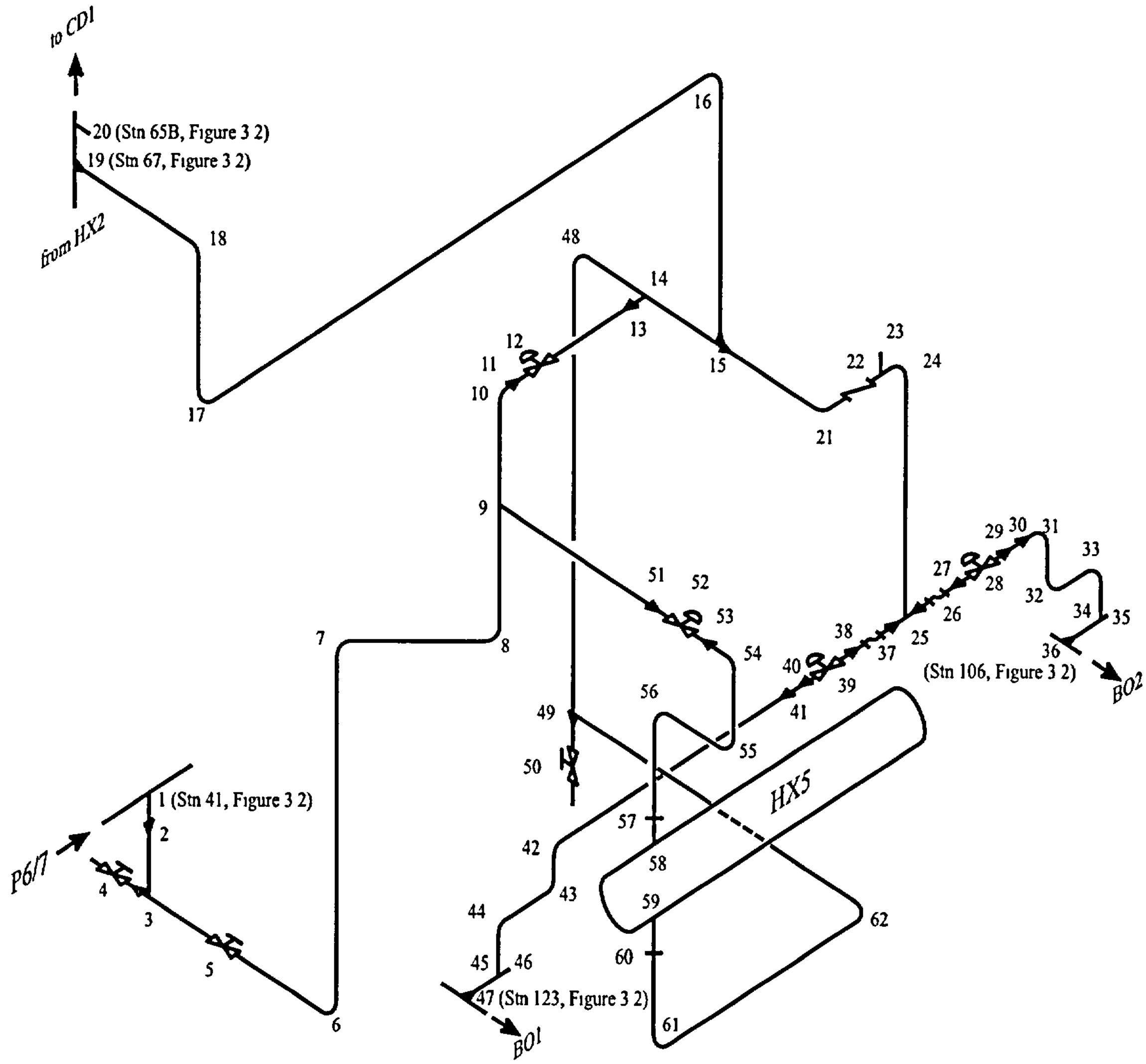


FIGURE 3.3: Elevation Diagram for Secondary-System Low-Power Addition

FIGURE 3.3 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
1	Tee	14.10			
	(tie-in to high-power secondary; same as Stn. 41, Fig. 3.2)		0.09	146.33	90
2	Reducer	14.01			
			0.12	32.46	90
3	Tee Reducer	13.89			
			0.20	13.87	0
4	Drain Valve (V475)	13.89			
3	Tee Reducer	13.89			
			0.25	32.46	0
5	Gate Valve (V469)	13.89			
			0.24	32.46	0
6	Elbow (90°)	13.89			
			1.78	32.46	90
7	Elbow (90°)	15.67			
			0.65	32.46	0
8	Elbow (90°)	15.67			
			0.56	32.46	90
9	Tee	16.23			
			0.13	32.46	90
10	Elbow (90°)	16.36			
			0.07	32.46	0
11	Reducer	16.36			
			0.14	24.31	0
12	Control Valve (43T-CV3)	16.36			
			0.31	24.31	0
13	Reducer	16.36			
			0.08	32.46	0
14	Tee	16.36			
			0.40	32.46	0
15	Tee Reducer	16.36			
			4.02	24.31	90
16	Elbow (90°)	20.38			
			5.32	24.31	0
17	Elbow (90°)	20.38			
			1.07	24.31	90

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
18	Elbow (90°)	21.45			
			0.77	24.31	0
19	Tee Reducer	21.45			
	(tie-in to high-power secondary; same as Stn. 67, Fig. 3.2)		0.80	73.66	90
20	Thermocouple (43T) (for low-power configuration; same as Stn. 65B, Fig. 3.2)	22.25			

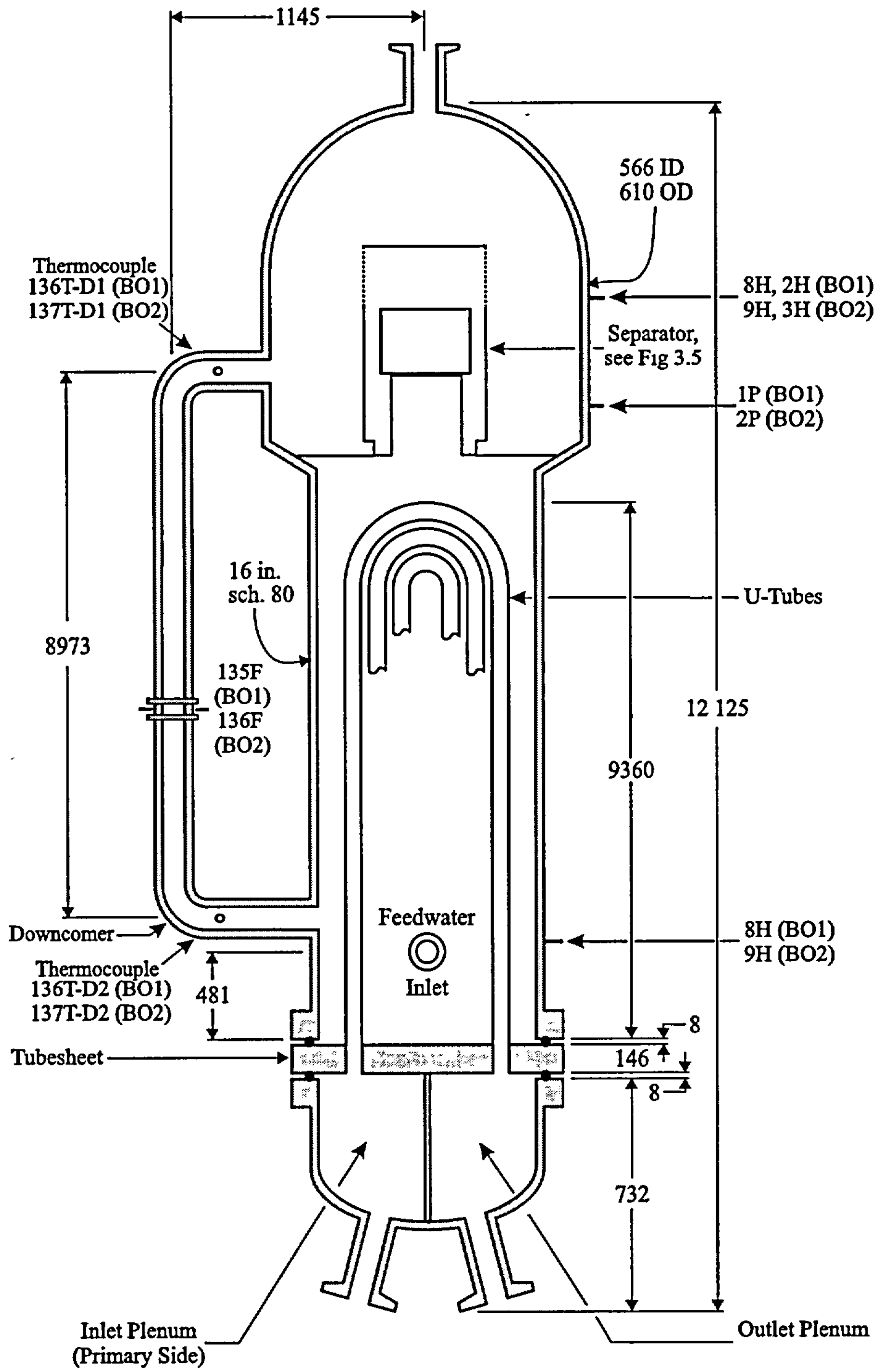
STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
15	Tee Reducer	16.36			
			0.30	13.87	0
21	Elbow (90°)	16.36			
			0.21	13.87	0
22	Check Valve (NV-39)	16.36			
			0.23	13.87	0
23	Thermocouple (331T-D1)	16.36			
			0.10	13.87	0
24	Elbow (90°)	16.36			
			0.20	13.87	90
25	Tee Reducer	16.16			
			0.47	15.75	0
26	Turbine Flowmeter (236F)	16.16		15.60	
			0.37	15.75	0
27	Reducer	16.16			
			0.12	24.31	0
28	Control Valve (3H-CV2)	16.16			
			0.10	24.31	0
29	Reducer	16.16			
			0.02	13.87	0
30	Reducer	16.16			
			0.11	7.04	0
31	Elbow (90°)	16.16			
			0.40	7.04	90
32	Elbow (90°)	15.76			
			2.00	7.04	0
33	Elbow (90°)	15.76			
			1.82	7.04	90
34	Tee	13.94			
35	Thermocouple (333T-D1)	13.94			

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
34	Tee	13.94			
			0.14	7.04	0
36	Tee Reducer (tie-in to high-power secondary and BO2; same as Stn. 106, Fig. 3.2)	13.94			
25	Tee Reducer	16.16			
			0.47	15.75	0
37	Turbine Flowmeter (235F)	16.16		15.60	
			0.37	15.75	0
38	Reducer	16.16			
			0.12	24.31	0
39	Control Valve (2H-CV2)	16.16			
			0.10	24.31	0
40	Reducer	16.16			
			0.02	13.87	0
41	Reducer	16.16			
			0.10	7.04	0
42	Elbow (90°)	16.16			
			0.30	7.04	90
43	Elbow (90°)	15.86			
			1.60	7.04	0
44	Elbow (90°)	15.86			
			1.92	7.04	90
45	Tee	13.94			
46	Thermocouple (332T-D1)	13.94			
45	Tee	13.94			
			0.80	7.04	0
47	Tee Reducer (tie-in to high-power secondary and BO1; same as Stn. 120, Fig. 3.2)	13.94			
14	Tee	16.36			
			0.20	32.46	0
48	Elbow (90°)	16.36			
			1.18	32.46	90
49	Tee Reducer	15.18			

3. SECONDARY HEAT TRANSPORT SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
			0.15	13.87	90
50	Drain Valve (V474)	15.03			
9	Tee	16.23			
			0.35	32.46	0
51	Reducer	16.23			
			0.25	24.31	0
52	Control Valve (43T-CV2)	16.23			
			0.13	24.31	0
53	Reducer	16.23			
			0.08	32.46	0
54	Elbow (90°)	16.23			
			0.17	32.46	90
55	Elbow (90°)	16.06			
			0.20	32.46	0
56	Elbow (90°)	16.06			
			0.31	32.46	90
57	Grayloc	15.75			
			0.12	32.46	90
58	Heat Exchanger HX5 Inlet	15.63			
59	Heat Exchanger HX5 Outlet	15.42			
			0.12	32.46	90
60	Grayloc	15.30			
			0.12	32.46	90
61	Elbow (90°)	15.18			
			0.62	32.46	0
62	Elbow (90°)	15.18			
			0.80	32.46	0
49	Tee Reducer	15.18			



