Once-Through Integral System Test Program

OTIS Loop Functional Specification

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QUALITY ASSURANCE STATEMENT

To the best of my knowledge and belief, the material presented in this report was conducted in accordance with the following Quality Assurance Plan:

Once-Through Integral Test Program (OTIS), 8/2/83 QA 83014

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SUMMARY

This report contains documentation of the Once-Through Integral System (OTIS) Test Facility built at the Alliance Research Center. This facility, known as OTIS, was a scaled simulation of a Babcock & Wilcox raised loop, 205 Fuel Assembly (FA) Pressurized Water Reactor. The test facility was originally built and tested for Brown-Boveri Reaktor (BBR) under contract to the Utility Power Generation Division (UPGD). The test program for BBR was called GERDA and is referenced throughout this report. Facility modifications were made at the completion of GERDA and additional tests were performed as part of the Integral Systems Test Program sponsored by the Nuclear Regulatory Commission, EPRI, B&W Owners Group and B&W.

The test facility was designed to evaluate the post - small break loss of coolant accident (SBLOCA) thermal-hydraulic events expected to occur in the B&W 205 FA plant. The facility was used to perform separate effect and integral system tests at scaled power levels up to 3.7%. The objective of the program was to obtain experimental data for the verification and/or refinement of the analytical models used to predict plant performance during SBLOCA transients.

The purpose of this report is to document the OTIS mechanical design features, instrumentation, data acquisition, loop controls, and results of the loop characterization tests (performed during the GERDA test program as well as during the OTIS test program).

This report is divided into three volumes. The main text and its supporting documentation, Appendices A through E, are contained in Volume 1. The mechanical and electrical drawings for the test facility are contained in Volumes 2 and 3, respectively.

The main text includes an introductory section which describes the purpose of the loop, the loop components and instrumentation, and summarizes the scaling considerations. The key features of the test loop are described in Section 2. A detailed description of each OTIS sub-system is included in Section 3. Results of the loop characterization tests are contained in Section 4 and include results from the GERDA test program as well as the OTIS test program.

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TABLE OF ABBREVIATION

Abbreviation	Definition
177FA	177 Fuel Assembly
205FA	205 Fuel Assembly
AFW	Auxiliary Feedwater
ARC	Alliance Research Center
B&W	Babcock & Wilcox
BBR	Brown Boveri Reaktor
CDC	Control Data Corporation
CLD	Cold Leg Discharge
CLS	Cold Leg Suction
DAS	Data Acquisition System
DB	Davis-Bessee
DC	Direct Current
DEC	Digital Equipment Corporation
DP	Differential Pressure
GERDA	Geradrohr Dampfergeuger Anlage meaning straight-tube steam generator (test)
HLUB	Hot Leg U-Bend
HPI	High Pressure Injection
HPV	High Point Vent
ID	Inside Diameter
KW	Kilowatt
LPI	Low Pressure Injection
LTS	Lower Tubesheet
MK	Mulheim Karlich
MWT	Mega-Watt Thermal

TABLE OF ABBREVIATION (Cont'd)

Abbreviation	Definition
NCG	Noncondensible Gas
OD	Outside Diameter
OTIS	Once-Through Integral System (Test)
OTSG	Once-Through Steam Generator
PORV	Power Operated Relief Valve
QA	Quality Assurance
QQLP	Quick-Quick Look Plots
RCP	Reactor Coolant Pump
RTD	Resistance Temperature Detector
RVVV	Reactor Vessel Vent Valve
SBLOCA	Small Break Loss of Coolant Accident
SFLTS	Secondary Face of the Steam Generator Lower Tubesheet
TC	Thermocouple
TSP	Tube Support Plate
TVA	Tennessee Valley Authority
UPGD	Utility Power Generator Division
UTS	Upper Tubesheet
VTAB	Variable Table Entry

1.0 INTRODUCTION

Phase 1 of a contract between the NRC, owners of B&W nuclear steam supply systems, B&W, and EPRI, involved modifications to and testing of the GERDA facility at B&W's Alliance Research Center. This experimental test facility was designed to evaluate the thermal/hydraulic conditions in the reactor coolant system and steam generator of the Mulheim Karlich (MK) plant, a raised-loop B&W 205 fuel assembly, pressurized water reactor during the natural circulation phases of a small break loss-of-coolant accident (SBLOCA). The test facility was a 1 x 1 (one hot leg, one cold leg) electrically heated loop specifically simulating the important features of a raised loop plant. The facility was used to perform separate effect and integral system tests at simulated scale power levels of about 1 to 5%.

Modifications were made to GERDA to support the subject Phase 1 workscope of the renamed facility, OTIS. Specifically, the OTIS facility modifications consisted of the following items:

- Addition of a reactor vessel head vent and flow restrictor between the upper plenum and upper head of the reactor vessel
- Addition of guard heaters to the upper plenum and upper head of the reactor vessel
- Addition of a guard heater to the pressurizer surge line
- Relocation of the cold leg flow measurement orifice by adding a flanged section in the cold leg near the steam generator outlet
- Installation of a branched leak of the cold leg suction piping with a thermocouple for fluid temperature measurement
- Installation of a string thermocouple in one of the steam generator tubes (a string thermocouple was added to a second tube but experienced early failure) and pitot tubes at the outlet of three steam generator tubes
- Installation of control valve limit switches for the high and low flow feedwater and steam circuits to indicate valve closure
- Relocation of the lower tap for the cold leg suction piping differential pressure measurement.

The general arrangement of the major components and systems of the OTIS Test Facility is shown in Figure 1-1. The loop consisted of one 19-tube Once-Through Steam Generator (OTSG), a simulated reactor, a pressurizer, a single hot leg, and a single cold leg. Reactor decay heat, following a scram, was simulated in the test loop by electrical heaters in the reactor vessel. No pump was included in the main primary loop, but a pump in an isolatable cold leg bypass line was available to provide forced primary flow. The test loop was full raised-loop plant elevation, approximately 95 feet high, and shortened in the horizontal plane (to approximately 6 feet) to maintain approximate volumetric scaling.

Other primary loop components included a reactor vessel vent valve (RVVV), pressurizer pilot-operated relief valve (PORV) or safeties, and a hot leg high point vent (HPV). Auxiliary systems were available for scaled high pressure injection (HPI), controlled primary leaks in both the two-phase and single-phase region, a secondary forced circulation system for providing auxiliary feedwater (AFW) to the OTSG, steam piping and pressure control, a cleanup system for the secondary loop, and gas addition for the primary loop.

The configuration of the test loop was dictated by scaling considerations[1]. The four scaling criteria used to configure OTIS, in order of priority, were:

- Elevations
- Post-SBLOCA Flow Phenomena
- Volumes
- Irrecoverable Pressure Loss Characteristics

SBLOCA fluid behavior is typically buoyancy driven; therefore, full elevation modeling was assigned first priority. To obtain flow phenomena in the test loop as close to plant-typical as possible, the governing phenomena were determined,

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[1]Details of scaling considerations are presented in Design Requirements Specification for GERDA, B&W Document No. 12-1123163-01, July 1981, and in the OTIS Design Requirements, B&W Document No. 51-1149127-00, February 1984.

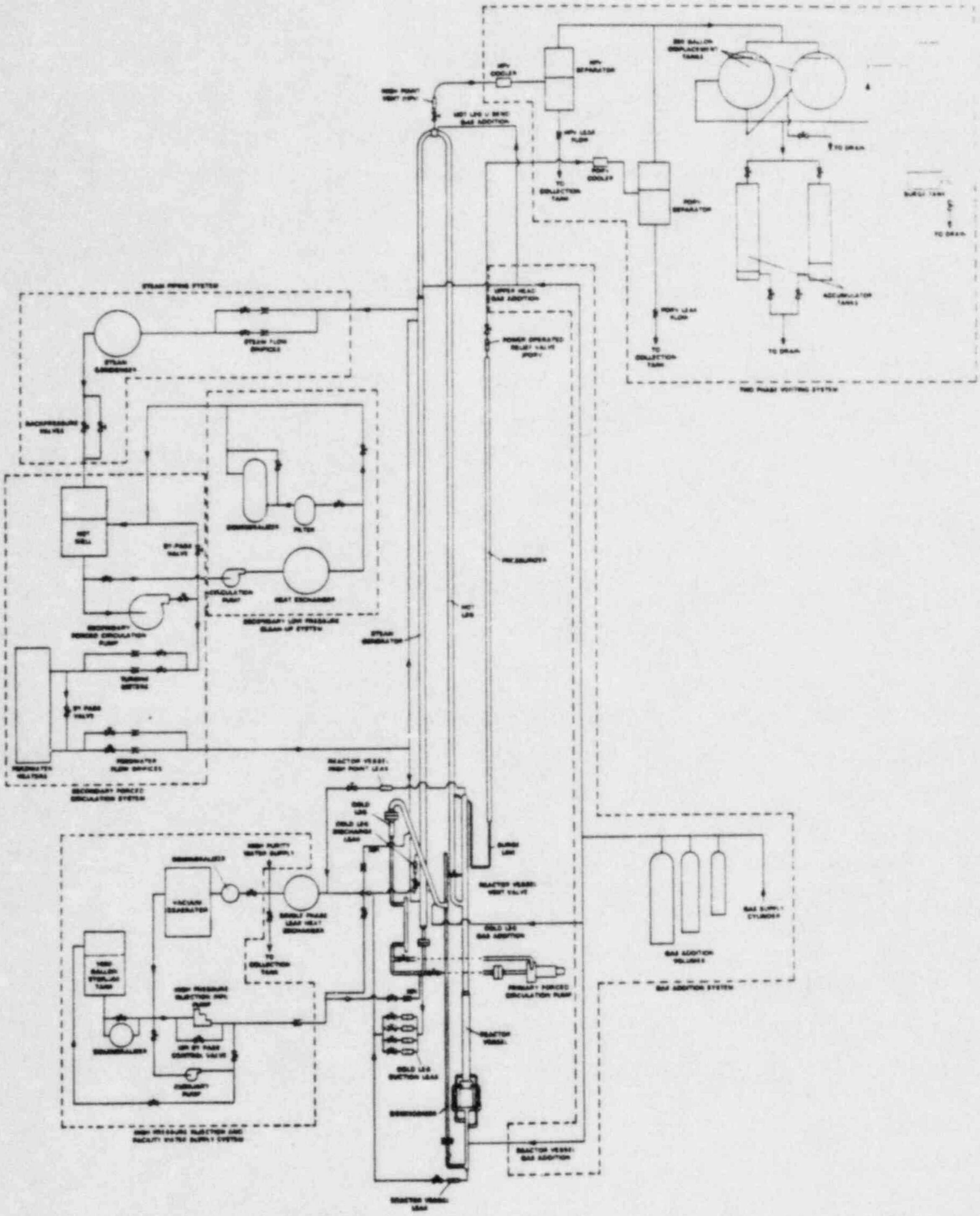

Figure 1-1 OTIS Test Facility

evaluated, and accommodated as second priority in the scaling criteria. Volumetric scaling of the loop components was generally possible, but was assigned third priority. The last major scaling criterion was the loop irrecoverable pressure losses. When the other scaling considerations were accommodated, irrecoverable losses were adjusted to plant-typical by the inclusion of flow restrictors in expected single-phase water locations in the loop.