Note: Dimensions in mm

FIGURE 3.4: Schematic of Steam Generators (BO1, BO2) With Secondary-Side Instrumentation

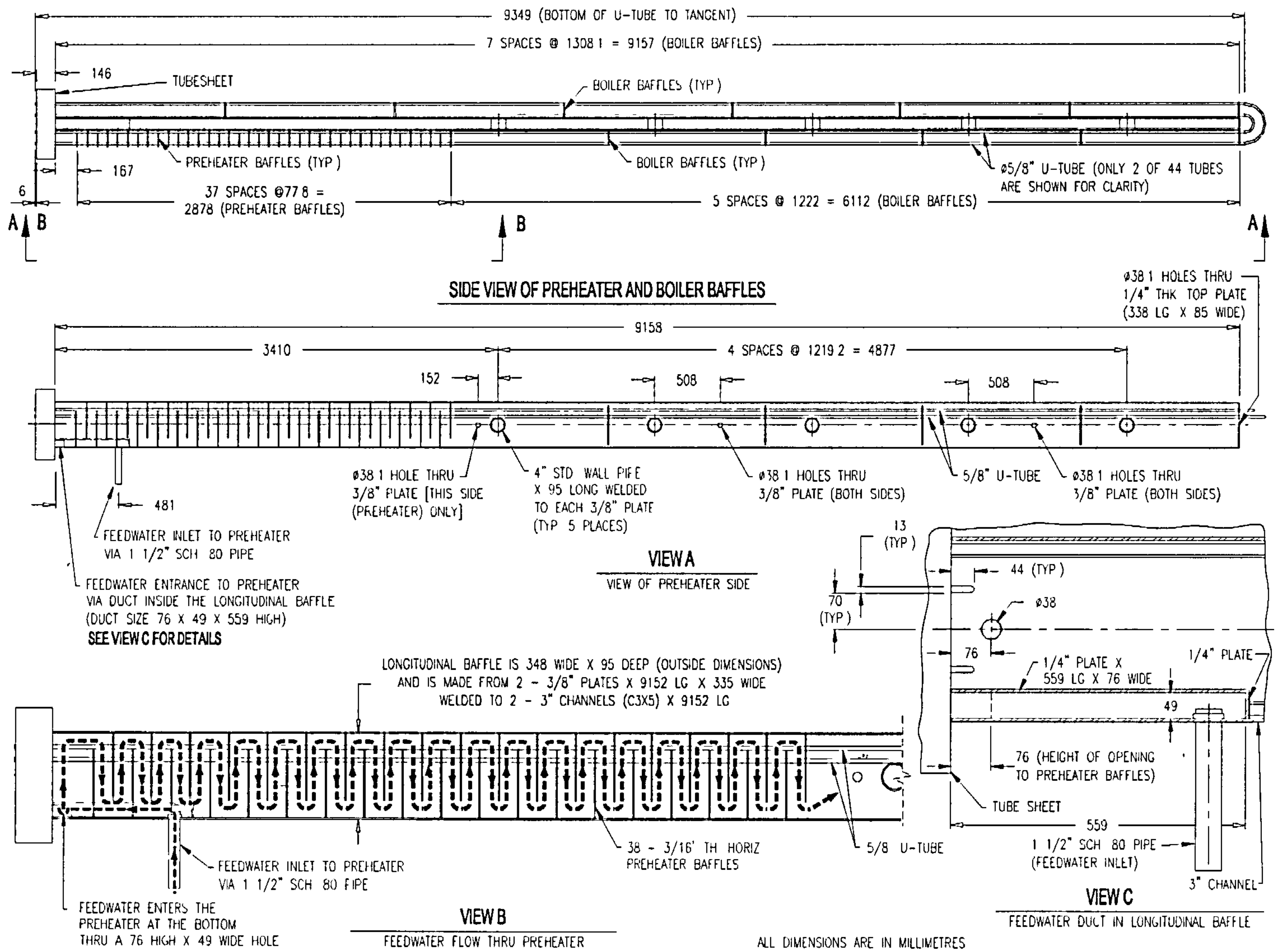


FIGURE 3.5: Details of the Secondary-Side Preheater and Boiler Baffles

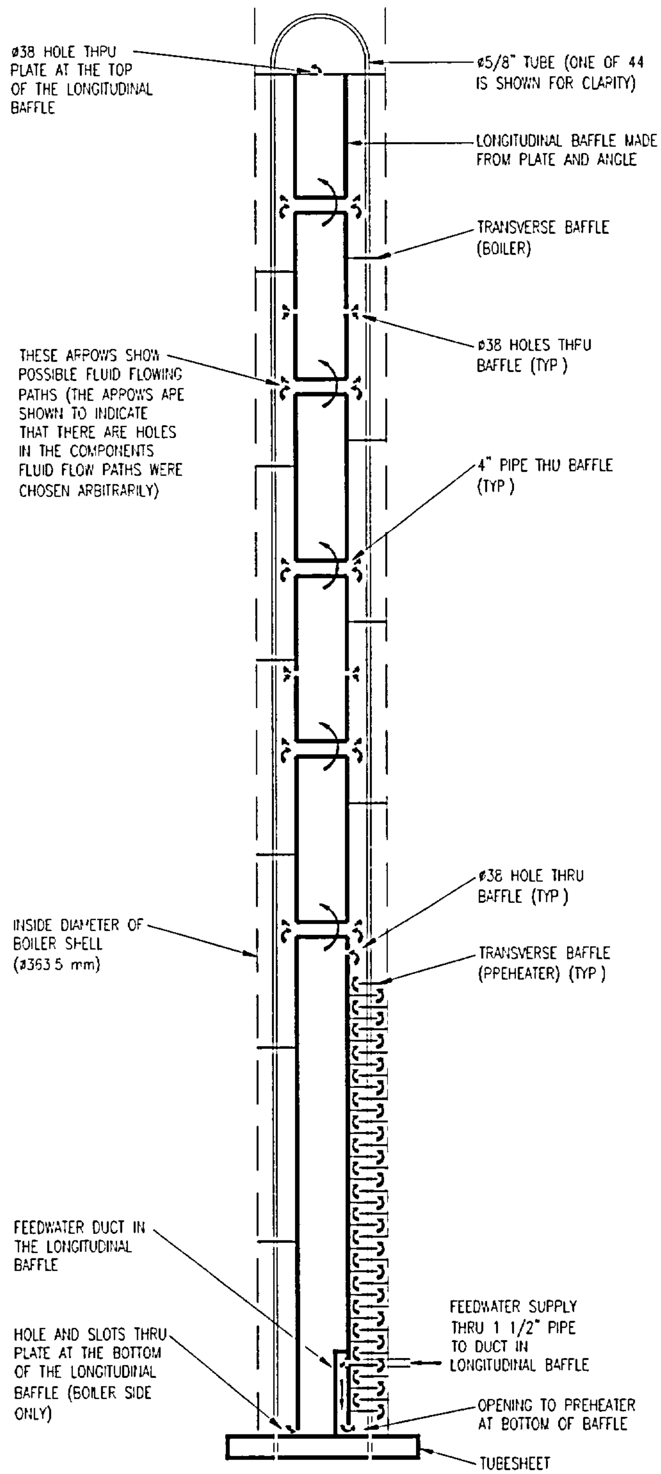


FIGURE 3.6: Schematic of the Secondary-Side Preheater and Boiler Baffles

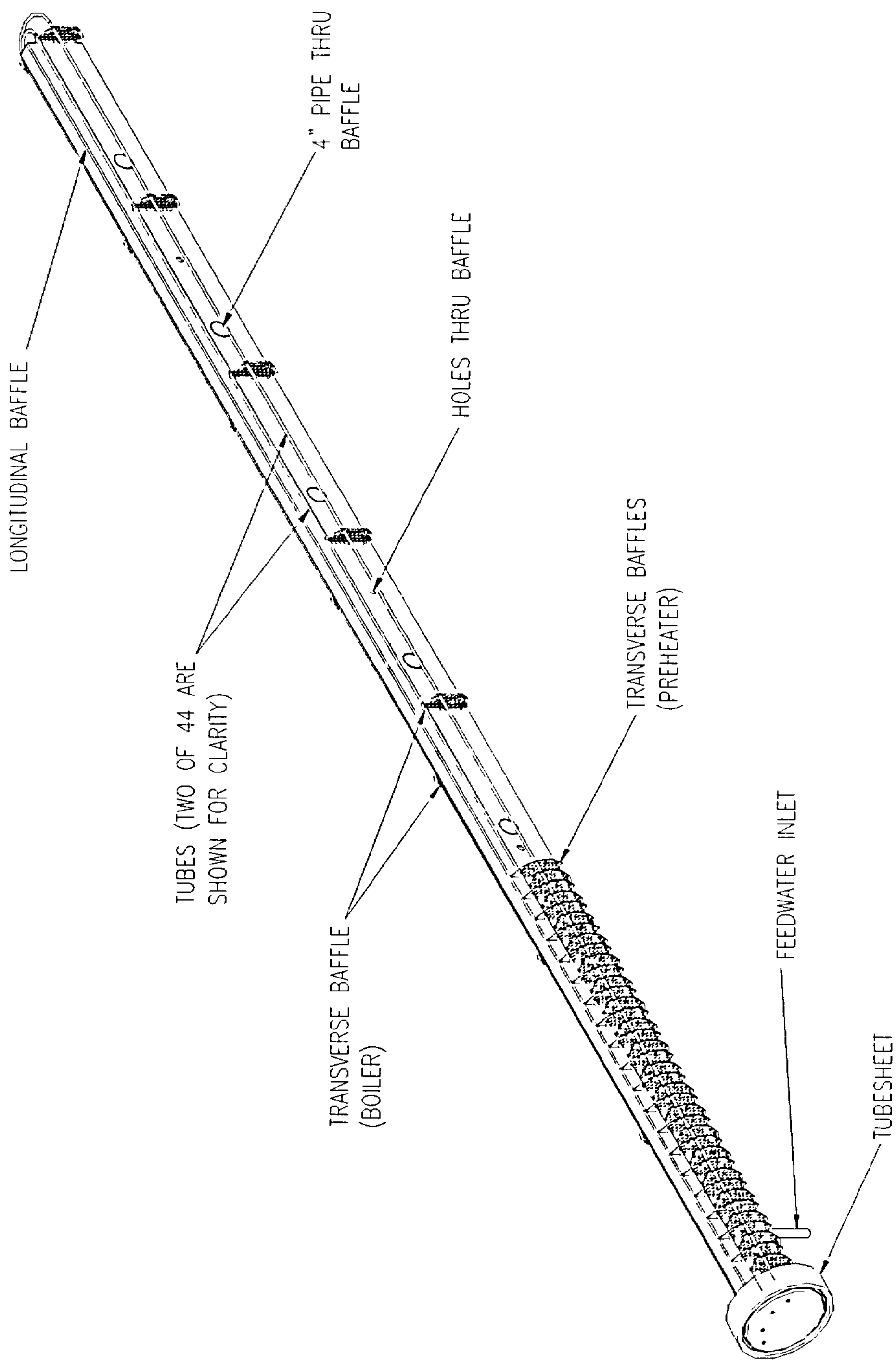
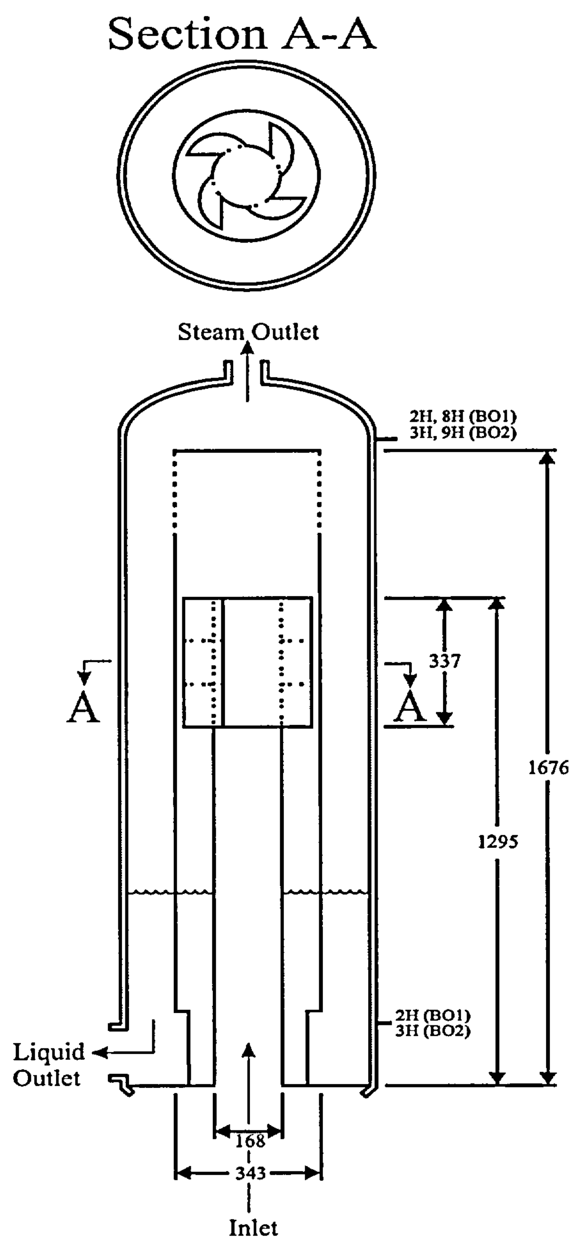


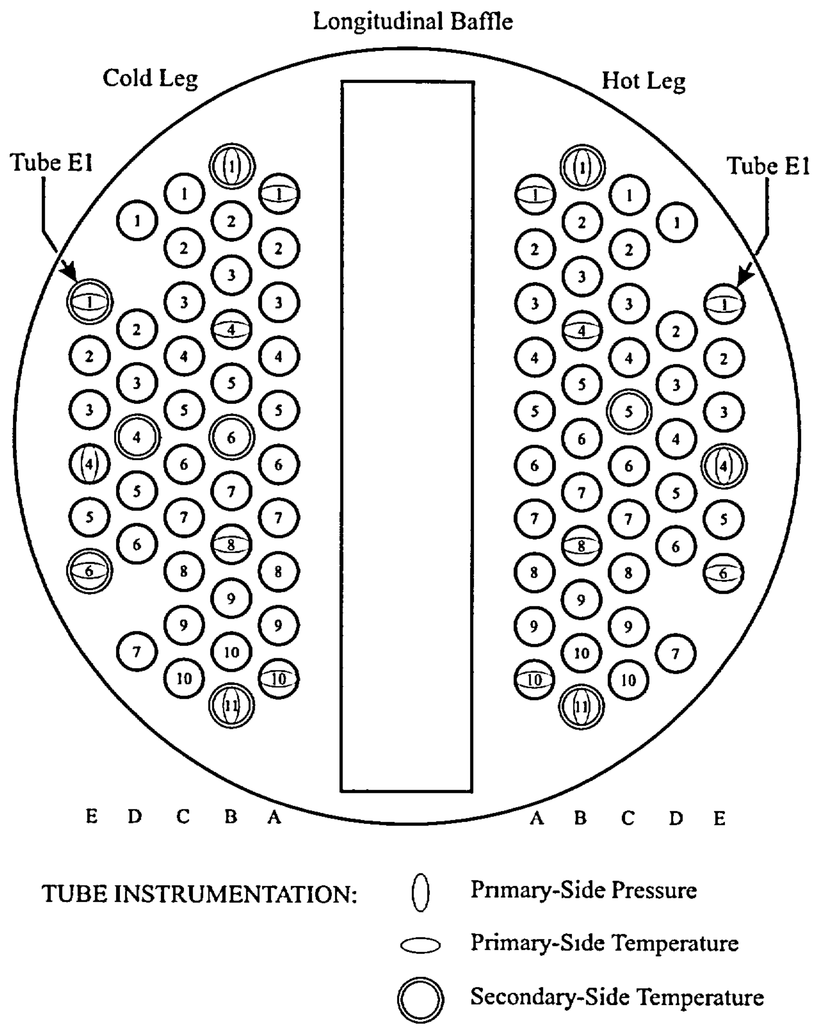
FIGURE 3.7: Three-Dimensional View of the Secondary-Side Preheater and Boiler Baffles



Note: Dimensions in mm

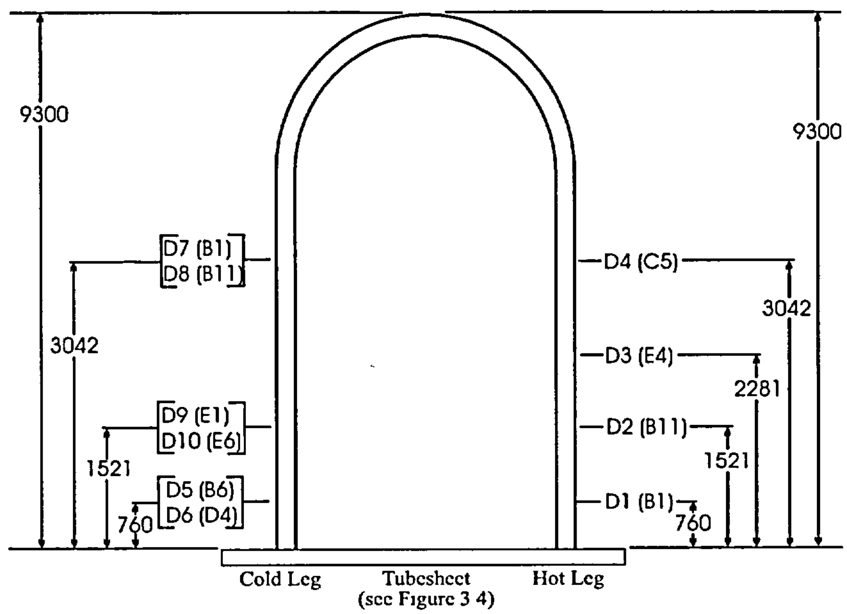
FIGURE 3.8: Steam Generator Separator Schematic

3. SECONDARY HEAT TRANSPORT SYSTEM



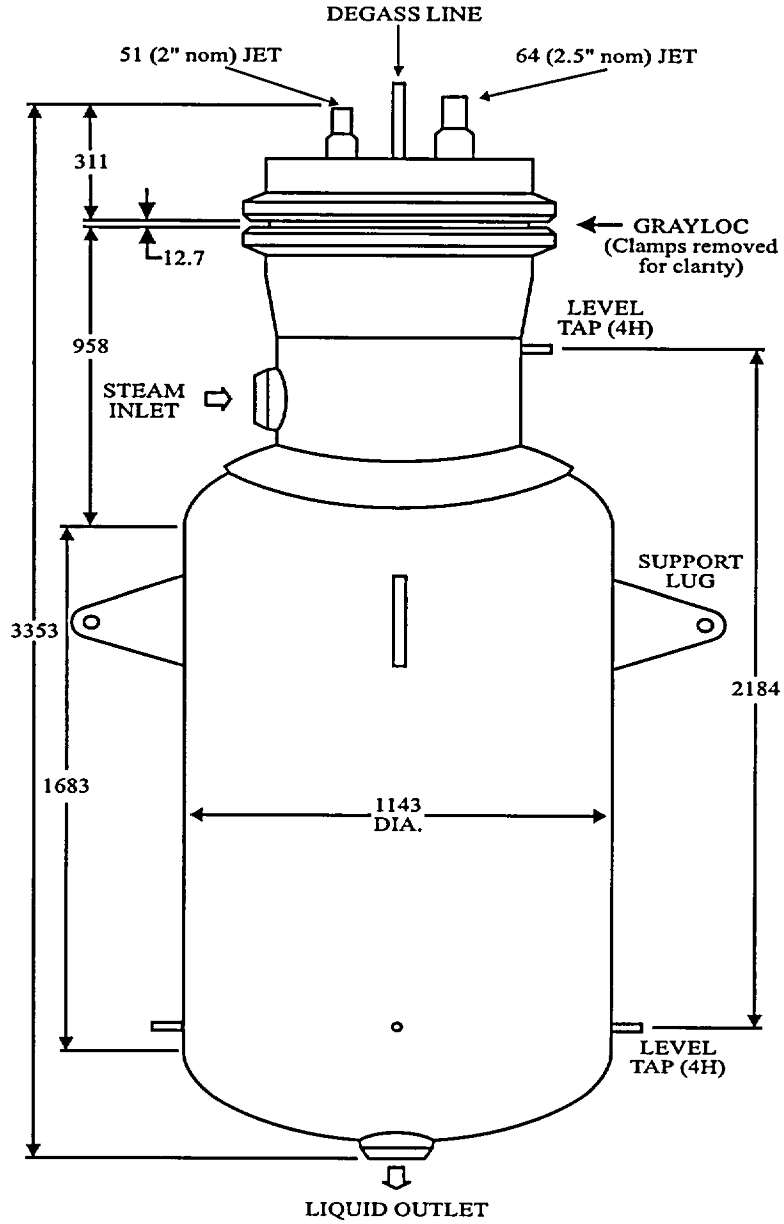
Note: See Figures 2 29 to 2 31 (primary-side) and Figure 3.10 (secondary-side) for elevations of steam generator instruments

FIGURE 3.9: Steam Generator Tube Bundle Layout



Notes: All elevations shown are in mm; tubesheet is zero datum
Device Codes are 74T-nn for BO1 and 75T-nn for BO2, where nn is D1-D10
Numbers in brackets ( ) indicate tube numbers.
Dimensions in mm.

FIGURE 3.10: Steam Generator Tube-Side Thermocouple Locations



Note: Dimensions are in mm

FIGURE 3.11: Jet Condenser CD1 Schematic

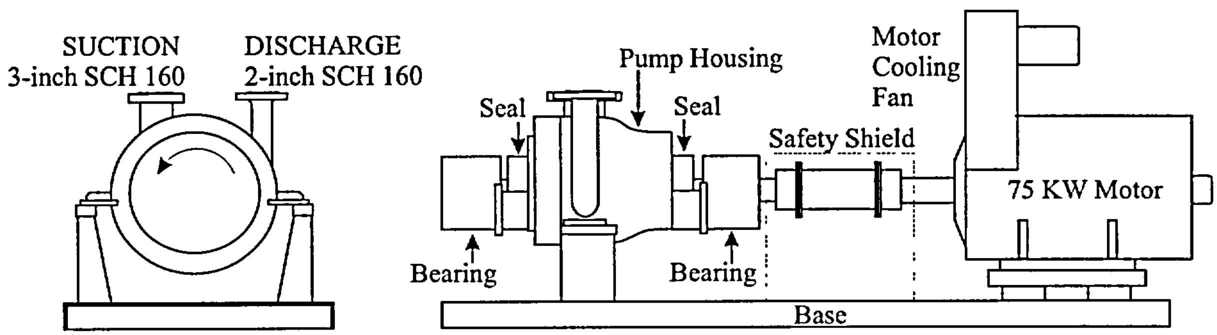
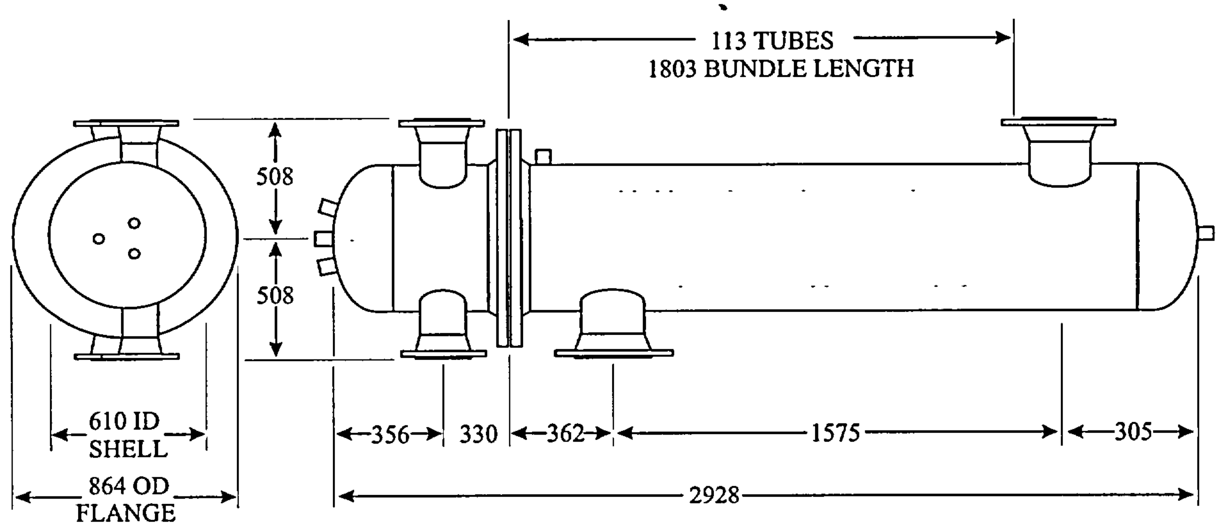
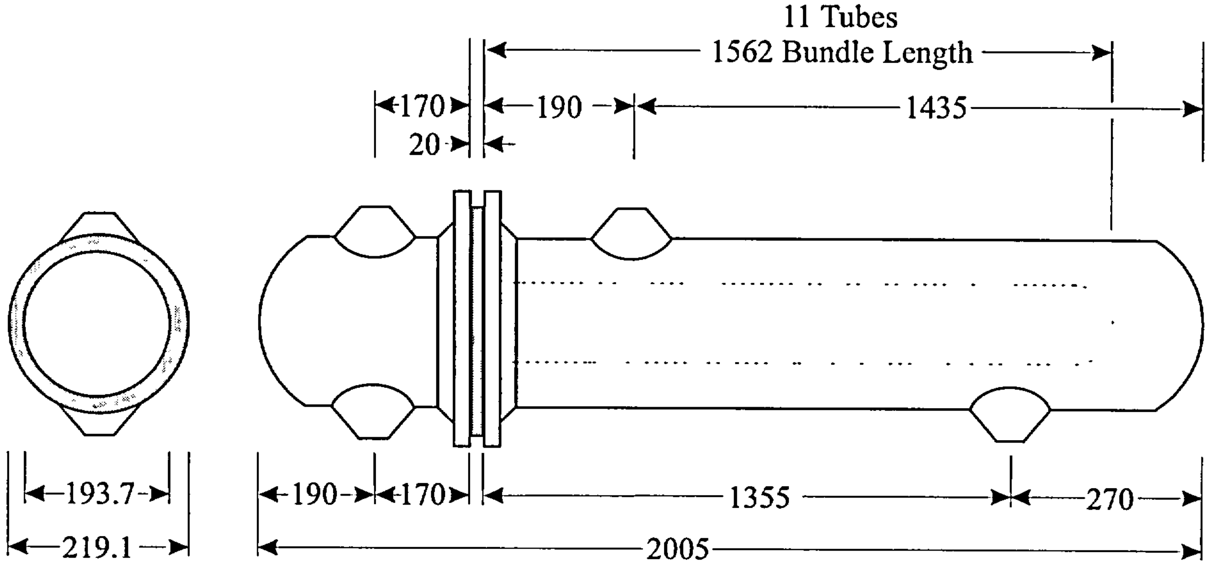