OTIS power and volume scaling originated with the size of the model OTSG shown in Figure 1-2. The model OTSG contained nineteen (19) full-length and plant-typical tubes, which represented the 32,026 tubes in the two steam generators used in the 205-FA plants. Therefore, the dominant power and volume scaling in the loop was:

$$\text{Scaling Factor} = \frac{19}{2 \times 16013} = \frac{1}{1686}$$

As indicated in Figure 1-2, the distance between secondary faces of the lower and upper tubesheets in the 19-tube OTSG was full length. Auxiliary feedwater nozzles were located in the model steam generator at two elevations. The low AFW nozzles were located in an elevation approximately plant-typical of MK. The model also had high AFW nozzles located at an elevation typical of the 177 Fuel Assembly Plants. The tubesheet thicknesses in the model OTSG were not plant-typical, and the inlet and outlet plenums were reducers. Therefore, the hot leg-to-steam generator inlet and steam generator-to-cold leg elevations were atypical. Piping runs beyond the steam generator and plenums were used to retain plant-typical elevations. For example, Figure 1-2 indicates that the hot leg U-bend elevation of the plant was matched in OTIS.

The hot leg inside diameter was scaled to preserve Froude number, and thus the ratio of inertial to buoyant forces. This criterion was considered to preserve two-phase flow regimes and flooding phenomenon according to correlations of Dukler-Taitel and Wallis, respectively. Scaling with Froude number resulted in a hot leg diameter twice the diameter indicated by ideal volumetric scaling. Although this added approximately 20% to the ideal system volume (total loop

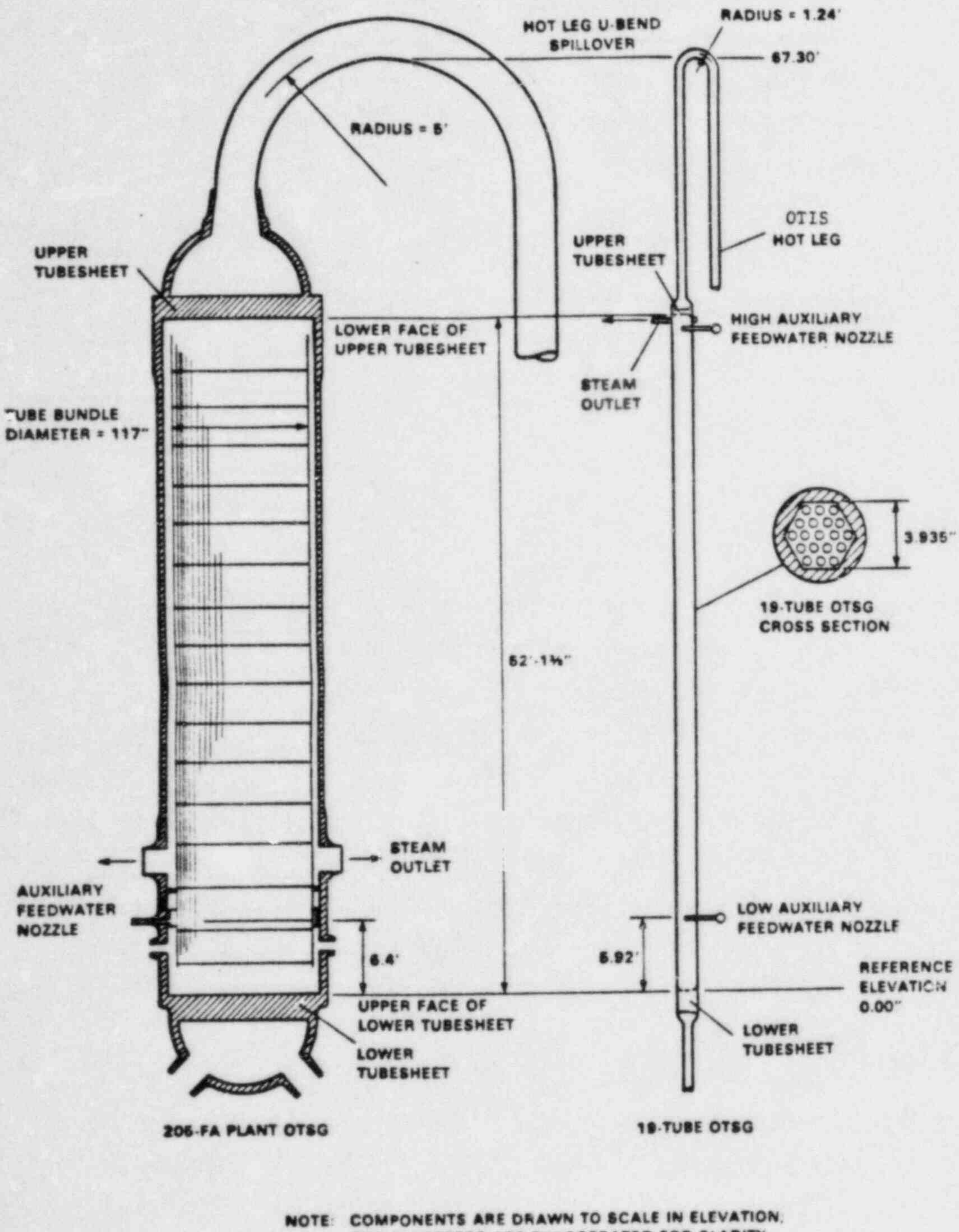

Figure 1-2 Comparison of Full-Size 205-FA Plant OTSG to 19-Tube OTSG in OTIS.

volume), this choice of hot leg inside diameter was considered most likely to avoid the whole-pipe slugging behavior observed in the SRI Reflux Boiler Tests[2].

The hot leg U-bend in OTIS is shown overlayed on the plant hot leg U-bend in Figure 1-3. As indicated in the figure, the plant spillover elevation is obtained in OTIS by matching the elevations of the bottom (inside) of the plant and OTIS hot leg U-bend pipes. The hot leg U-bend in OTIS is exactly volumetrically scaled (1/1686). The inside diameter of the hot leg U-bend pipe was set by the phenomenological scaling of the hot leg. The radius of the U-bend was chosen to achieve exact volumetric scaling.

The pressurizer in OTIS was volume and elevation scaled. With this scaling, the OTIS pressurizer was approximately 20 inches shorter than plant-typical. The elevation of the bottom of the pressurizer was plant typical as was the spillunder elevation of the pressurizer surge line. The centerline elevation of the hot leg-to-pressurizer surge connection matched the plant hot leg-to-surge centerline elevation.

An electrically heated reactor vessel provided heat input to the primary fluid to simulate reactor decay heat levels to 3.7% scaled power. Based on a power rating for the Tennessee Valley Authority (TVA) Plant (a domestic B&W 205 fuel assembly, raised loop plant) of 3600 MWt, 3.7% scaled power in OTIS corresponded to 79KW (3600/1686 x 0.037 x 1000). The OTIS reactor vessel heat input capacity was 180KW.

The design of the OTIS reactor vessel compared to the 205-FA plant reactor vessel is shown in Figure 1-4. The annular downcomer of the reactor vessel was simulated by a single external downcomer in OTIS. The spillunder elevation in the horizontal run at the bottom of the downcomer corresponded to the elevation of the uppermost flow hole in the lower plenum cylinder. The OTIS reactor vessel con-

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[2] "Reflux Boiling Heat Removal in a Scaled TMI-2 System Test Facility," R.T. Fernandez, et. al., paper presented at Thermal Reactor Safety Meeting, Knoxville, (April, 1980).

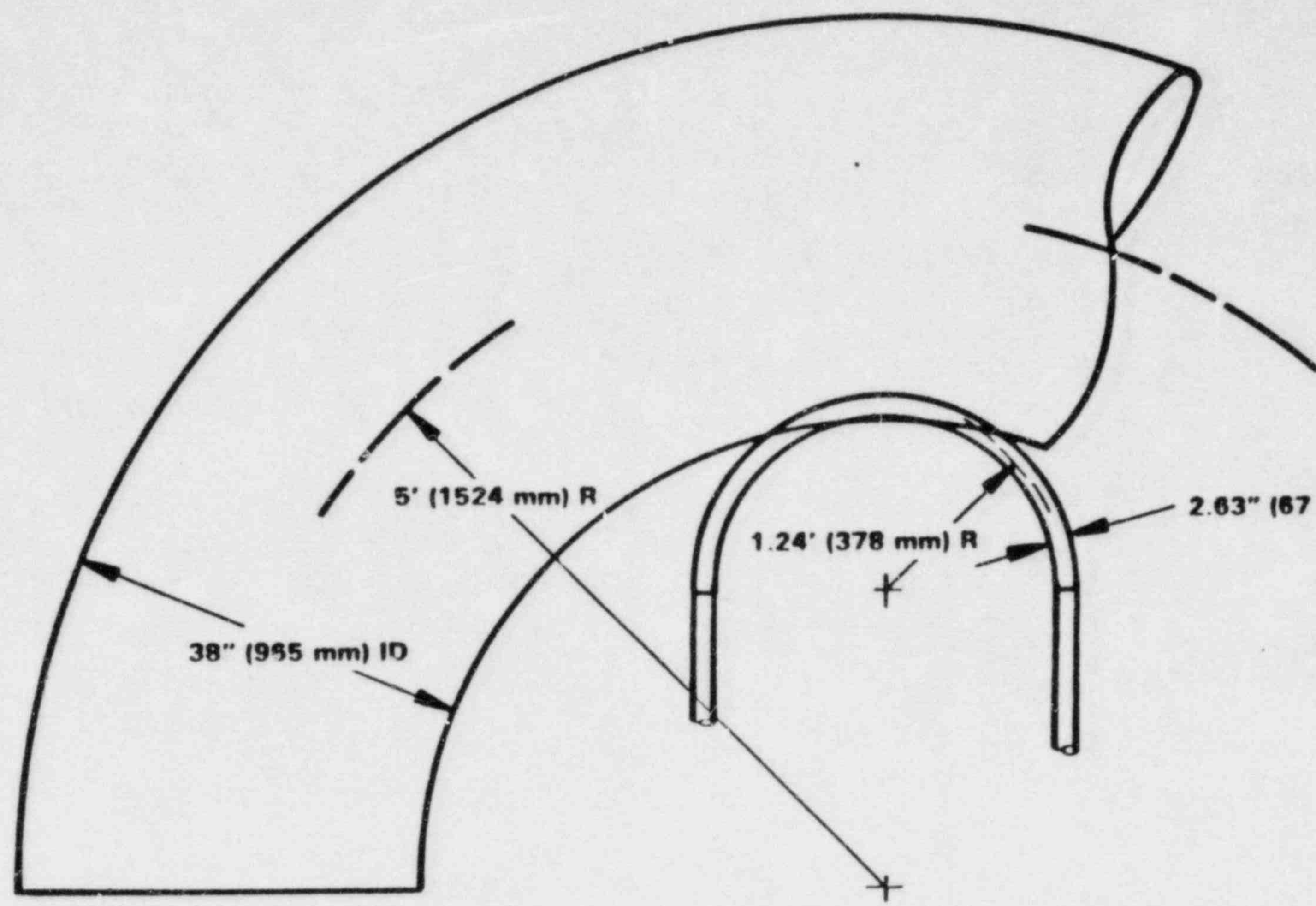


Figure 1-3 Plant and Model HLUB

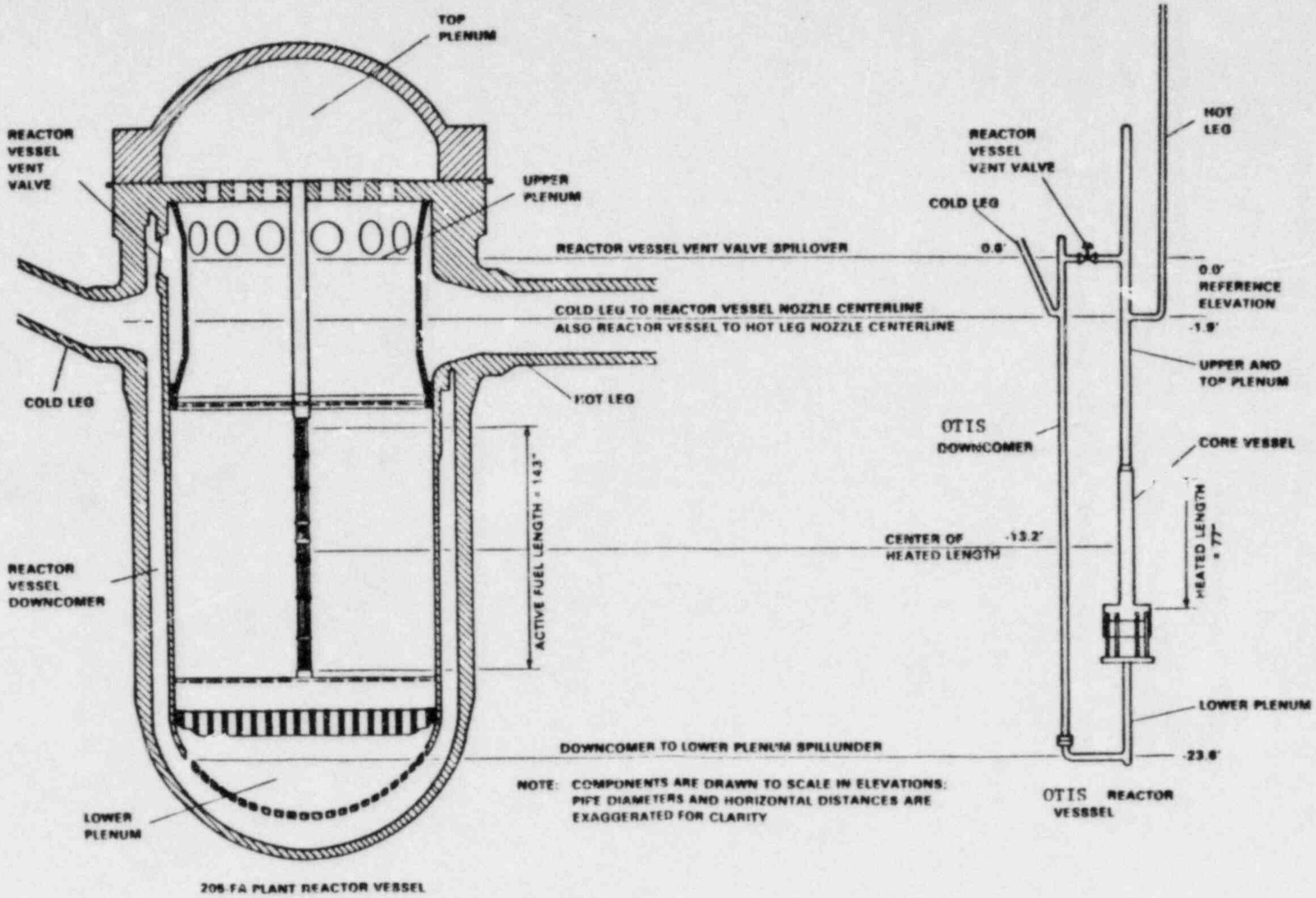


Figure 1-4 Comparison of Full-Size 205 Fuel Assembly Plant Reactor Vessel to OTIS Reactor Simulation

sisted of three regions: a lower plenum, a heated section (core vessel), and an upper and top plenum. The center of the heated length of the core vessel corresponded to the center of the active fuel length in the plant core. The core vessel portion of the reactor vessel contained excess volume due to construction constraints; therefore, to maintain the total reactor vessel model scaled volume, the reactor vessel was shorter than plant-typical. Non-flow lengths were sacrificed to maintain reactor vessel scaled volume, that is, the lower plenum was shortened below the downcomer spillunder point, and the upper and top plenum was shortened above the reactor vessel vent valve spillover point.

Cold primary fluid entered the downcomer from the cold leg, and heated primary fluid exited the upper plenum to enter the hot leg. The center of the cold leg to downcomer connection in OTIS corresponded to the cold leg-to-reactor vessel nozzle centerline in the plant. Similarly, the center of the hot leg-to-upper and top plenum connection in OTIS corresponded to the reactor vessel-to-hot leg nozzle centerline in the plant.

The cold leg in OTIS is compared to the 205-FA Plant cold leg in Figure 1-5. As indicated in the figure, the OTIS cold leg did not contain a pump, since OTIS was designed to simulate the natural circulation phases of a SBLOCA. A flange was provided in the OTIS cold leg just upstream of the reactor coolant pump spillover point so that a flow restrictor could be inserted to simulate the irrecoverable pressure loss characteristic of a stalled reactor coolant pump rotor. This flange was not used in OTIS to provide simulated locked pump rotor resistance. Rather, the resistance was positioned at the flange assembly downstream from the OTSG outlet for flow rate measurement.

The OTIS cold leg originated at the lower plenum of the 19-tube OTSG and extended downward in order that the elevation of the horizontal run of the OTIS cold leg matched the spillunder elevation of the plant cold leg. The highest point in the cold leg, that is, the spillover into the sloping cold leg discharge line, matched the reactor coolant pump spillover elevation in the plant. Because horizontal distances were shortened in OTIS, the slope of the cold leg discharge line was atypical in order that the cold leg to downcomer connection elevation was plant typical.

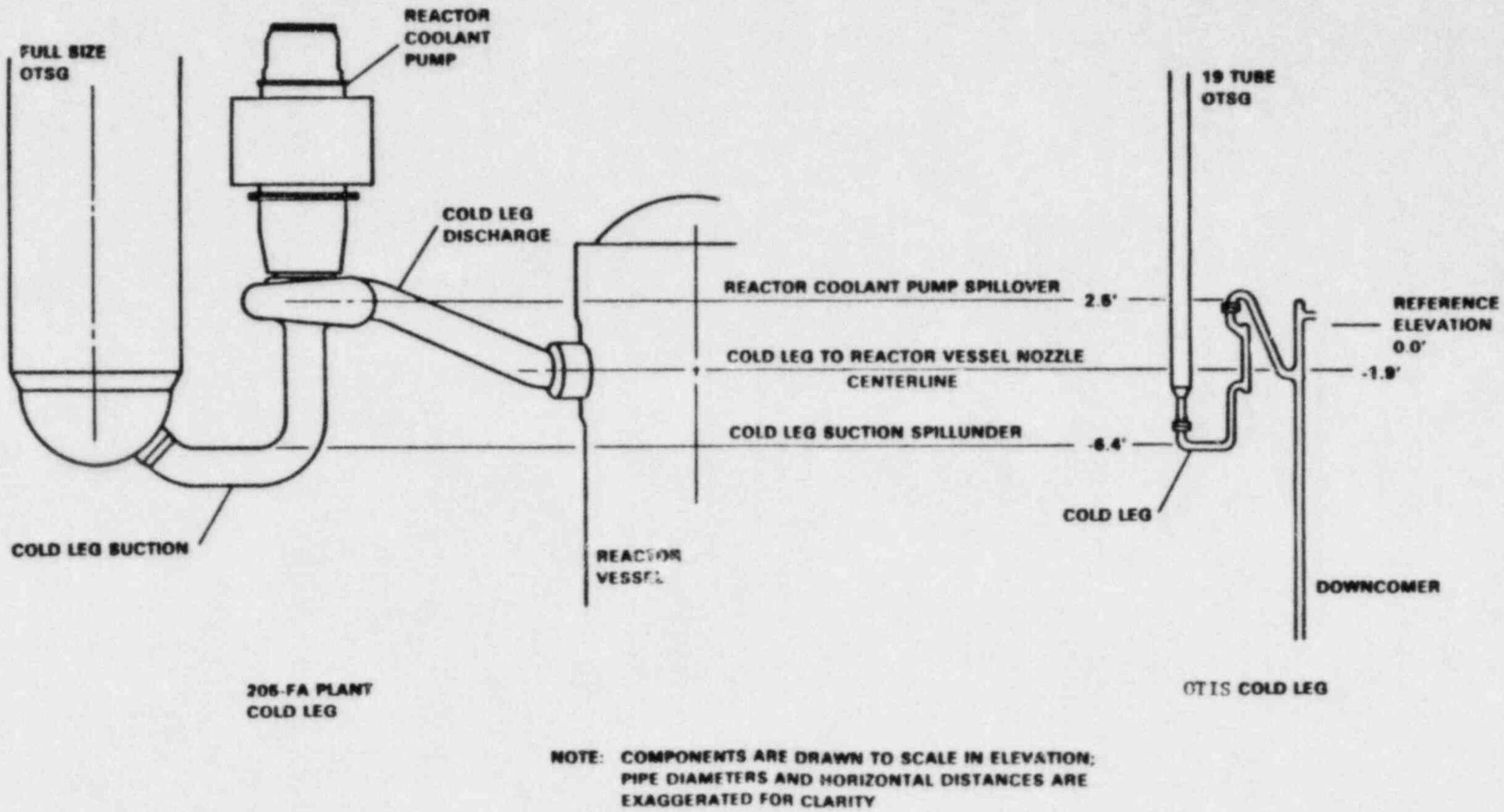


Figure 1-5 Comparison of Full-Size 205-FA Plant Cold Leg to OTIS Cold Leg

The diameters of the cold leg suction and cold leg discharge lines were chosen to preserve Froude number. Because of the shortened horizontal distances in OTIS, the cold leg volume was within 1% of the ideal volumetrically scaled volume.

Atypicalities in the OTIS test loop are summarized as follows:

- OTIS was predominantly a vertical system, due to the shortened horizontal distances and small cross sections of the various components such as steam generator and reactor vessel. Therefore, OTIS was inherently a one-dimensional model.

- Because of the small size of the piping used in OTIS, the ratio of loop wall surface to fluid volume was approximately 20 times that of the plant. Therefore, the fluid and wall-surface temperatures were much more closely coupled than those of a plant.

- In high-pressure models, the ratio of metal volume to fluid volume increases as the model is made smaller. In OTIS, the ratio of metal volume to fluid volume was approximately twice that of the plant.