FIGURE 3.12: Secondary System Pumps P6 and P7



Note: Dimensions in mm

FIGURE 3.13: Secondary System Heat Exchanger HX2



Note: Dimensions are in mm

FIGURE 3.14: Secondary System Heat Exchanger HX5

4. EMERGENCY COOLANT INJECTION (ECI) SYSTEM

4.100 GENERAL DESCRIPTION OF REACTOR ECI SYSTEMS

The Emergency Coolant Injection (ECI) system, also referred to as the Emergency Core Cooling (ECC) system, supplies coolant to the reactor headers in the event of a loss-of-coolant accident. Generally, there are three modes of ECI in a CANDU system: a high-pressure phase, a recovery phase, and a gravity-feed phase.

The first ECI initiated following a LOCA is the high-pressure phase. This system supplies coolant from either high-pressure accumulator tanks or high-pressure pumps supplied from a low-pressure tank. Injection begins when the primary heat transport system pressure drops below the injection pressure, typically 5 MPa, and continues until the recovery phase is initiated, or until the coolant supply tanks are emptied.

Coolant discharged from the heat transport system collects in sumps located at the bottom of the containment building. During the ECI recovery phase, this coolant is pumped from these sumps through a heat exchanger and injected back into the heat transport system. The injection pressure during the recovery phase varies from plant to plant.

For most CANDU reactor designs, in the unlikely event that the ECI pumps are inoperable, emergency coolant is also available from dousing tanks by gravity feed.

Figure 4.1 shows a schematic of a typical CANDU ECI system.

4.200 DESCRIPTION AND OPERATION OF THE RD-14M ECI SYSTEM

The RD-14M ECI system can simulate either high-pressure pumped ECI or pressurized accumulator tank ECI, low-pressure pumped ECI (recovery phase), and, to a limited degree, gravity feed ECI. The type of high-pressure ECI system, pumped or accumulator tank, must be manually configured in the facility before each test. This involves the installation of specific orifices, check valves, and flowmeters, which provide the necessary simulated flow rates and measurements for each high-pressure ECI system. Coolant from the ECI system can be selectively directed to each of the four headers through use of motorized isolation valves located at each header. Figures 4.2 and 4.3 provide detailed information on the arrangement of the RD-14M ECI system. Elevation diagrams are given in Figures 4.4 to 4.6. Table 4.1 summarizes the normal position of the various valves under the different modes of ECI.

The actual operation of the ECI system can be controlled manually or automatically using a programmable sequencer (see Section 5.700) and relays functioning from pressure and level signals. A typical sequence for simulated LOCA experiments is as follows:

1. Open ECI isolation valves located at headers following a pressure signal from header HDR7 (typically 5.5 MPa).
2. High-pressure ECI phase begins only when loop pressure falls below injection pressure.
3. Terminate high-pressure ECI phase when coolant level in ECI tank, TK2, reaches 10%. Start low-pressure pumped (recovery) ECI phase from distilled water tanks.
4. Terminate low-pressure pumped ECI phase when level in distilled water tanks falls below 50%.
5. Initiate gravity feed ECI system. (Note: operation of the gravity feed ECI system is restricted as described in Section 4.250).

Deviations from this event sequence can, and have, occurred during RD-14M tests.

4.210 High-Pressure Accumulator Tank ECI System

This system approximates the high-pressure ECI systems typical of the CANDU-6 generating stations. A schematic of this system is shown in Figure 4.2. In this mode, the ECI tank (TK2) is pressurized with nitrogen prior to an experiment (see Section 4.350). Typically, the ECI tank is pressurized to 4.2 MPa for RD-14M LOCA experiments. Continuous depressurization of TK2 results when coolant flows through MV11 into the loop during the test, except for some tests where the pressure in the tank can be controlled (feedback from pressure cell 27P). This mode of ECI is terminated when the coolant level in TK2 reaches 10%.

As summarized in Table 4.2, five orifices (OR21-OR25) are used to provide scaled simulation of reactor injection flow rates. Check valves are also installed in the two main injection lines to prevent flow from the loop back into TK2 (a summary of the check valve arrangement is given in Table 4.3). This configuration does allow the exchange of fluid between headers 6 and 5, and between headers 8 and 7, once the ECI isolation valves are opened. As a result of this potential for reverse flow, turbine flowmeters capable of indicating flow direction are installed before each header. Turbine flowmeters are well suited to measure the low flows obtained with this system

4.220 High-Pressure Pumped ECI System

This system approximates the high-pressure ECI systems typical of Darlington generating stations, using pump P14 (see Section 4.330). The pump has a bypass to allow start-up with a closed discharge. A spring-operated control valve (CV10) opens when P14 discharge pressure reaches 5.5 MPa (g) to divert flow back to the top of the ECI tank (TK2). A constant head at the pump discharge is maintained during small break LOCA tests by recycling excess coolant flow back into TK2 using the control valve (not all of the ECI coolant flow is needed during a small break LOCA). Since the pump motor for P14, which is located in the pump case, is submerged in water, continuous operation of this pump is not recommended when the inlet pump temperature exceeds 30°C. This temperature limit can be exceeded when ambient temperatures are high and significant heat, produced by the pump, is added to TK2 through the recycled coolant. Under these conditions, P14 is stopped when the pump inlet temperature reaches 40°C. Otherwise, the high-pressure ECI phase is normally terminated when the level in TK2 reaches 10%. A schematic of this system is shown in Figure 4.3.

As shown in Table 4.2, only one orifice (OR25), located in the main ECI line, is used with the high-pressure pumped ECI system. Check valves, as summarized in Table 4.3, are located in each of the ECI lines adjacent to each header. Consequently, no significant exchange of fluid between headers should occur. Temperature measurements in the ECI lines to the headers can be made to determine if fluid exchange between headers is occurring in some tests. Turbine flowmeters are used to measure coolant flow to each of the headers.

The high-pressure pumped ECI system described in the original RD-14M facility description [4.1], using two centrifugal pumps in series (P8 and P9), was never used in RD-14M experiments. Vibrations generated by P9 were found to induce excessive noise in the data collected from the flow instrumentation. As a consequence, this combination of pumps (P8 and P9) was replaced with a single pump (P14) in 1989 November.

4.230 Simulated High-Pressure Pumped ECI System

Prior to the installation of pump P14, high-pressure pumped ECI conditions were simulated for one set of tests. In partial inventory natural circulation experiments T8901 to T8904, the main ECI tank, TK2, was pressurized to an initial pressure of 5.5 MPa, and the coolant was discharged through the orifice and check valve configuration described in Section 4.220 for the high-pressure pumped ECI system. No pumps were used to deliver emergency coolant in these tests.

4.240 Low-Pressure Recovery Phase ECI System

The low-pressure recovery phase ECI system, is simulated using pump P8 (see Section 4.340) to deliver coolant from the distilled water storage tanks. Recovery phase ECI begins when the level in TK2 falls below 10%, which automatically isolates TK2, valves the distilled tanks on-line, and starts P8. The low-pressure ECI system terminates when the water in the distilled water tanks falls to 50%. This is the way this system is typically used.

Alternatively, pump P8 can be activated manually, and draw coolant from TK2 until the level reaches 10%, after which coolant would be drawn from the distilled water tanks. The low-pressure ECI system terminates when the water in the distilled water tanks falls to 50%.

4.250 Gravity Feed ECI System

To simulate the situation in which ECI pumps are unavailable, coolant may also be fed by gravity from the distilled water storage tanks. This will only occur when the level in the distilled water tanks falls below 50%, stopping the low-pressure injection pump, P8, and opening MV13.

4. EMERGENCY COOLANT INJECTION SYSTEM

The delivery pressure and duration of the RD-14M gravity feed system is limited. The distilled water tanks supplying gravity feed ECI are only about 2.8-m above the headers. Consequently, the hydrostatic head available for gravity feed ECI is only about 27 kPa. The time during which gravity feed ECI is available is usually in the order of one to two minutes. This restriction is caused by the automatic refilling of the distilled water tanks from a central reservoir which clears the low-level signal. This in turn causes MV13 to close terminating the gravity feed ECI injection phase.

4.300 COMPONENTS OF ECI SYSTEM

4.310 ECI System Piping

The RD-14M ECI system piping is made of schedule-80 carbon steel ranging from 146.3 mm (ID) on the discharge line from the ECI tank, to 38.1 mm (ID) on the injection lines to the headers. Elevation diagrams can be found in Figures 4.4-4.6, and the ECI system components can be found in the legends following each of these elevation diagrams.

It should be noted that the 146.3-mm (ID) P14 inlet line (discharge line from TK2), Stations 85-91 on Figure 4.4, was installed in 1998 March. All ECI tests conducted before this time utilized the smaller 73.66 mm (ID) inlet line. ECI tests conducted after 1998 March utilized the 146.3 mm (ID) inlet line.

4.320 ECI Tank (TK2)

ECI tank TK2, shown in Figure 4.7, is a cylindrical, vertically-suspended, carbon-steel tank. The utilizable volume between the upper and lower level taps is 2.36 m^3. The design pressure is 6.9 MPa (g). The interior surface is lined with a coal-tar epoxy for corrosion protection.

A 25-kW strap-on electrical heater permits pre-heating of the injection water to a maximum 90°C. This temperature restriction is imposed by the coal tar epoxy lining. The pre-heater is not normally used.

4.330 High-Pressure Pump (P14)

The RD-14M ECI high-pressure pump, P14, is an eleven-stage, constant-speed, 250 hp submersible pump manufactured by Pleuger (model #10-XKL-11), capable of delivering 20 L/s at 5.5 MPa. The entire pump, including the motor, is enclosed in a tank (P14 well) and immersed in water. See Section 8.531 for pump characterization information.

4.340 Low-Pressure Pump (P8)

The RD-14M low-pressure pump, P8, is a Hayward-Gordon (model #A-30) horizontal, single-stage, constant-speed, centrifugal pump, driven by a 75 kW electric motor. See Section 8.532 for the pump characterization.