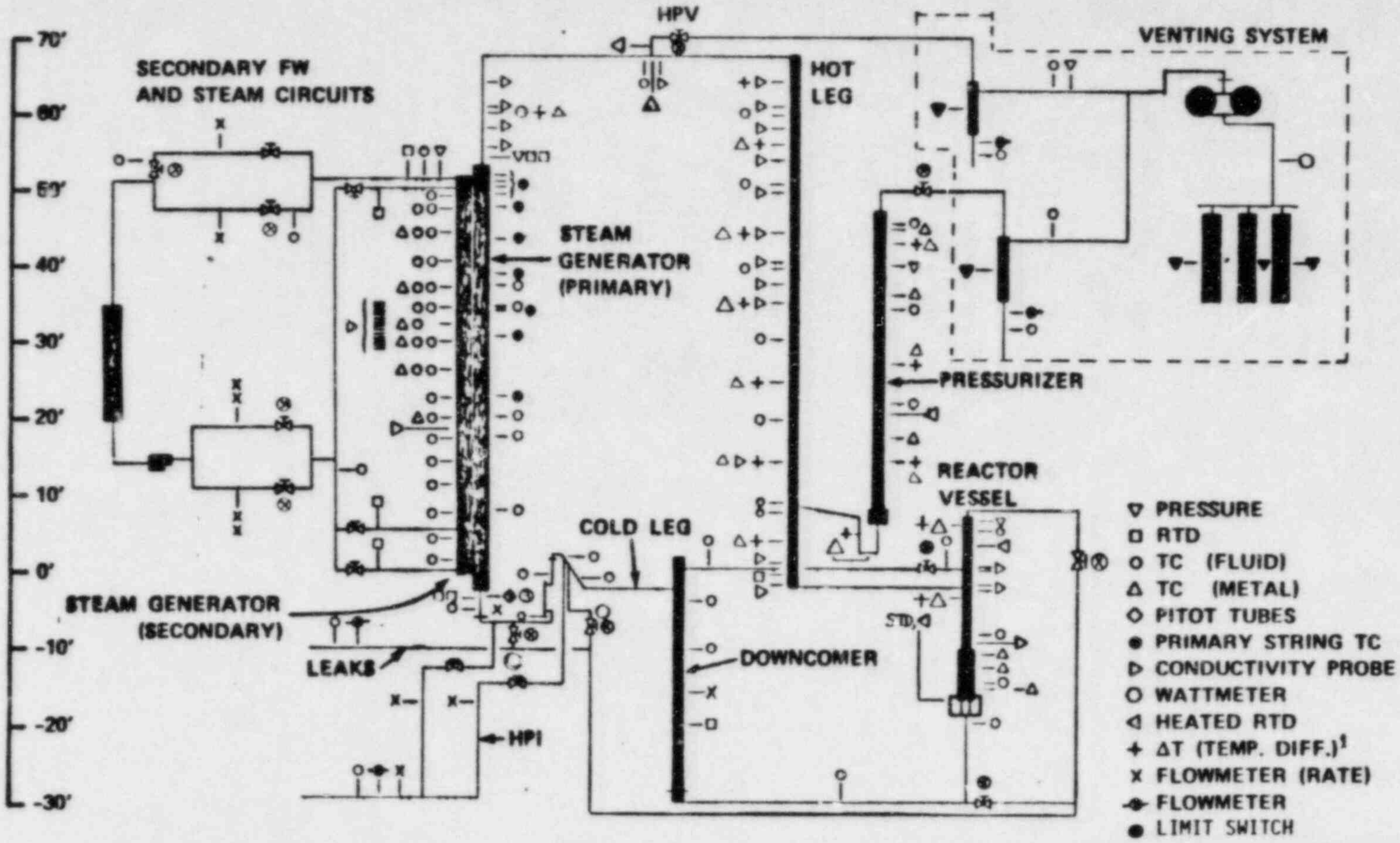
Little can be done to eliminate the one-dimensionality and the excess metal volume atypicalities of scaled integral-system facilities unless the scale factor approaches one. However, data from scaled integral test facilities is important for benchmarking computer codes if the facility is shown to display the expected system phenomenon. Data obtained from a scaled facility can be used to benchmark the computer code which in turn, can be used to predict the performance of the plant.

The pipe surface to fluid volume ratio atypicality of scaled facilities results in higher heat losses in the scaled facilities than in the plants. This atypicality can be minimized by using both active (guard heaters) and passive insulation on the model piping in critical regions. Guard heaters were used for OTIS on the hot leg, pressurizer, reactor vessel upper and top plenums, and the pressurizer surge line.

The secondary side of OTIS provided the steam generator secondary inventory and those fluid boundary conditions which impact SBLOCA phenomenon. This included the steam generator level and auxiliary feedwater control, auxiliary feedwater inlet elevation, and the cooldown valves. These controls are discussed further in Section 2.0.

Figure 1-6 is a schematic of the test loop, indicating the types and locations of instrumentation installed in OTIS. The OTIS instrumentation included pressure and differential-pressure measurements; thermocouple (TC) and resistance temperature detector (RTD) measurements of fluid, metal, and insulation temperatures; level and phase indications by optical-ports, heated RTD, and conductivity probes as well as by differential pressures; and pitot tubes and head flowmeters for measurements of flow rates in the loop. Figure 1-7 is provided to indicate the differential-pressure (DP) measurements in OTIS. In addition to these measurements, loop boundary conditions were metered; HPI, hot leg HPV, controlled leak (cold leg suction, cold leg discharge, RV lower plenum or RV upper head vent), PORV relief, and secondary steam and feed flow and energy transport were measured; noncondensible gas (NCG) injections are controlled and metered; NCG discharges with the two-phase primary effluent streams were measured; and the aggregate primary effluent were cooled and collected for integrated metering.

In total, OTIS instrumentation consisted of approximately 250 channels of data which were acquired and stored by a high-speed data acquisition system. At the base of the data acquisition system was a dedicated Digital Equipment Corporation (DEC) PDP 11/34 minicomputer which converted raw voltages to engineering values on-line to provide the operators with visual displays and printouts of the loop conditions as testing was proceeding. The acquisition rate could be event-actuated or adjusted by the loop operator to acquire and store a full set of data as often as every 5 seconds.



1. ΔT's used for guard heating control and monitoring of guard heating performance.

Figure 1-6 OTIS Instrumentation

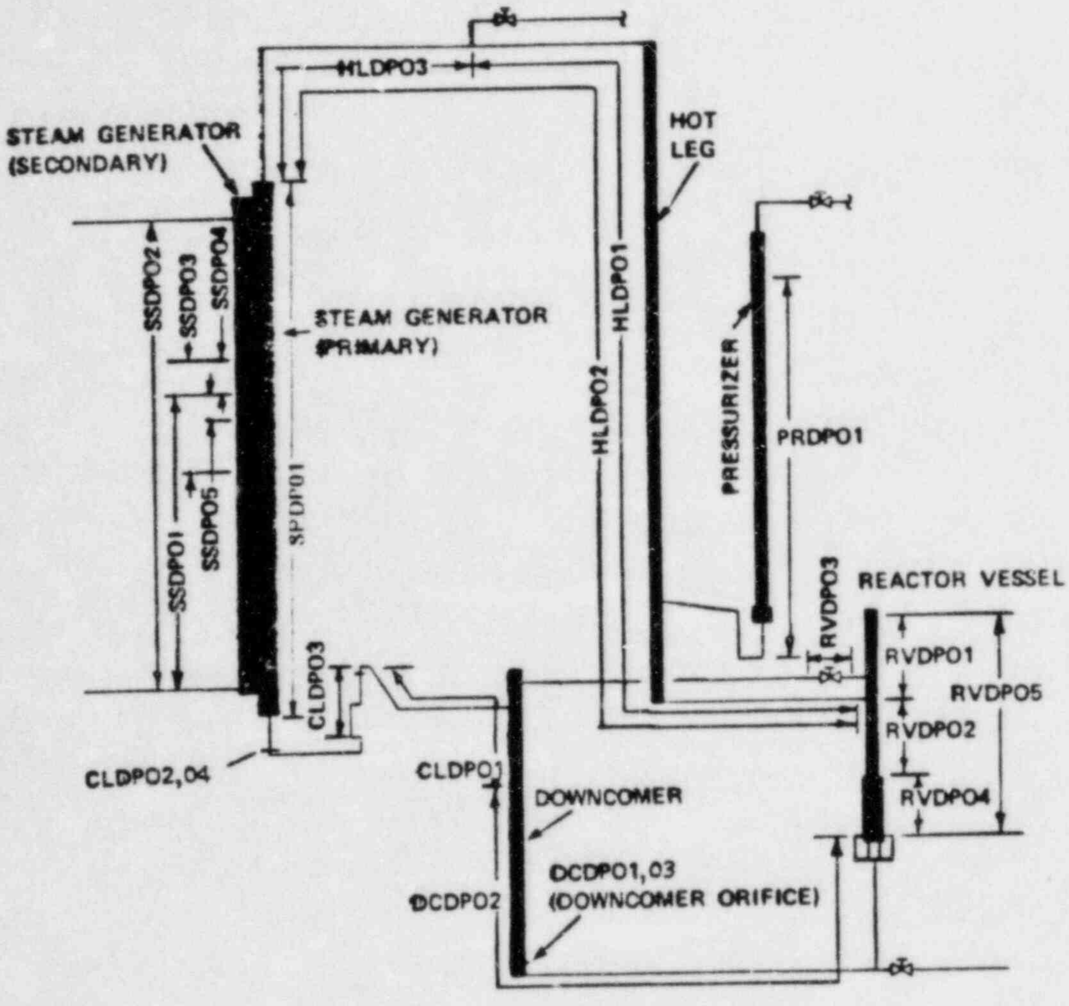


Figure 1-7 OTIS Differential Pressure Measurements

2.0 KEY FEATURES OF TEST LOOP

OTIS consisted of a closed primary loop, closed secondary loop, and several auxiliary systems. A general arrangement showing the relationship of the key components of these systems is shown in Figure 2-1. In this section the key features of these systems will be discussed. The key features are:

- Multiple leak location,
- Gas addition capability,
- Guard heating,
- Scaled high pressure injection (HPI),
- Simulated reactor vessel vent valve (RVVV),
- OTSG level control,
- Automatic cooldown,
- High and low auxiliary feedwater addition.

Multiple leak locations were present in OTIS to allow a controlled SBLOCA. Controlled leaks were located at the bottom of the lower plenum of the reactor vessel, at the top of the top plenum of the reactor vessel, in the cold leg upstream of the simulated reactor coolant pump (RCP) spillover, in the cold leg downstream of the RCP spillover, a high point vent (HPV) at the top of the hot leg U-bend (HLUB), and a simulated pilot operated relief valve (PORV) at the top of the pressurizer. Leak flow was controlled by an orifice located just downstream of the leak site. The leak flow control orifice was located in a 5/8" diameter tube as shown in Figure 2-2, to form the leak flow control orifice assembly. The details of the orifice design are illustrated in Figure 2-3. During the GERDA program, scaled leaks in the range of 5 cm^2 to 40 cm^2 were tested in the single phase regions (cold leg and reactor vessel leaks), while 3 cm^2, 10 cm^2, and 77 cm^2 scaled leaks were tested at the HPV and PORV. The actual diameter of the scaled leak was obtained from the ideal volume scaling factor of 1686. Thus a scaled leak of 10 cm^2 has a diameter of 0.034 inches in OTIS. Scaled leak control orifices of 3, 5, 10, 20, and 40 cm^2 were characterized prior to installation in GERDA. During GERDA, the 5, 10, 20, and 40 cm^2 leaks were characterized in saturated water, while the 3 and 10 cm^2 leaks were characterized in saturated steam. The characterization tests provided the critical flow rate for each orifice at pressures of 1000 and 2000 psia. These characterization tests are discussed further in Section 4.2. No additional orifice characterization tests were performed for OTIS.

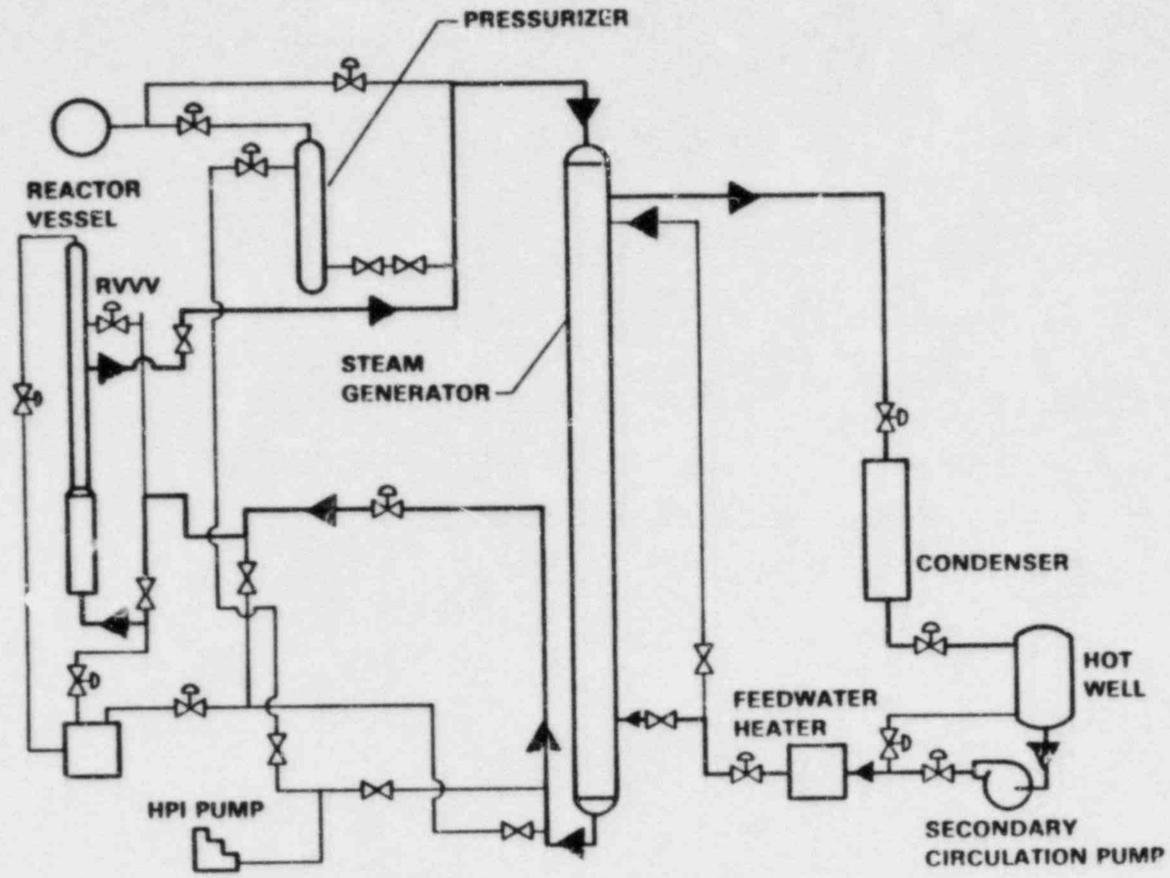


Figure 2-1 OTIS General Arrangement

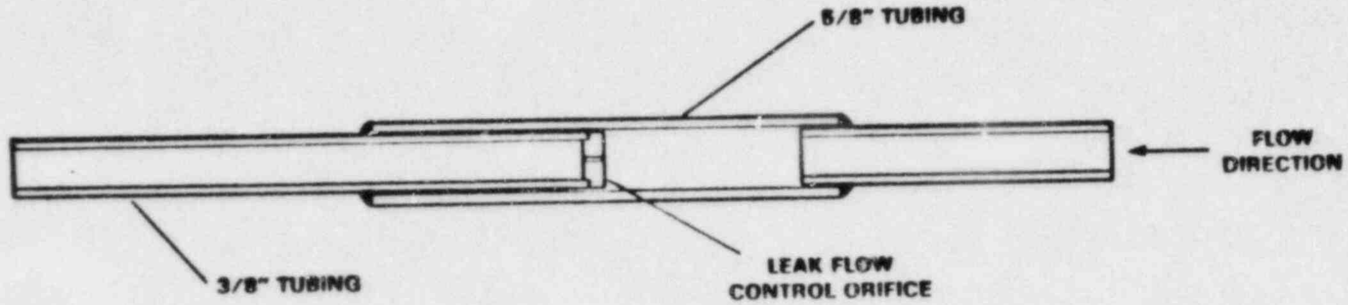


Figure 2-2 Leak Flow Control Orifice Assembly

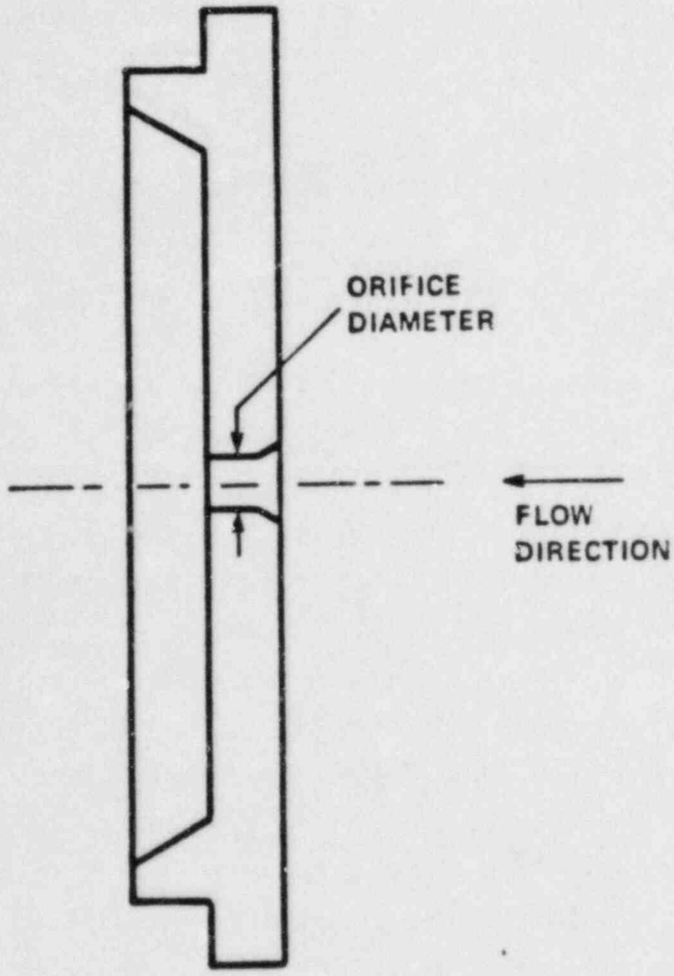


Figure 2-3 Leak Flow Control Orifice

Batch addition of noncondensible gases (NCG) could be made to the primary loop to study the effect of NCGs on system performance. The NCGs could be added at four locations around the loop. These locations included:

- lower plenum of reactor vessel
- cold leg piping downstream of RCP spillover
- top of steam generator
- top of hot leg at HLUB

To preclude leakage of NCGs from the loop, sealed stem valves were used, where possible, throughout the loop. Additionally, all instrument fittings in the reactor coolant system, above the top of the core heaters were seal welded. To characterize the leak tightness of the loop, a helium leak check was performed during the GERDA program. The results of this test are discussed in Section 4.1.

As a result of the large surface area to fluid volume ratio, heat loss in the OTIS loop was proportionally greater than that in the plant. To minimize this effect, guard heaters were used along the hot leg piping, pressurizer, pressurizer surge line, and the reactor vessel upper and top plenums. The objective of the guard heating system was to provide heat to the components in an amount equal to heat loss of that component to ambient. The concept used for guard heating is illustrated in Figure 2-4. A layer of control insulation, approximately 1/2" thick, enclosed by a thin shell of stainless steel lagging, was placed over the pipe sections to be guard heated. The heater tapes were spirally wrapped over the lagging material, covering nearly 100% of the pipe section. Two layers of passive insulation then covered the guard heaters. The heaters were controlled based on thermocouples located on the pipe OD and at a point mid-way into the control insulation. Tests were performed to evaluate the heat loss from the OTIS loop and to characterize the operation of the guard heaters. The heat loss tests are described in Section 4.5 and the performance of the hot leg guard heaters is discussed in Section 4.6.

Two high pressure injection (HPI) locations were provided on OTIS - one at the cold leg low point, upstream of the simulated RCP spillover, the other in the downward sloping cold leg, downstream of the simulated RCP spillover. A scaled

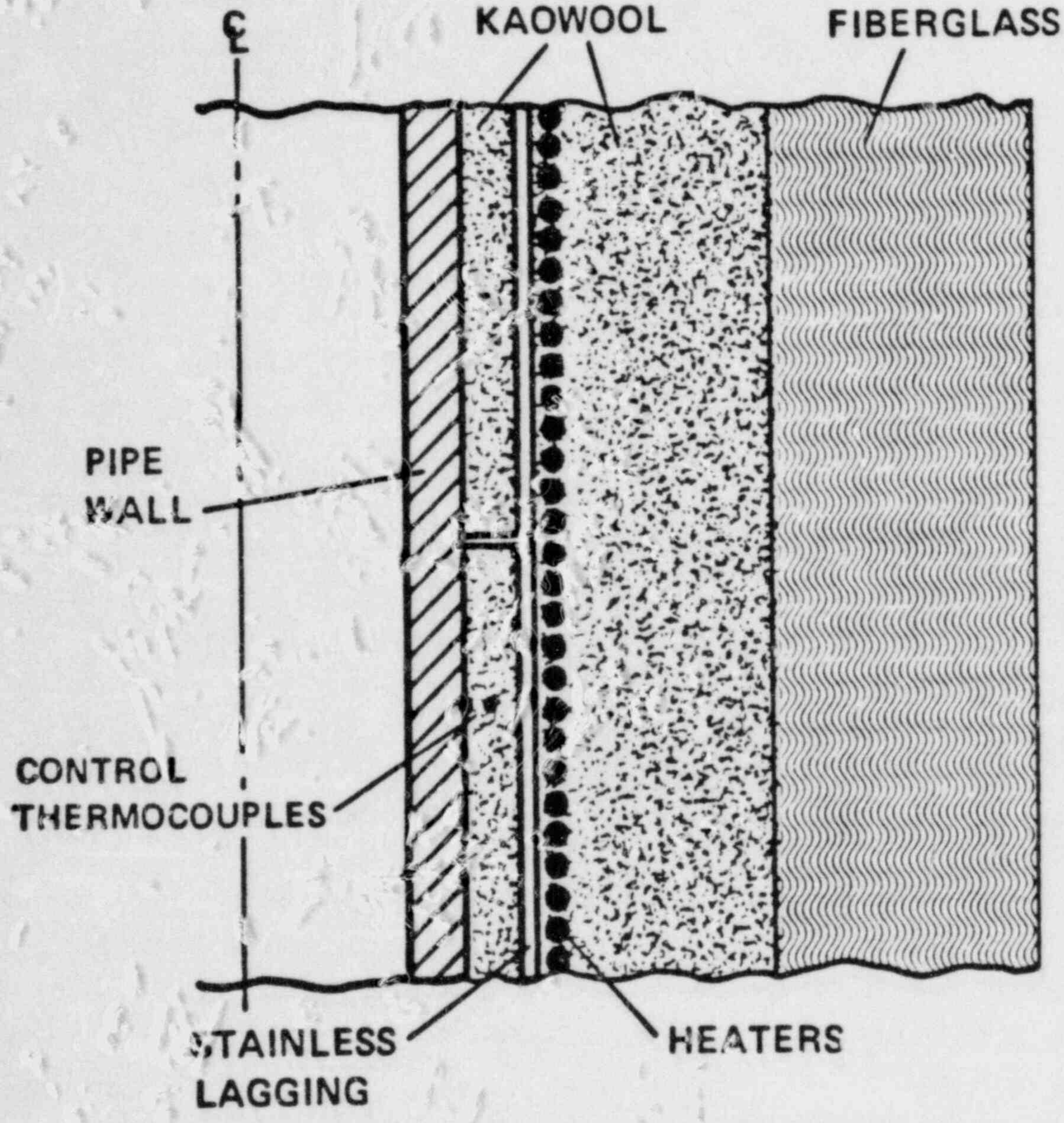


Figure 2-4 Guard Heater Concept

HPI flow was provided by a positive displacement pump. The flow into the loop was controlled to simulate the plant scaled head-flow curve. HPI flow could be directed to either one or both of the HPI injection locations.