4.350 Nitrogen Supply

Nitrogen is used to pressurize ECI tank TK2, if required. One of two external nitrogen sources can be used to maintain tank pressure. A nitrogen cylinder located just outside the loop enclosure provides a capacity of 8.3 m^3 at standard conditions. Alternately, a nitrogen trailer with a capacity of 620 m^3 at standard conditions, located outdoors near the loop enclosure, may be used. The two nitrogen sources may be operated together.

4.360 Distilled Water Storage Tanks

The two distilled water storage tanks, DW-TK4 and DW-TK9, are used to supply ECI coolant during the recovery and gravity feed ECI phases. The tanks have a combined capacity of 5.7 m^3. The liquid level of the tanks is at an elevation approximately 2.8 m above the headers.

4.400 ECI ALARM SIGNALS

Constraints on the operating conditions of the ECI system arising from system trips, alarms, and control set-points are summarized in Table 4.4.

REFERENCE

[4.1] M[c]Gee, G.R., Spitz, K.O., Borgford, T.A., Findlay, J.W., Hood, B.E., and Thomson, R.G., "RD-14M Facility Description," COG-88-42, 1989.

TABLE 4.1

ECI VALVE POSITIONING FOR SELECTED ECI MODES

Valve	High-Pressure Accumulator Tank ECI (CANDU-6)	High-Pressure Pumped ECI (Darlington)	Simulated High-Pressure Pumped ECI	Low-Pressure Recovery Phase ECI	Gravity Feed ECI
MV4	Open	Open	Open	Open	Open
MV5	Open	Open	Open	Open	Open
MV6	Open	Open	Open	Open	Open
MV7	Open	Open	Open	Open	Open
MV10	Closed	Closed	Closed	Closed*	Closed
MV11	Open	Closed	Open	Closed	Closed
MV12	Closed	Closed	Closed	Open*	Closed
MV13	Closed	Closed	Closed	Closed	Open
MV22	Closed	Open	Closed	Closed	Closed

* In the alternative low-pressure ECI mode (see Section 4.240), MV10 is initially open until TK2 drains to 10% level, then it is closed, and MV12 is initially closed until TK2 reaches 10% level, then it is opened.

TABLE 4.2

TYPICAL ECI ORIFICE ARRANGEMENT

Orifice #	Description	Orifice Size (mm)	
		High-Pressure Accumulator Tank ECI (CANDU-6)	High-Pressure Pumped ECI (Darlington)
OR21	ECI line to HDR5	13.7	--
OR22	ECI line to HDR6	20.6	--
OR23	ECI line to HDR7	13.7	--
OR24	ECI line to HDR8	20.6	--
OR25	Main ECI line	21.2	35.5
OR25	Main ECI line (single channel tests)	--	15.0

4. EMERGENCY COOLANT INJECTION SYSTEM

TABLE 4.3

ECI CHECK VALVE ARRANGEMENT

Description	Check Valve	
	High-Pressure Accumulator Tank ECI (CANDU-6)	High-Pressure Pumped ECI (Darlington)
ECI line to HDR5 and HDR6	NV30	--
ECI line to HDR7 and HDR8	NV31	--
ECI line to HDR5	--	NV4
ECI line to HDR6	--	NV5
ECI line to HDR7	--	NV7
ECI line to HDR8	--	NV6

TABLE 4.4

ECI SYSTEM TRIPS, ALARMS AND CONTROL SET-POINTS

Device	Description	Set-Point
1H-Kl	ECI Tank High Level	80%
1H-Kl	ECI Tank Low Level	10%
17H-Kl	Distilled Water Tank Low Level	50%
27P-Kl	ECI Tank Pressure High	6.9 MPa
27P-K2	Pump P8 High Pressure Lockout	3.1 MPa
27P-K3	Pump P14 High Pressure Lockout	1.0 MPa
27P-K4	Nitrogen Pressurizing Set-point	4.2 MPa
321T-Kl	Pump P14 Outlet Temperature High Trip	40°C
6P-Kl	ECI Isolation Valves Open	5.5 MPa*

*The set-point for opening the ECI isolation valves are based on the desired experimental procedure. 5.5 MPa is a typical set-point (6.0 MPa has been used).