The reactor vessel vent valve (RVVV) was simulated in OTIS by a single pipe extending from the upper and top plenum of the reactor vessel to the external downcomer. The elevation at which the pipe was located matched the spillover elevation of the plant RVVV. This is illustrated in Figure 1-4. A pneumatically-operated, automatically-controlled valve was located in the pipe. The valve was controlled to open and close when the differential pressure between the reactor vessel and downcomer reached preset values. An orifice in the pipe, downstream of the valve was used to control the flow through the simulated vent valve. The simulation was for the plant vent valves in the full open position.

The secondary loop consisted of the 19-tube OTSG, steam piping, a water cooled condenser, hot well, feedwater pump, feedwater heater, and feedwater piping. The relationship between these components is shown in Figure 2-1. The secondary side simulation of the modeled plant was limited to the steam generator and the elevation of the auxiliary feedwater (AFW) inlets. Additionally, several control functions were used to simulate plant performance. These included:

- continuous level (inventory) control
- band level control
- steam pressure control
- automatic cooldown

Two modes of steam generator level control were available on OTIS, continuous level control and "band" level control. With continuous level control, the operator set the desired steam generator level from 0 to 100%. The controller maintained the collapsed water level at this set point by adjusting the feedwater flow rate. A second mode of steam generator level control was termed band level control. With this mode of level control the steam generator collapsed water level was maintained between specified elevations relative to the secondary face of the lower tubesheet (SFLTS). When the collapsed level reached the upper level, the feedwater valve was cycled closed. When the collapsed level reached the lower level, the feedwater valve opened. The feedwater flow rate obtained during this mode of level control was determined by the position of several control valves in the feedwater piping. These valves could be positioned to supply the required AFW flow rate for a single fixed steam generator pressure or adjusted to simulate the AFW head-flow curve of interest. The signal for the collapsed level, for both modes of level control, was based on a differential pressure measurement.

The secondary loop could operate at steam pressures of approximately 100 to 1200 psia. Steam pressure was automatically controlled by a steam control valve, based on a signal from the steam pressure transmitter. In addition to automatic steam pressure control, the steam pressure could be controlled to decrease at a pre-programmed rate. This feature allowed simulation of the plant operator initiated "automatic cooldown mode", where the steam generator is depressurized to obtain a fixed cooldown rate. In OTIS, the desired cooldown rate was keyed into the controller as a series of linear segments of pressure and time. When activated, the steam pressure control valve modulated to maintain the set point pressure versus time.

Auxiliary feedwater addition could be made at one of two locations in the steam generator - a high feed elevation, typical of the B&W domestic 177 FA plants, and a low feed elevation, typical of the MK plant. The configuration of the AFW nozzle at each elevation could be for maximum wetting or minimum wetting of the steam generator tubes. The two configurations, maximum or minimum wetting of the tubes, allows comparison of the effects of a spray pattern on heat transfer (typical of the outer rows of tubes near the AFW nozzles in the plant), with the effects of pool heat transfer (typical of the large majority of tubes that are away from the AFW nozzles in the plant).

3.0 OTIS SUB-SYSTEMS

The major primary, secondary, and auxiliary components of the OTIS loop have been sub-divided into systems. Each of these systems will be discussed in detail in the following sections.

The primary loop was fabricated from stainless steel and was designed for 2500 psi at 650°F. The secondary loop was fabricated from carbon steel and was designed for 1500 psi at 600°F. The test loop was hydro-static tested to 3750 and 2250 psi at ambient temperatures, on the primary and secondary respectively, in accordance with the pressure piping and boiler codes.

Prior to discussing the details of each system, a reference comparison of the key elevations and volumes for OTIS and the MK plant will be made. Full elevation modeling was assigned first priority in the OTIS scaling criteria. OTIS piping generally models the MK spillover and spillunder elevations. Additionally, a number of other key elevations are preserved in the OTIS model. These key elevations for OTIS and MK are compared in Table 3-1.

Table 3-1

COMPARISON OF KEY ELEVATIONS -- OTIS VS MULHEIM KARLICH (MK)

	Elevation-Inches Relative to the Secondary Face of the Steam Generator Lower Tubehseet	
	OTIS	MK (1)
Bottom of Reactor Vessel	-287-1/2	-336
Downcomer to Lower Plenum	-283-1/4	-283-1/4
Bottom of Heated Section	-196-1/4	-230-1/2
Center of Heated Section	-157-1/2	-158-1/2
Top of Heated Section	-119	- 86-1/2
Hot Leg Nozzle-Reactor Vessel Centerline	- 23	- 23
Reactor Vessel Vent Valve Spillover	+ 6-1/2	+ 6-3/4
Top of Reactor Vessel Upper Plenum	+ 15-7/8	+ 61
Top of Reactor Vessel	+ 91-1/4	+134-1/2
Hot Leg U-bend (HLUB) Spillover	+807-1/2	+807-1/2
Primary Face of Upper Tubesheet (UTS)	+628-3/8	+646-3/4
Secondary Face of UTS	+625-3/8	+625-1/4
Secondary Face of Lower Tubesheet (UTS)	0	0
Primary Face of LTS	- 24	- 21-1/2
Steam Generator Outlet/Cold Leg Interface	- 30-1/2	- 79-1/4
Cold Leg Low Point (Top of Pipe ID)	- 76-7/8	- 76-3/4
Pump Spillover	+ 30 (2)	+ 30
Cold Leg to Downcomer Interface	- 23	- 23-1/4
Top of Downcomer	+ 25-1/4	43-1/4
Pressurizer Bottom	+ 79-1/4	+ 79-1/4
Pressurizer Top	+566-1/2	+585-1/2
Hot Leg-To-Surge Line Connection (Centerline)	+103-1/4	+103-1/4
Surge Line Sloping-to-Vertical Interface	+ 94-3/4	+ 94-3/4
Surge Line Low Point, Top of Pipe	+ 30	+ 30
Auxiliary Feedwater (AFW) Injection Elevation -- Low Injection Point	+ 71	+ 77
Auxiliary Feedwater (AFW) Injection Elevation -- High Injection Point Used on Some 177FA Plants	+610-3/8	+610-3/8

(1) MK elevations are rounded to nearest 1/4"

(2) Simulated RCP spillover

Volumetric scaling of the loop components was generally adhered to. As part of the Phase 0 -- GERDA Loop Characterization Tests, the volume versus elevation was obtained for four (4) primary-side regions and for the secondary side of the steam generator. These primary regions included the pressurizer, the reactor vessel (excluding the downcomer), the active region. and the inactive region. The active region included the volume in the cold leg piping between the cold leg spillover and the downcomer, the downcomer piping, reactor vessel, and the hot leg piping between the reactor vessel outlet and the HLUB spillover. The inactive region included the volume in the hot leg between the HLUB and the steam generator outlet, and the cold leg between the outlet of the steam generator and the cold leg spillover. The volume versus elevation results are presented in Section 4.12. In Table 3-2, the volume checks are summarized for these regions and compared with the ideal volume scaled loop.

Table 3-2

GERDA VOLUME CHECKS

	Ideal Scaled Loop Volume, ft^3	GERDA Volumes, ft^3
Primary		
Pressurizer	1.61	1.58
Reactor Vessel (excluding downcomer)	2.21	2.23
Active Region	4.06	5.74
Inactive Region	2.78	2.82
TOTAL Primary Volume	8.48	10.14
Secondary		
Steam Generator	2.45	2.58

3.1 REACTOR VESSEL AND DOWNCOMER

An electrically heated reactor vessel provided the heat input to the primary fluid to simulate decay heat levels up to 3.7% simulated full power (neglecting heat losses). Based on the TVA plant power rating of 3600 MWt and on the ratio of the number of tubes in the model steam generator to the plant OTSG's (19/32,026), 3.7% simulated full power corresponds to 79 KW. The OTIS reactor vessel heat input capacity was 180 KW.

The stainless steel reactor vessel and downcomer design was similar to that shown in Figure 3-1. The reactor vessel was composed of three (3) regions; a lower plenum, a heated section, and an upper and top plenum. The downcomer consisted of a single pipe external to the reactor vessel. The overall length of the reactor vessel was about 31 feet with a net fluid volume of about 3850 in^3 (excluding the downcomer). A single line with a pneumatically operated control valve connected the upper and top plenum of the reactor vessel to the upper downcomer simulating the reactor vessel vent valve (RVVV).

The cold leg pipe connected with the downcomer at elevation -23"[3]. The external downcomer connected the lower plenum at elevation -283-1/4". The lower plenum consisted of a straight vertical section of 2" Schedule 160 pipe, and a six (6) pipe header arrangement consisting of four (4) 1" Schedule XXS pipes and two (2) 1-1/4" Schedule 160 pipes. This header supplied the heated section, which was enclosed in a 6" Schedule 160 pipe. The four (4) 1" Schedule XXS pipes were spaced 90° apart around the bottom flange while the 1-1/4" Schedule 160 pipes were 180° apart. All six (6) inlets were normal to the heater rods. The details of the downcomer piping and lower plenum are shown on B&W drawings 9510E, 9542E, and 9560E. A complete list of the facility drawings is contained in Appendix A. The mechanical and electrical drawings are contained in Volumes 2 and 3 of this report, respectively.

The heated section of the reactor vessel started at elevation -196-1/4". The four (4) 1" Schedule XXS inlets were approximately 2-1/2" below the start of the heated section, and the two (2) 1-1/4" Schedule 160 inlets were approximately 6-3/4" above the start of the heated section. The top of the heated section was at elevation -119", for a heated length of about 77-1/4". The upper and top plenums extended from the top of the heated section, elevation -119", to the top of the reactor vessel, elevation +91-1/4". An orifice plate (1/8" thick and having 7 holes of 0.469" diameter each) at elevation +15-7/8" separated the upper and top plenums. The pipe sections consisted of a short section of 6" Schedule

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[3] All dimensions are relative to the secondary face of the steam generator lower tubesheet. The horizontal dimensions are from the centerline of the pipe unless otherwise noted.

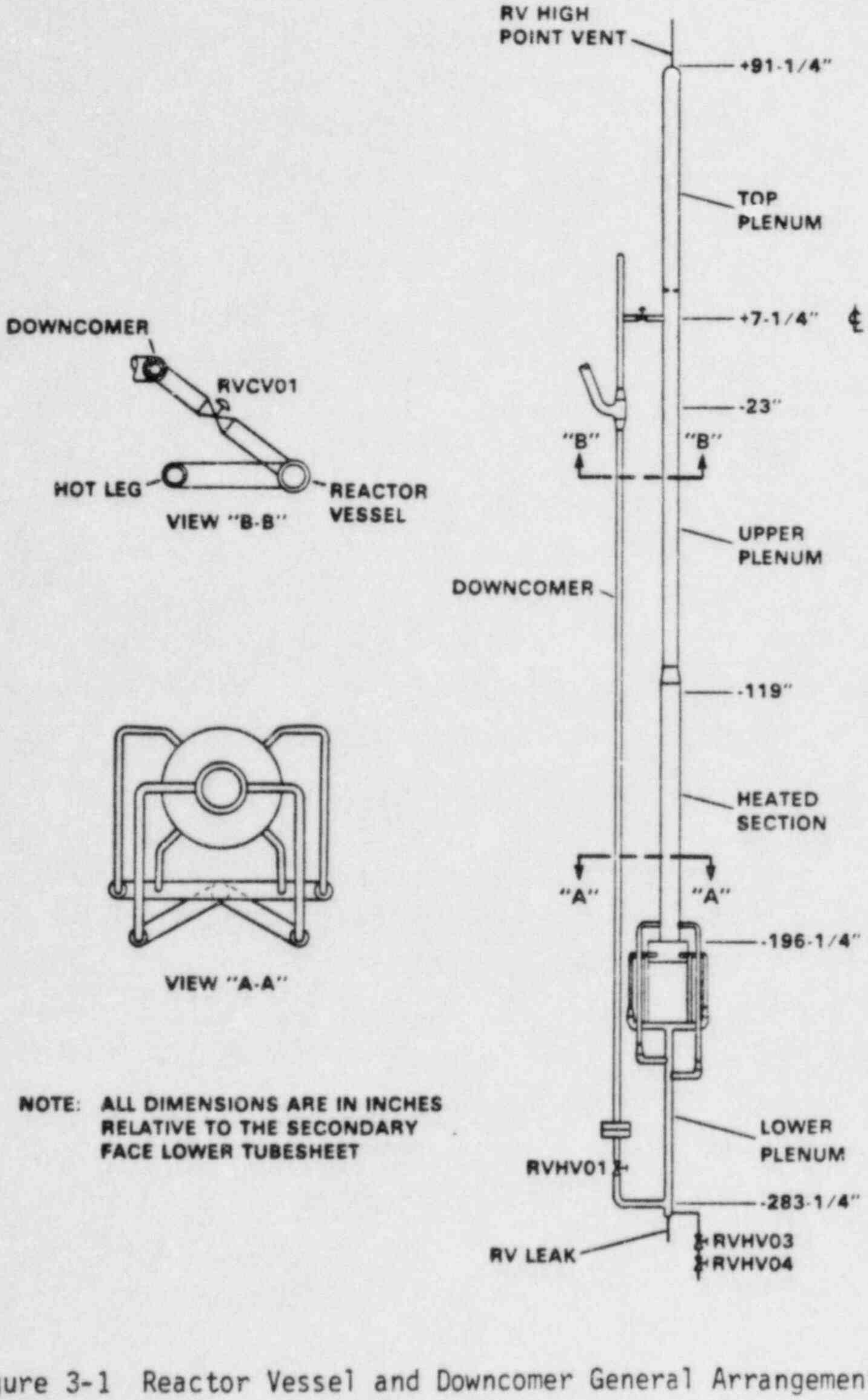


Figure 3-1 Reactor Vessel and Downcomer General Arrangement

160 pipe, a 6" x 4" concentric reducer, and about 200" of 4" Schedule 160 pipe. At elevation -23", the fluid leaves the reactor vessel through a 4" x 4" x 3" tee, where it entered the hot leg. A 1-1/2" Schedule 160 pipe, with the centerline located at elevation +7-1/4" connected the reactor vessel top plenum with the downcomer, through the RVVV simulation. A single-phase leak site was located at the bottom of the lower plenum of the reactor vessel. A high point vent (HPV), a scaled 3 square centimeter orifice for OTIS testing, was located at the top of the reactor vessel as shown on Figure 3-1. The details of the heated section, upper and top plenums, and RVVV connection are shown in B&W drawings 9505E, 9506E, and 9552D.

Reactor vessel decay heat was simulated using three (3) 60 KW Watlow rod heaters. The 1-1/4" OD heaters were spaced 120° apart on an ~3" bolt circle. The heaters were seal welded to the flanged head of the reactor vessel. There were three (3) flow distributor/rod spacer plates along the length of the heaters -- located at elevations -186-3/4", -159-3/4", and -123-1/4". Details of the reactor vessel heaters and plate design are shown on B&W drawings 9524C and 9512E. The reactor vessel power could be controlled to either a constant power or to a power ramp. Decay heat was controlled using a Leeds & Northrup 1300 Process Programmer. This programmer allowed the operator to key-in the desired power level and time intervals to approximate the decay heat curve.

The reactor vessel upper plenum and top plenum were guard heated. The guard heaters were divided into two (2) control zones, one each for the upper plenum and the top plenum. The upper plenum guard heater zone covered from -23" to +15-7/8" with the control ΔT, RVDT01, at -4". The top plenum guard heater zone covered the remainder of the top of the reactor vessel, extending from +15-7/8" up to 91-1/4". The control ΔT, RVDT02, was located at 58". The operation of the guard heaters is discussed in Section 4.6.

The RVVV simulation consisted of a single 1-1/2" Schedule 160 pipe connecting the top and upper plenum with the downcomer, with a 1-1/2" Rockwell Edwards Hermavalve and an orifice (downstream of the valve) for RVVV flow control. This pneumatically actuated valve was controlled to open and close at specified differential pressures between the upper plenum and the downcomer. The opening and closing ΔPs were adjustable, but typically the RVVV was set to full open at a

ΔP greater than +.25 psid and to close at a ΔP less than +.125 psid. A (vertical) slotted orifice was located just downstream of the Hermavalve to control the amount of flow through the RVVV. A test was performed during GERDA to determine the pressure drop -- flow characteristics of the RVVV. The RVVV flow rate was measured using three independent measurements -- weight-time, accumulating flowmeter, and a turbine meter. Pressure drop was measured using the ΔP transmitter across the vent valve, RVDP03, and a water over oil manometer. The results of this test are summarized in Table 3-3.

Table 3-3

REACTOR VESSEL VENT VALVE FLOW-ΔP MEASUREMENTS

	Flow Measurement			ΔP Measurement	
Nominal Flow lbm/hr	Weight/Time lbm/hr	Accumulating Flowmeter lbm/hr	Turbine lbm/hr	RVDP03 in. H_2O	Manometer in. H_2O
500	419.2	387.7	433.6	.23	.11
750	745.5	750.7	778.9	.55	.45
1000	993.9	1047.0	1023.5	.83	.75
1250	1244.2	1259.3	1269.1	(2)	1.01
1500	1437.1	(1)	(1)	(2)	1.42
1800	1837.0	(1)	(1)	(2)	2.33

(1) Flowmeters out of range

(2) Zero shift on transmitter -- unit taken out of service

The predicted and measured pressure drop-flow characteristics are shown in Figure 3-2, as is the calculated loss coefficient versus Reynolds number. The loss coefficient approached a constant value of about 17.6 for Reynolds numbers above 10,000.

The response time for the vent valve (a Rockwell Edwards Hermavalve) was measured during the GERDA program. The data is recorded on Table 3-4. The delay time in going from close-to-open was the time from valve actuation to the first indication of valve movement (time required to vent air out of actuator). The ramp time was the total elapsed time from valve actuation to 100% or 50% travel.

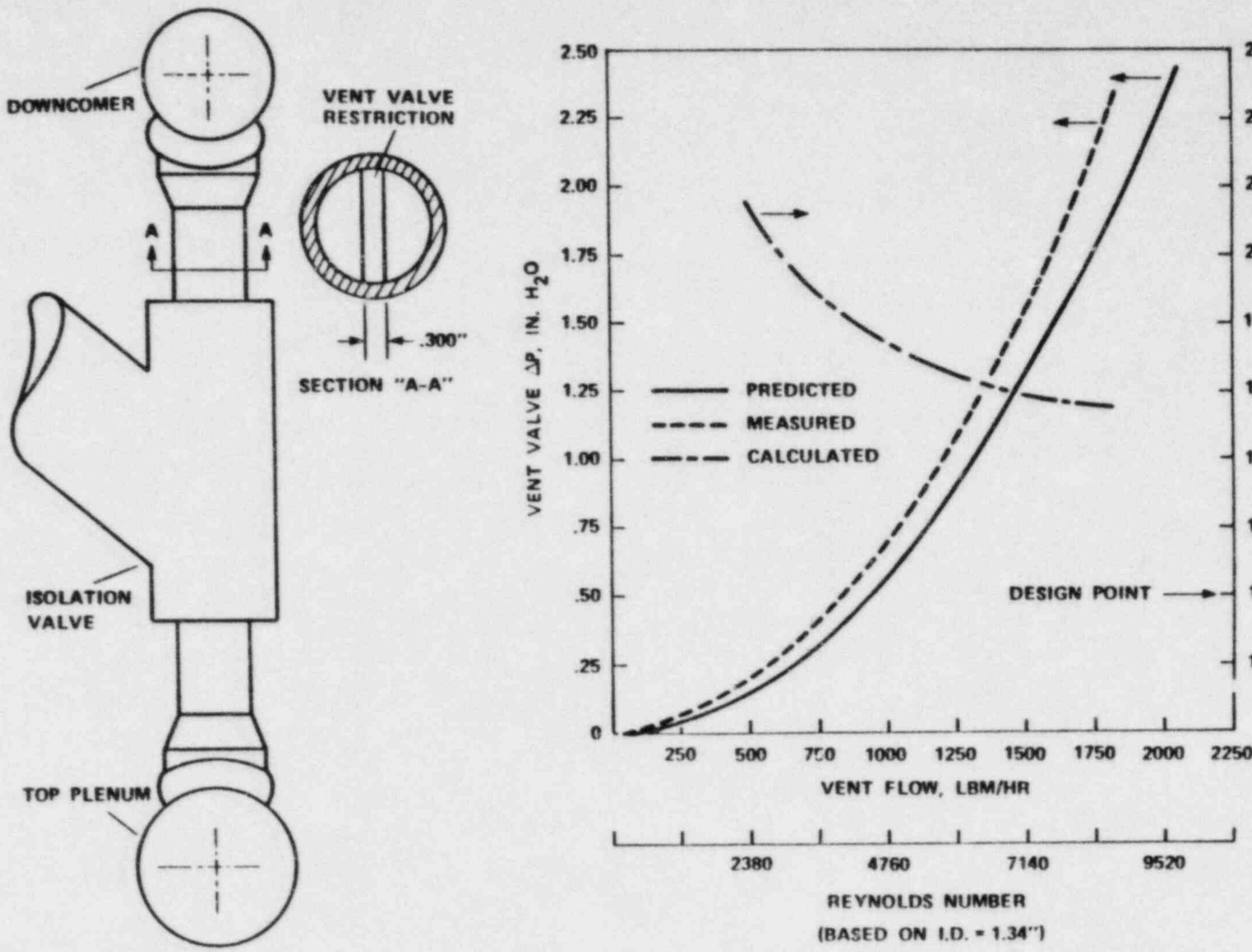


Figure 3-2 RVVV Arrangement and Flow Characteristics

Table 3-4

REACTOR VESSEL VENT VALVE RESPONSE TIME

Close to Open	Open to Close	Delay Time (Seconds)	Ramp Time (Seconds)	Percent Travel	Temperature °F	Pressure psia
X		1.3	18.7	100	520	1951
X		1.2	19.3	100	520	1951
X		1.2	18.6	100	520	1951
	X	0	13.2	100	520	1951
	X	0	12.7	100	520	1951
	X	0	13.3	100	520	1951
X		1.1	4.9	50	512	2023
X		1.3	5.1	50	512	2023
	X	0	4.0	50	512	2023
	X	0	3.8	50	512	2023
	X	0	13.5	100	512	2023
	X	0	12.9	100	512	2023

NOTE: Instrument air pressure is 46.5 psi

A GERDA test was run to determine the response time of the reactor vessel heater sheath to a step change in power. The heater response to a 60 KW step change in power is shown in Figure 3-3. The time constant of the heater sheath, that is the time required for the normalized sheath temperature to reach 63% of its maximum value, was found to be about 20 seconds.

The instrumentation associated with the reactor vessel and downcomer are shown in Figures 3-4 and 3-5. The following measurements were recorded as test data:

- fluid and metal temperatures at key elevations along the vessel
- guard heater control differential temperature
- static pressure
- differential pressures
- phase detection at key locations using conductivity probes
- mass flow rate from a Venturi meter (throat diameter of 0.775 inches)
- power input to reactor vessel heaters

Calibration of the venturi meter will be discussed in Section 4.8.