4. EMERGENCY COOLANT INJECTION SYSTEM

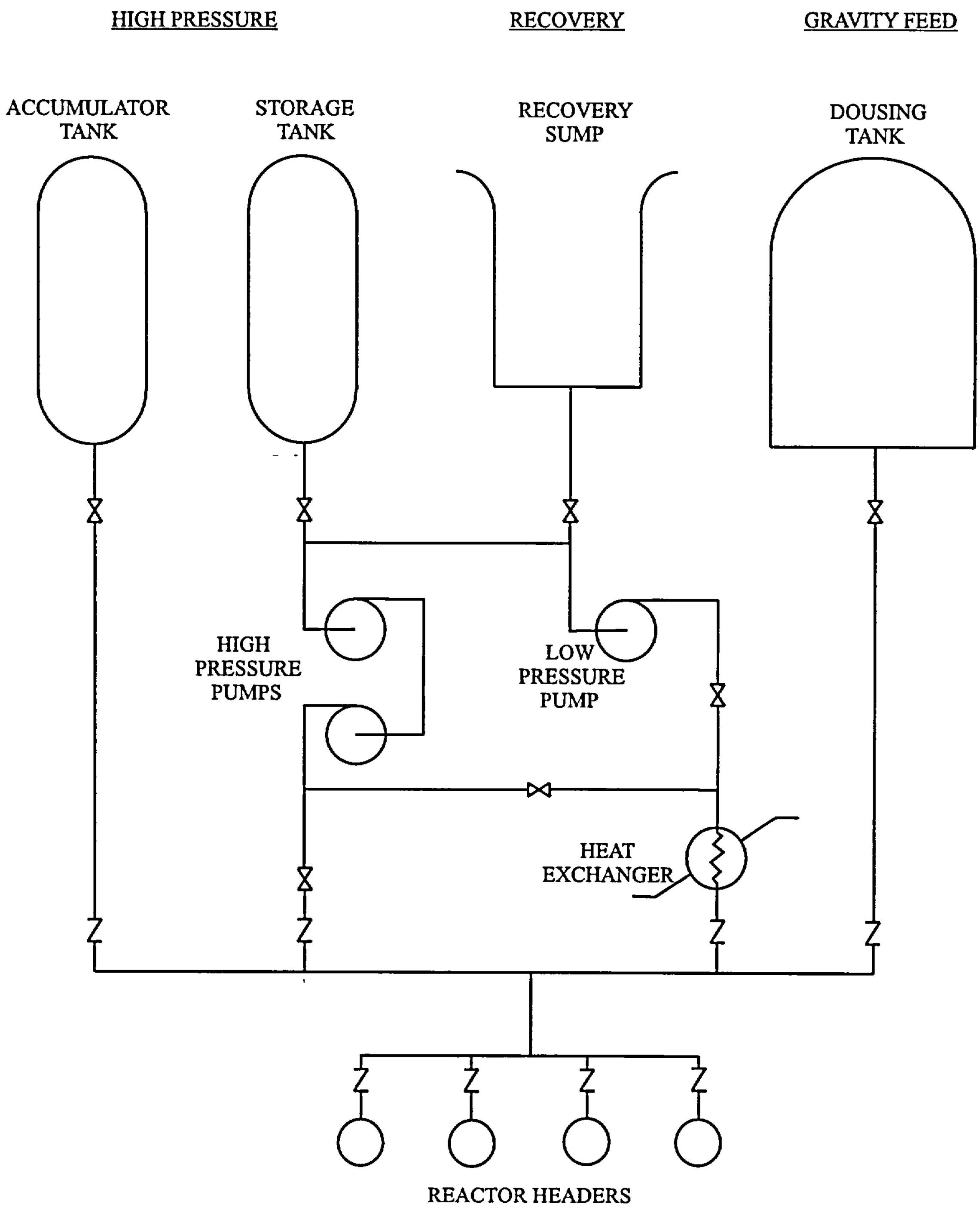


FIGURE 4.1: CANDU ECI System Schematic

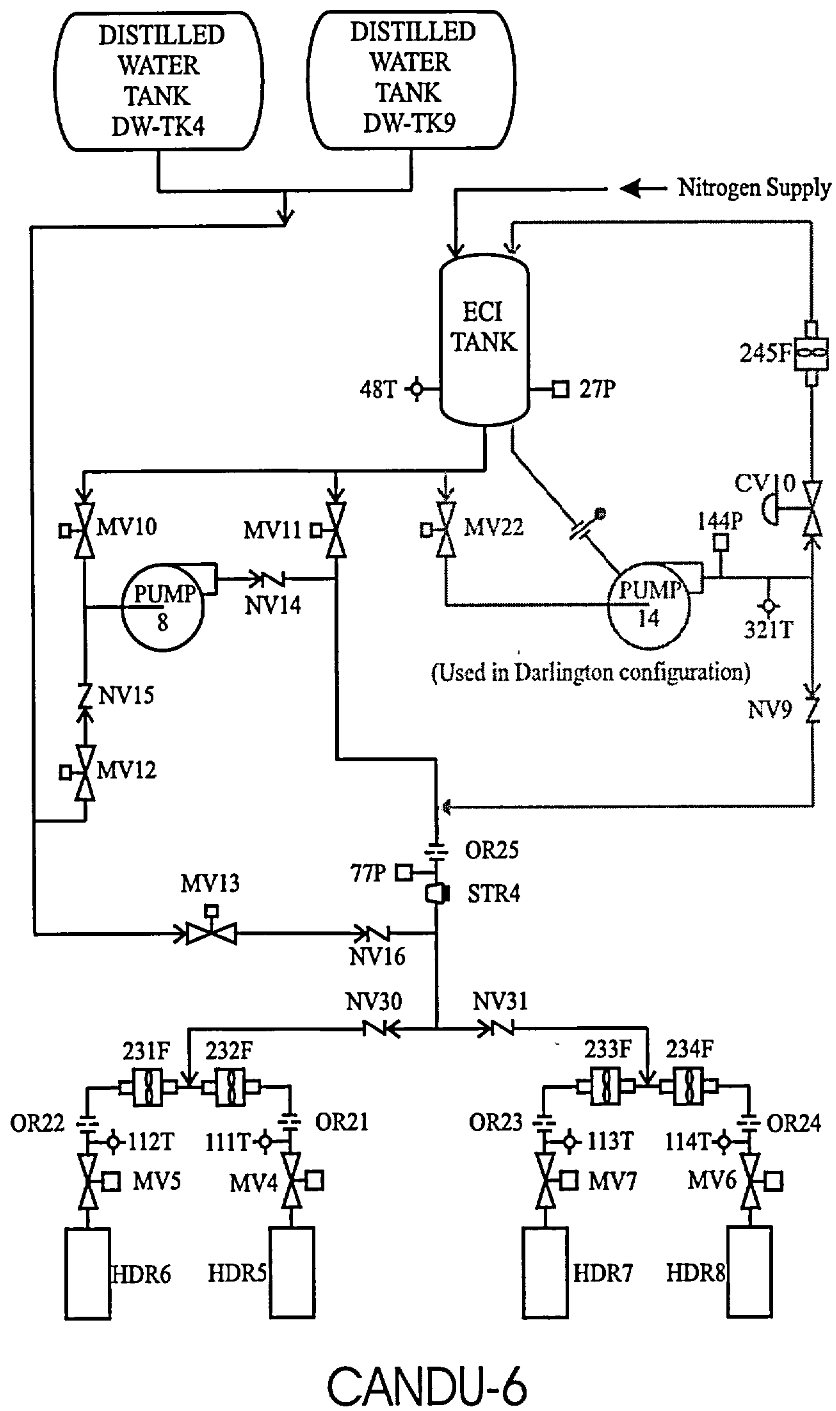


FIGURE 4.2: RD-14M ECI System in the CANDU-6 Configuration

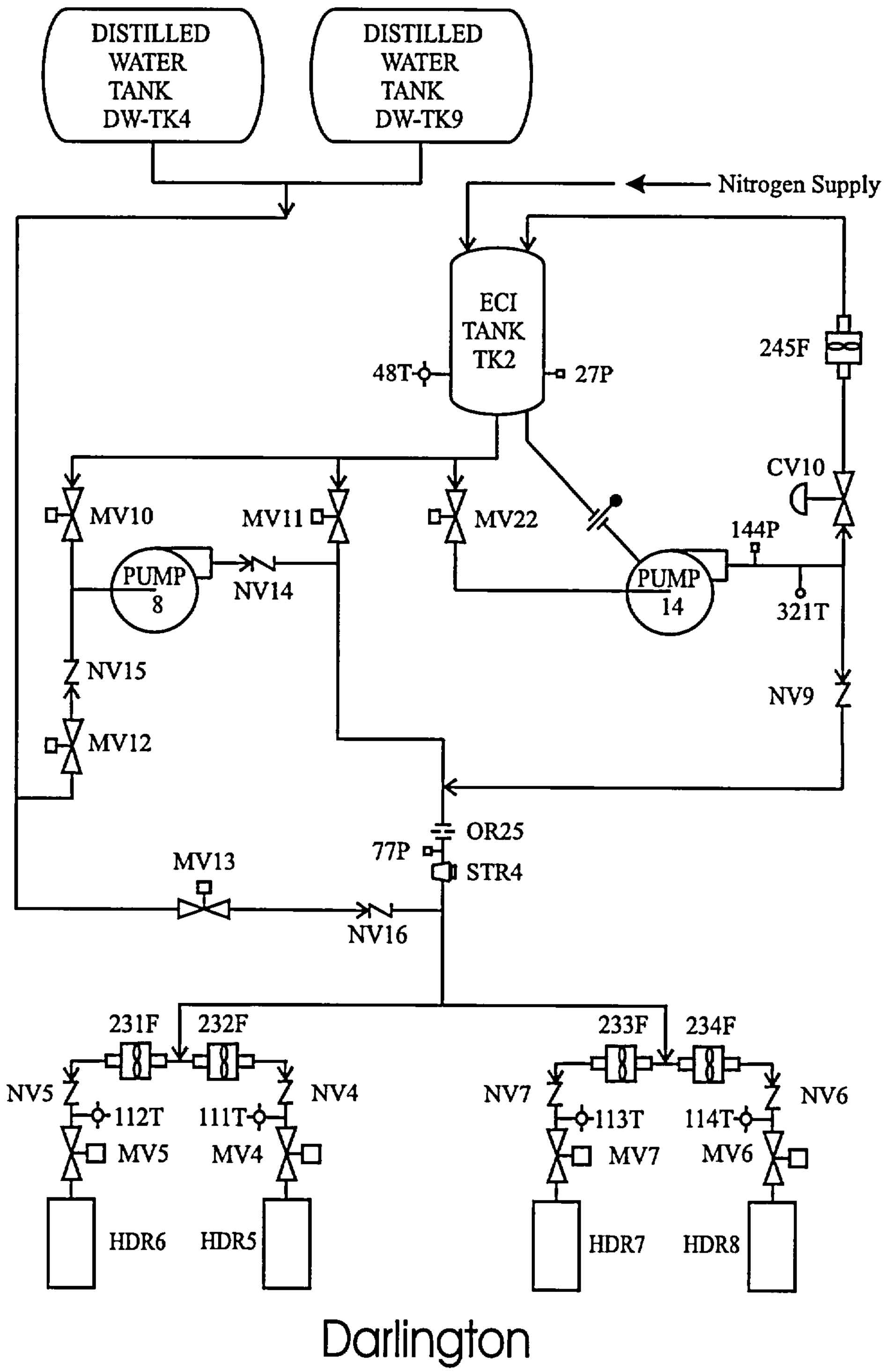


FIGURE 4.3: RD-14M ECI System in the Darlington Configuration

4. EMERGENCY COOLANT INJECTION SYSTEM

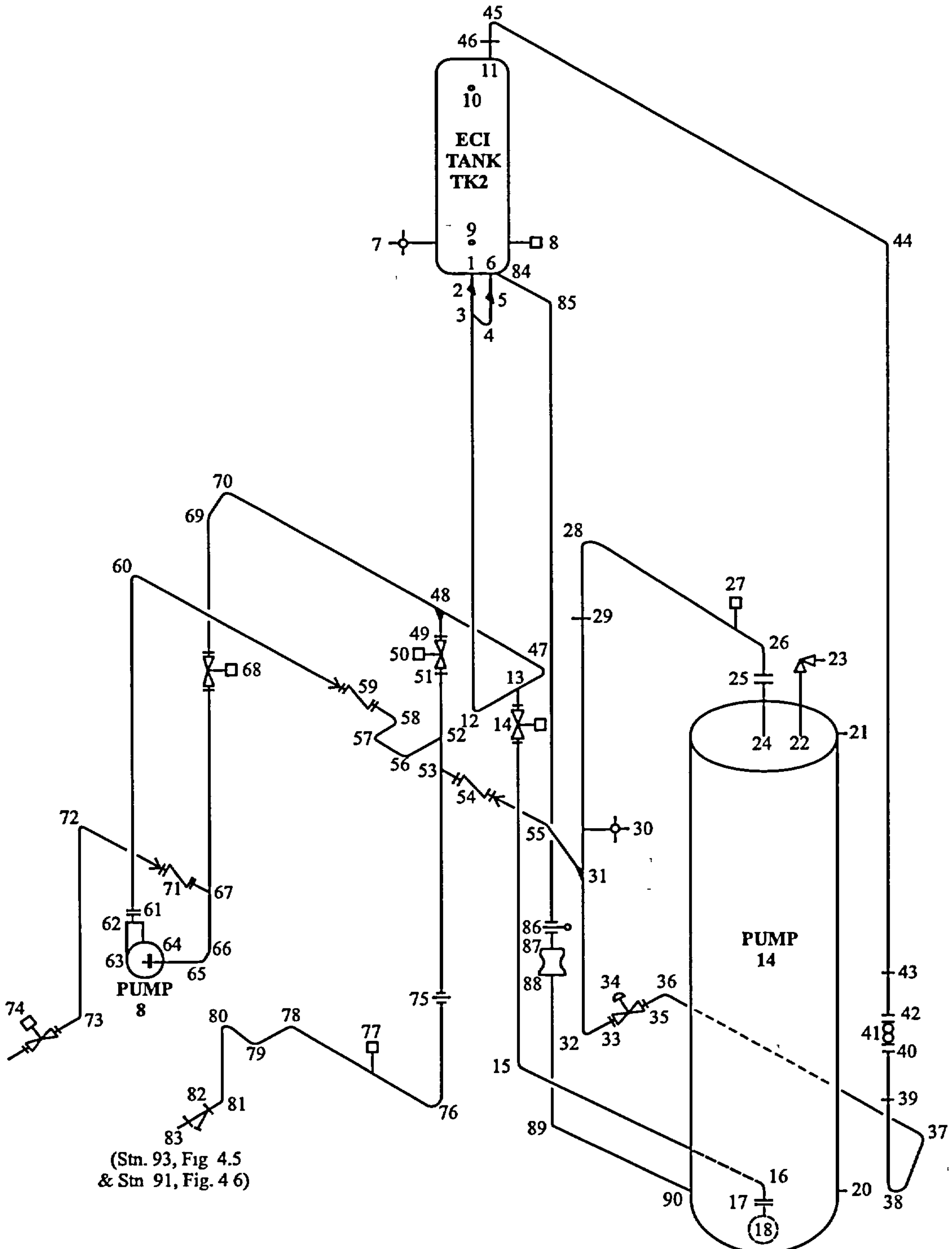


FIGURE 4.4: RD-14M ECI System Configuration Elevation Diagram: Equipment Common to CANDU-6 and Darlington Configurations

FIGURE 4.4 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
1	ECI Tank TK2 Bottom	21.62			
			0.02	38.10	90
2	Reducer	21.60			
			0.37	73.66	90
3	Tee	21.23			
			0.18	73.66	0
4	Elbow (90°)	21.23			
			0.07	73.66	90
5	Reducer	21.30			
			0.32	49.25	90
6	ECI Tank TK2 Bottom	21.62			
7	Thermocouple (48T-D1)	22.02			
8	Pressure Tap (27P)	22.02			
9	Level Tap (1H - Lower)	22.02			
			3.59		90
10	Level Tap (1H - Upper)	25.61			
			0.38		90
11	ECI Tank TK2 Top	25.99			
3	Tee	21.23			
			6.27	73.66	90
12	Elbow (90°)	14.96			
			0.80	73.66	0
13	Tee	14.96			
			0.20	73.66	90
14	Valve (MV22)	14.76			
			2.39	73.66	90
15	Elbow (90°)	12.37			
			0.90	73.66	0
16	Elbow (90°)	12.37			
			0.50	73.66	0
17	Inlet Flange	12.37			
			0.20	73.66	0
18	Pump P14 Inlet	12.37			

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
19	Pump P14 Bottom	12.01			
			0.29		
20	P14 Well Level (13H-D1 - Lower)	12.30			
			4.73		
21	P14 Well Level (13H-D1 - Upper)	17.03			
22	Pump P14 Top	17.03			
			0.50	38.10	90
23	Relief Valve (RV7)	17.53			
24	Pump P14 Outlet	17.03			
			0.27	73.66	90
25	Outlet Flange	17.30			
			0.20	73.66	90
26	Elbow (90°)	17.50			
			0.30	73.66	0
27	Pressure Tap (144P-D1)	17.50			
			0.30	73.66	0
28	Elbow (90°)	17.50			
			1.00	73.66	90
29	Grayloc	16.50			
			2.94	73.66	90
30	Thermocouple (321T-D1)	13.56			
			0.16	73.66	90
31	Reducing Tee	13.40			
			0.75	73.66	90
32	Elbow (90°)	12.65			
			0.20	73.66	0
33	Grayloc	12.65			
34	Control Valve (CV10)		0.50		0
35	Grayloc	12.65			
			0.20	73.66	0
36	Elbow (90°)	12.65			
			1.06	73.66	0
37	Elbow (90°)	12.65			
			0.68	73.66	0
38	Elbow (90°)	12.65			
			0.40	73.66	90

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
39	Grayloc	13.05			
			0.87	73.66	90
40	Flange	13.92			
41	Vortex Flowmeter (245F)		0.20		90
42	Flange	14.12			
			0.43	73.66	90
43	Grayloc	14.55			
			12.34	73.66	90
44	Elbow (90°)	26.89			
			1.23	73.66	0
45	Elbow (90°)	26.89			
			0.60	73.66	90
46	Grayloc	26.29			
			0.30	73.66	90
11	ECI Tank TK2 Top	25.99			
13	Tee	14.96			
			0.20	73.66	0
47	Elbow (90°)	14.96			
			0.25	73.66	0
48	Reducing Tee	14.96			
			0.49	49.25	90
49	Grayloc	14.47			
50	Valve (MV11)		0.52	42.9	90
51	Grayloc	13.95			
			0.25	49.25	90
52	Tee	13.70			
			0.30	49.25	90
53	Tee	13.40			
			0.20	49.25	0
54	Check Valve (NV9)	13.40			
			0.30	49.25	0
55	Elbow (90°)	13.40			
			1.06	49.25	0
31	Reducing Tee	13.40			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
52	Tee	13.70			
			0.52	49.25	0
56	Elbow (90°)	13.70			
			0.42	49.25	0
57	Elbow (90°)	13.70			
			0.36	49.25	90
58	Elbow (90°)	14.06			
			0.31	49.25	0
59	Check Valve (NV14)	14.06			
			0.70	49.25	0
60	Elbow (90°)	14.06			
			1.40	49.25	90
61	Outlet Flange	12.66			
			0.13	49.25	90
62	Pump P8 Outlet	12.53			
			0.15		90
63	Pump P8 Inlet	12.38			
			0.08		0
64	Inlet Flange	12.38			
			0.19	73.66	0
65	Elbow (90°)	12.38			
			0.44	73.66	0
66	Elbow (90°)	12.38			
			0.21	73.66	90
67	Tee	12.59			
			1.20	73.66	90
68	Valve (MV10)	13.79			
			0.96	73.66	90
69	Elbow (45°)	14.75			
			0.30	73.66	45
70	Elbow (45°)	14.96			
			1.00	73.66	0
48	Reducing Tee	14.96			

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
67	Tee	12.59			
			0.30	73.66	0
71	Check Valve (NV15)	12.59			
			1.00	73.66	0
72	Elbow (90°)	12.59			
			0.92	73.66	90

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
73	Elbow (90°)	11.67			
			1.17	73.66	0
74	Valve (MV12)	11.67			
53	Tee	13.40			
			0.80	49.25	90
75	Orifice (OR25-DP)	12.60		(see Table 4.1)	
			0.50	49.25	90
76	Elbow (90°)	12.10			
			0.70	49.25	0
77	Standoff (77P, ECI DP1, ECI DP2, ECI DP3, ECI DP4)	12.10			
			1.17	49.25	0
78	Elbow (90°)	12.10			
			0.20	49.25	0
79	Elbow (90°)	12.10			
			0.45	49.25	0
80	Elbow (90°)	12.10			
			0.80	49.25	90
81	Elbow (90°)	11.30			
			0.15	49.25	0
82	Strainer (STR4) Inlet	11.30			
			0.62		
83	Strainer (STR4) Outlet (same as Stn. 93, Fig. 4.5 and Stn. 91, Fig. 4.6)	11.30			
6	ECI Tank TK2 Bottom	21.62			
			0.30	146.05	75
84	6″ Nozzle Outlet (75°)	21.33			
			0.39	146.33	75
85	Elbow (15°)	20.95			
			7.66	146.33	90
86	Flange (Seal Ring/Blank)	13.29			
			0.40	146.33	90
87	Bellows Top Flange	12.89			
			0.24	152.4	90
88	Bellows Bottom Flange	12.65			
			0.35	146.33	90
89	Elbow (90°)	12.30			
			0.46	146.33	0
90	Pump P14 Inlet	12.30			

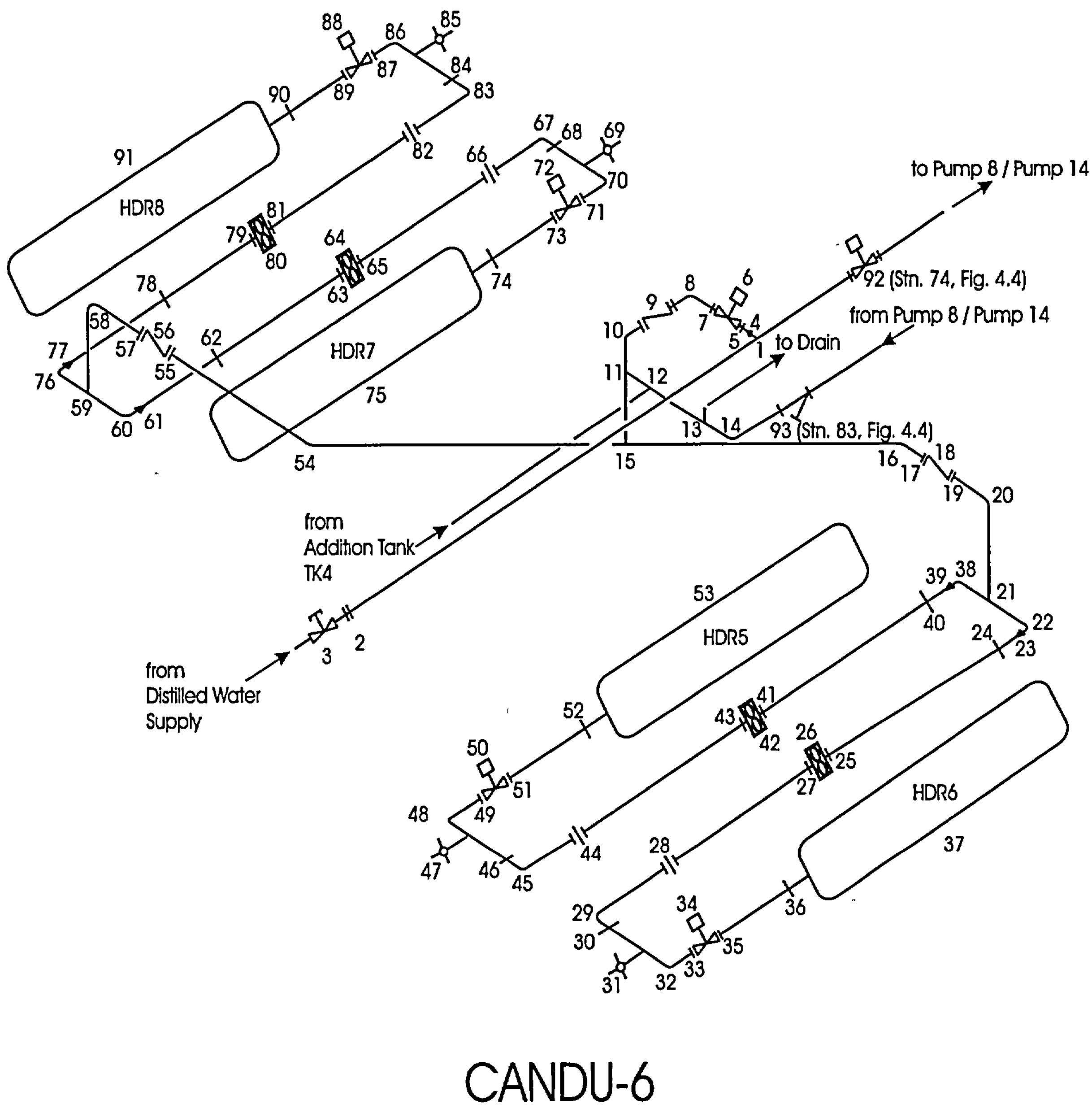


FIGURE 4.5: RD-14M ECI System Elevation Diagram: CANDU-6 Configuration

FIGURE 4.5 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
3	Manual Valve (V24)	11.67			
			0.23	73.66	90
2	Flange	11.67			
			0.15	73.66	0
1	Tee	11.67			
			0.93	73.66	0
92	Valve (MV12) (same as Stn. 74, Fig. 4.4)	11.67			
1	Tee	11.67			
			0.12	73.66	0
4	Reducer	11.67			
			0.20	49.25	0
5	Grayloc	11.67			
6	Valve (MV13)		0.51	42.9	0
7	Grayloc	11.67			
			0.70	49.25	0
8	Elbow (90°)	11.67			
			0.30	49.25	0
9	Check Valve (NV16)	11.67			
			0.28	49.25	0
10	Elbow (90°)	11.67			
			0.37	49.25	90
11	Tee	11.30			
			0.53	49.25	0
12	Tee (from TK4)	11.30			
			0.26	49.25	0
13	Tee (to drain)	11.30			
			1.19	49.25	0
14	Elbow (90°)	11.30			
			1.98	49.25	0
93	STR4 Outlet (same as Stn. 83, Fig. 4.4)	11.30			

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
11	Tee	11.30			
			0.11	49.25	90
15	Tee	11.19			
			0.73	49.25	0
16	Elbow (45°)	11.19			
			4.12	49.25	0
17	Grayloc	11.19			
18	Check Valve (NV30)	11.19	0.51	49.25	0
19	Grayloc	11.19			
			0.31	49.25	0
20	Elbow (90°)	11.19			
			0.15	49.25	90
21	Tee	11.04			
			0.20	49.25	0
22	Elbow (90°)	11.04			
			0.07	49.25	0
23	Reducer	11.04			
			0.14	38.10	0
24	Grayloc	11.04			
			0.62	38.10	0
25	Grayloc	11.04			
26	Turbine Flowmeter (232F-D1)		0.21	33.99	0
27	Grayloc	11.04			
			0.62	38.10	0
28	Orifice (OR22-DP)	11.04		20.60	
			0.51	38.10	0
29	Elbow (90°)	11.04			
			0.15	38.10	45
30	Grayloc	10.93			
			0.20	38.10	45
31	Thermocouple (112T-D1)	10.79			
			0.11	38.10	45
32	Elbow (90°)	10.71			
			0.11	38.10	0

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
33	Grayloc/Reducer	10.71			
34	Valve (MV5)		0.50	42.90	0
35	Grayloc/Reducer	10.71			
			0.21	38.10	0
36	Grayloc	10.71			
			0.05	38.10	0
37	Header HDR6	10.71			
21	Tee	11.04			
			0.20	49.25	0
38	Elbow (90°)	11.04			
			0.07	49.25	0
39	Reducer	11.04			
			0.14	38.10	0
40	Grayloc	11.04			
			0.62	38.10	0
41	Grayloc	11.04			
42	Turbine Flowmeter (231F-D1)		0.21	33.99	0
43	Grayloc	11.04			
			0.62	38.10	0
44	Orifice (OR21-DP)	11.04		13.70	
			0.51	38.10	0
45	Elbow (90°)	11.04			
			0.15	38.10	45
46	Grayloc	10.93			
			0.20	38.10	45
47	Thermocouple (111T-D1)	10.79			
			0.11	38.10	45
48	Elbow (90°)	10.71			
			0.11	38.10	0
49	Grayloc/Reducer	10.71			
50	Valve (MV4)		0.50	42.90	0
51	Grayloc/Reducer	10.71			
			0.31	38.10	0

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
52	Grayloc	10.71			
			0.05	38.10	0
53	Header HDR5	10.71			
15	Tee	11.19			
			0.82	49.25	0
54	Elbow (90°)	11.19			
			4.14	49.25	0
55	Grayloc	11.19			
56	Check Valve (NV31)		0.51	49.25	0
57	Grayloc	11.19			
			0.31	49.25	0
58	Elbow (90°)	11.19			
			0.15	49.25	90
59	Tee	11.04			
			0.20	49.25	0
60	Elbow (90°)	11.04			
			0.07	49.25	0
61	Reducer	11.04			
			0.14	38.10	0
62	Grayloc	11.04			
			0.63	38.10	0
63	Grayloc	11.04			
64	Turbine Flowmeter (233F-D1)		0.21	33.99	0
65	Grayloc	11.04			
			0.63	38.10	0
66	Orifice (OR23-DP)	11.04		13.70	
			0.51	38.10	0
67	Elbow (90°)	11.04			
			0.15	38.10	45
68	Grayloc	10.93			
			0.18	38.10	45
69	Thermocouple (113T-D1)	10.80			
			0.13	38.10	45
70	Elbow (90°)	10.71			
			0.11	38.10	0

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
71	Grayloc/Reducer	10.71			
72	Valve (MV7)		0.50	42.90	0
73	Grayloc/Reducer	10.71			
			0.62	38.10	0
74	Grayloc	10.71			
			0.06	38.10	0
75	Header HDR7	10.71			
59	Tee	11.04			
			0.20	49.25	0
76	Elbow (90°)	11.04			
			0.07	49.25	0
77	Reducer	11.04			
			0.14	38.10	0
78	Grayloc	11.04			
			0.62	38.10	0
79	Grayloc	11.04			
80	Turbine Flowmeter (234F-D1)		0.21	33.99	0
81	Grayloc	11.04			
			0.62	38.10	0
82	Orifice (OR24-DP)	11.04		20.60	
			0.51	38.10	0
83	Elbow (90°)	11.04			
			0.15	38.10	45
84	Grayloc	10.93			
			0.18	38.10	45
85	Thermocouple (114T-D1)	10.80			
			0.13	38.10	45
86	Elbow (90°)	10.71			
			0.11	38.10	0
87	Grayloc/Reducer	10.71			
88	Valve (MV6)		0.50	42.90	0
89	Grayloc/Reducer	10.71			
			0.56	38.10	0

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
90	Grayloc	10.71			
			0.04	38.10	0
91	Header HDR8	10.71			

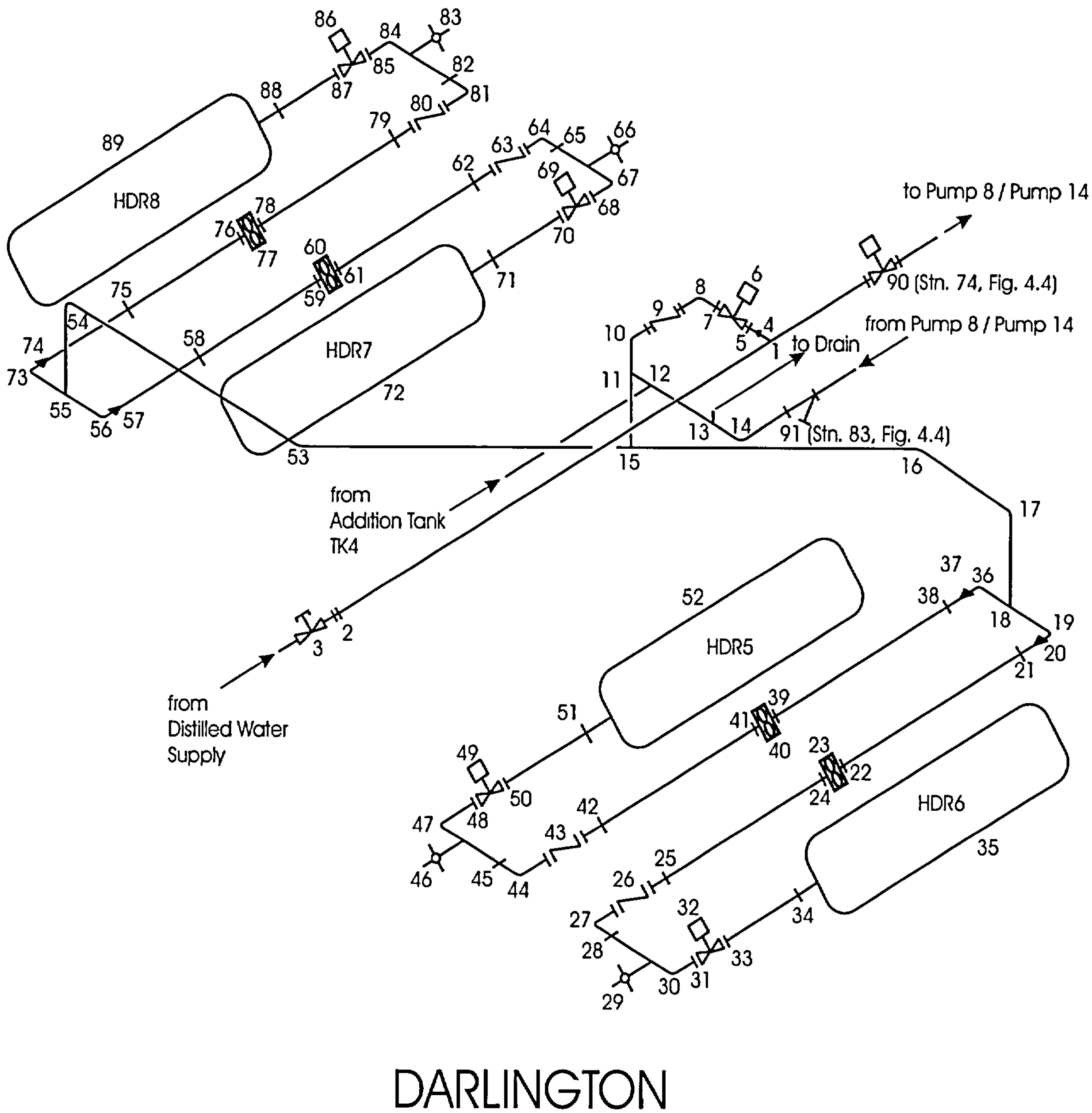


FIGURE 4.6: RD-14M ECI System Elevation Diagram: Darlington Configuration

FIGURE 4.6 Legend

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
3	Manual Valve (V24)	11.67			
			0.23	73.66	90
2	Flange	11.67			
			0.15	73.66	0
1	Tee	11.67			
			0.93	73.66	0
90	Valve (MV12) (same as Stn. 74, Fig. 4.4)	11.67			
1	Tee	11.67			
			0.12	73.66	0
4	Reducer	11.67			
			0.20	49.25	0
5	Grayloc	11.67			
6	Valve (MV13)		0.51	42.9	0
7	Grayloc	11.67			
			0.70	49.25	0
8	Elbow (90°)	11.67			
			0.30	49.25	0
9	Check Valve (NV16)	11.67			
			0.28	49.25	0
10	Elbow (90°)	11.67			
			0.37	49.25	90
11	Tee	11.30			
			0.53	49.25	0
12	Tee (from TK4)	11.30			
			0.26	49.25	0
13	Tee (to drain)	11.30			
			1.19	49.25	0
14	Elbow (90°)	11.30			
			1.98	49.25	0
91	Strainer STR4 Outlet (same as Stn. 83, Fig. 4.4)	11.30			

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
11	Tee	11.30			
			0.11	49.25	90
15	Tee	11.19			
			0.73	49.25	0
16	Elbow (45°)	11.19			
			4.94	49.25	0
17	Elbow (90°)	11.19			
			0.15	49.25	90
18	Tee	11.04			
			0.20	49.25	0
19	Elbow (90°)	11.04			
			0.07	49.25	0
20	Reducer	11.04			
			0.14	38.10	0
21	Grayloc	11.04			
			0.67	38.10	0
22	Grayloc	11.04			
23	Turbine Flowmeter (232F-D1)		0.11	33.99	0
24	Grayloc	11.04			
			0.68	38.10	0
25	Grayloc	11.04			
			0.17	38.10	0
26	Check Valve (NV5)	11.04			
			0.34	38.10	0
27	Elbow (90°)	11.04			
			0.15	38.10	45
28	Grayloc	10.93			
			0.20	38.10	45
29	Thermocouple (112T-D1)	10.79			
			0.11	38.10	45
30	Elbow (90°)	10.71			
			0.11	38.10	0
31	Grayloc/Reducer	10.71			
32	Valve (MV5)		0.50	42.90	0
33	Grayloc/Reducer	10.71			
			0.21	38.10	0

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
34	Grayloc	10.71			
			0.05	38.10	0
35	Header HDR6	10.71			
18	Tee	11.04			
			0.20	49.25	0
36	Elbow (90°)	11.04			
			0.07	49.25	0
37	Reducer	11.04			
			0.14	38.10	0
38	Grayloc	11.04			
			0.67	38.10	0
39	Grayloc	11.04			
40	Turbine Flowmeter (231F-D1)		0.11	33.99	0
41	Grayloc	11.04			
			0.68	38.10	0
42	Grayloc	11.04			
			0.17	38.10	0
43	Check Valve (NV4)	11.04			
			0.34	38.10	0
44	Elbow (90°)	11.04			
			0.15	38.10	45
45	Grayloc	10.93			
			0.20	38.10	45
46	Thermocouple (111T-D1)	10.79			
			0.11	38.10	45
47	Elbow (90°)	10.71			
			0.11	38.10	0
48	Grayloc/Reducer	10.71			
49	Valve (MV4)		0.50	42.90	0
50	Grayloc/Reducer	10.71			
			0.31	38.10	0
51	Grayloc	10.71			
			0.05	38.10	0
52	Header HDR5	10.71			

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
15	Tee	11.19			
			0.82	49.25	0
53	Elbow (45°)	11.19			
			4.96	49.25	0
54	Elbow (90°)	11.19			
			0.15	49.25	90
55	Tee	11.04			
			0.20	49.25	0
56	Elbow (90°)	11.04			
			0.07	49.25	0
57	Reducer	11.04			
			0.14	38.10	0
58	Grayloc	11.04			
			0.67	38.10	0
59	Grayloc	11.04			
60	Turbine Flowmeter (233F-D1)		0.11	33.99	0
61	Grayloc	11.04			
			0.67	38.10	0
62	Grayloc	11.04			
			0.17	38.10	0
63	Check Valve (NV7)	11.04			
			0.36	38.10	0
64	Elbow (90°)	11.04			
			0.15	38.10	45
65	Grayloc	10.93			
			0.18	38.10	45
66	Thermocouple (113T-D1)	10.80			
			0.13	38.10	45
67	Elbow (90°)	10.71			
			0.11	38.10	0
68	Grayloc/Reducer	10.71			
69	Valve (MV7)		0.50	42.90	0
70	Grayloc/Reducer	10.71			
			0.62	38.10	0
71	Grayloc	10.71			
			0.06	38.10	0
72	Header HDR7	10.71			

4. EMERGENCY COOLANT INJECTION SYSTEM

STATION NUMBER	DESCRIPTION	ELEVATION (m)	LENGTH (m)	PIPE ID (mm)	ANGLE (°)
55	Tee	11.04			
			0.20	49.25	0
73	Elbow (90°)	11.04			
			0.07	49.25	0
74	Reducer	11.04			
			0.14	38.10	0
75	Grayloc	11.04			
			0.68	38.10	0
76	Grayloc	11.04			
77	Turbine Flowmeter (234F-D1)		0.11	33.99	0
78	Grayloc	11.04			
			0.68	38.10	0
79	Grayloc	11.04			
			0.16	38.10	0
80	Check Valve (NV6)	11.04			
			0.33	38.10	0
81	Elbow (90°)	11.04			
			0.15	38.10	45
82	Grayloc	10.93			
			0.18	38.10	45
83	Thermocouple (114T-D1)	10.80			
			0.13	38.10	45
84	Elbow (90°)	10.71			
			0.11	38.10	0
85	Grayloc/Reducer	10.71			
86	Valve (MV6)		0.50	42.90	0
87	Grayloc/Reducer	10.71			
			0.56	38.10	0
88	Grayloc	10.71			
			0.04	38.10	0
89	Header HDR8	10.71			

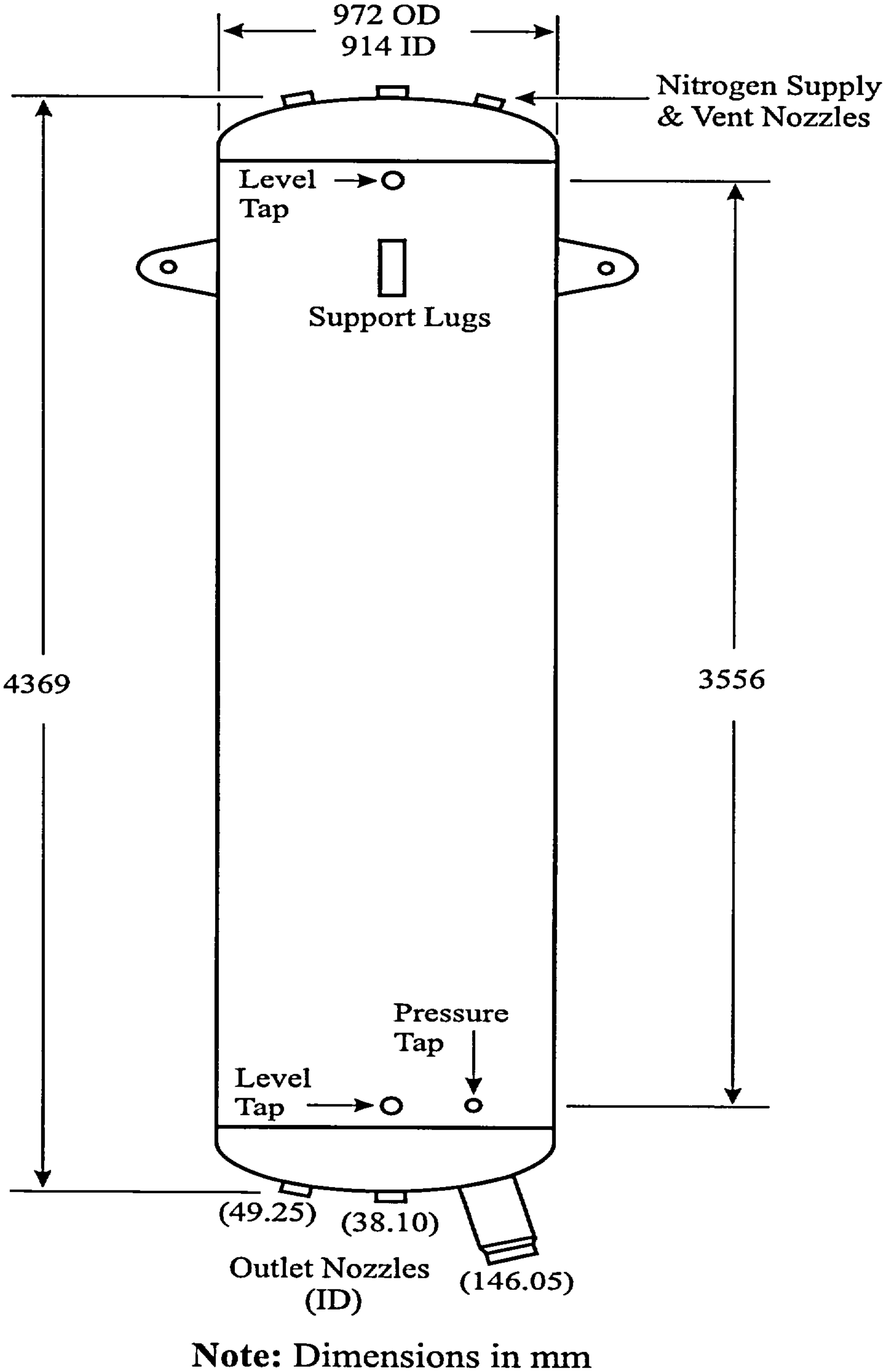


FIGURE 4.7: ECI Tank TK2