The notation used on the figures is defined in Appendix B. The elevation at which each instrument was located is given in the Instrument List, included as Appendix C. Additional instrumentation was used for loop operation and protection. This instrumentation, which was not recorded as test data, provided protection to the reactor vessel heaters for the following conditions:

- high fluid temperature
- high metal temperature
- high pressure
- low water level

Interlocks to the heaters were opened if any of these conditions occurred.

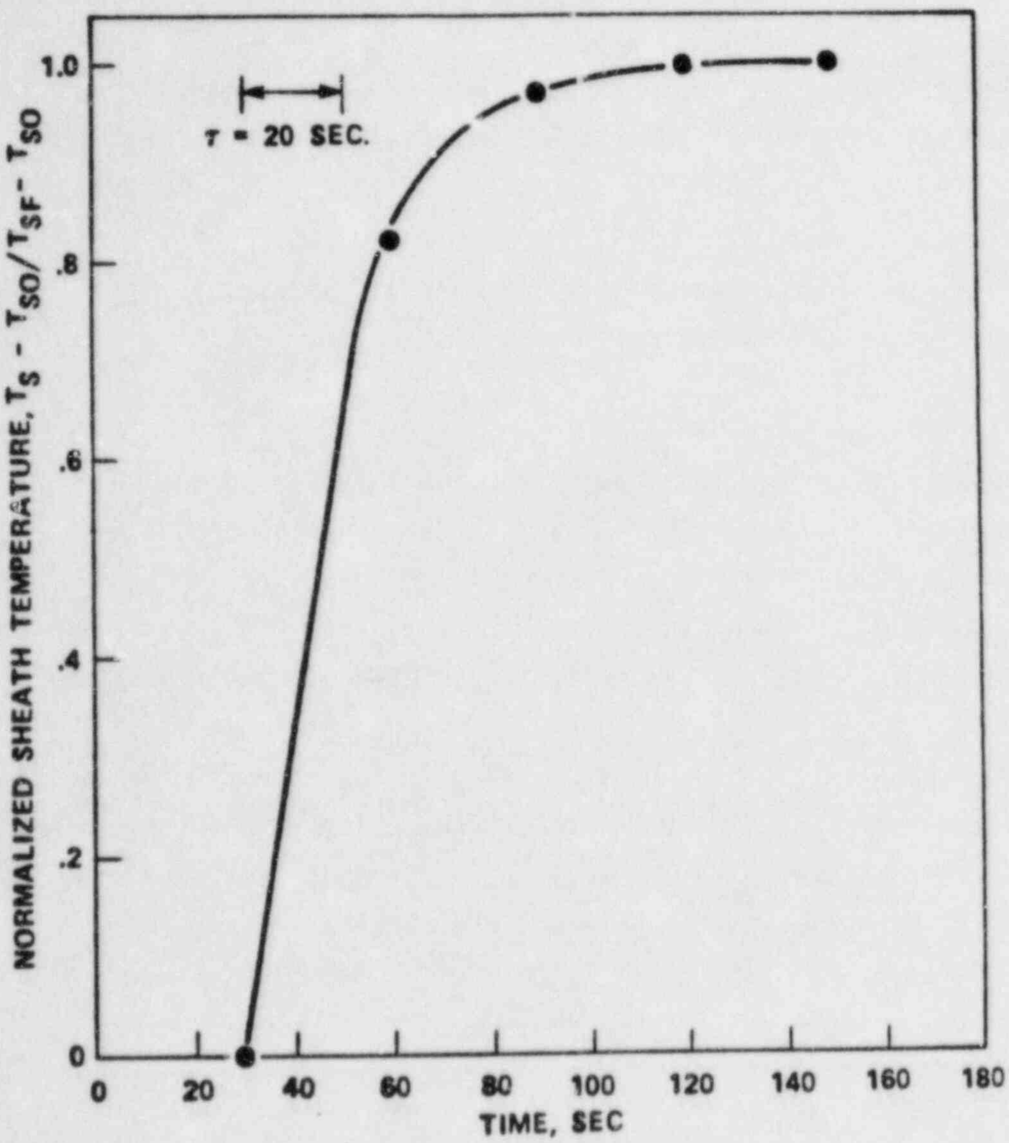


Figure 3-3 Reactor Vessel Heater Response to a 60KW Power Increase

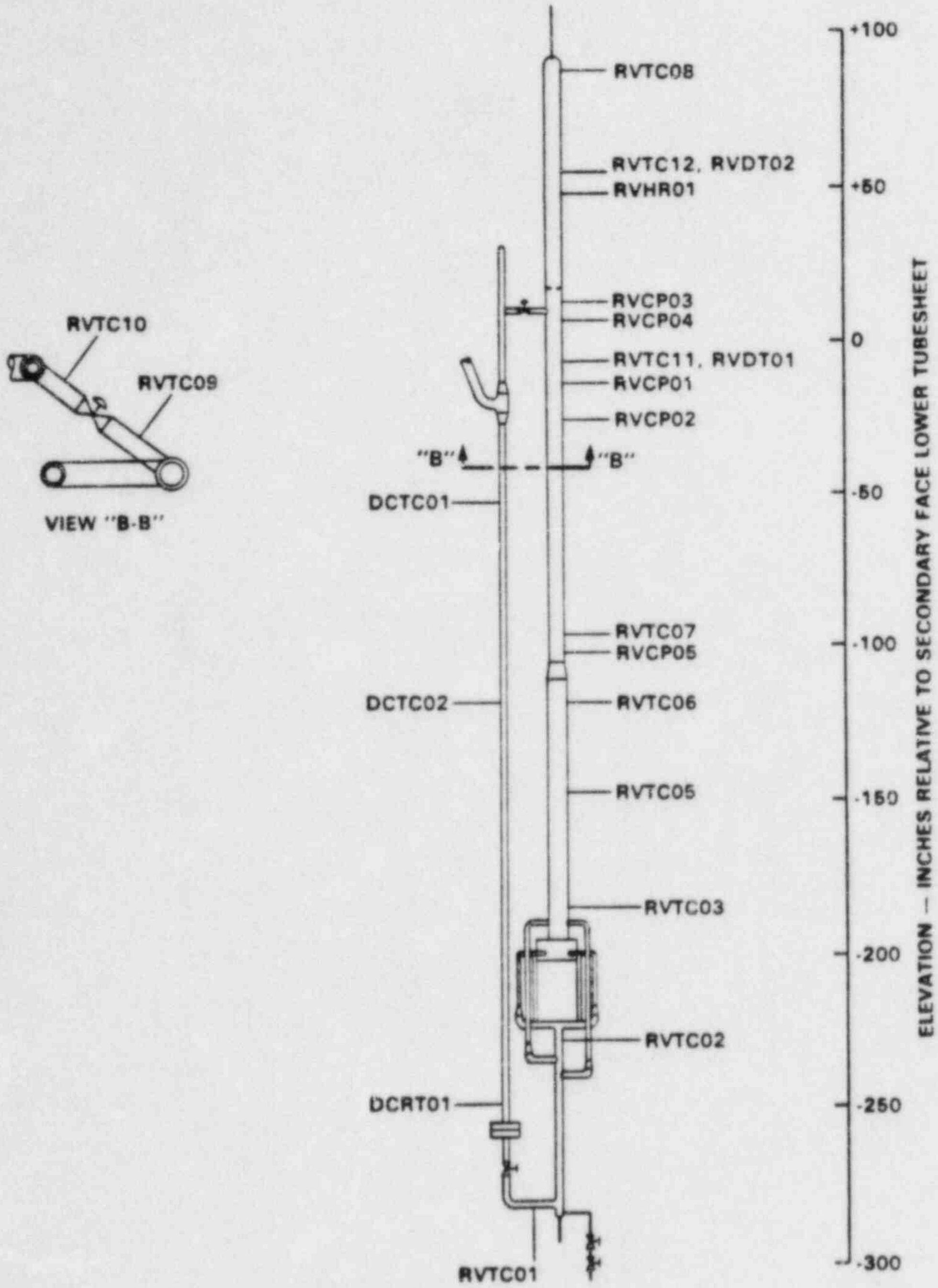


Figure 3-4 Reactor Vessel and Downcomer Instrumentation - Thermocouples, RTDs, and Conductivity Probes.

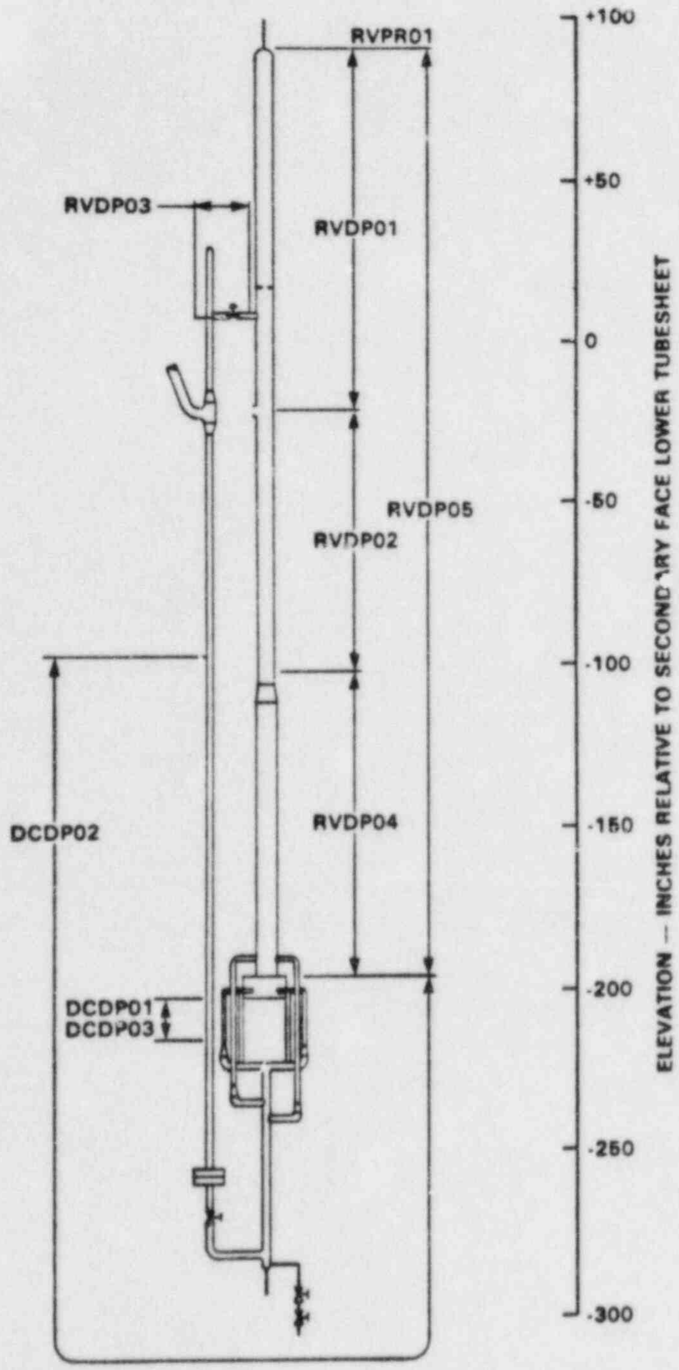


Figure 3-5 Reactor Vessel and Downcomer Instrumentation - Pressure and Differential Pressure Measurements

A valve was located in the bottom of the downcomer to satisfy pressure vessel code requirements. The manufacturers' specified flow coefficient (Cv) for this valve being fully opened and for a fully opened reactor vessel vent valve are shown in Table 3-5.

Table 3-5

MANUFACTURERS' SPECIFIED FLOW COEFFICIENTS
FOR VALVES IN REACTOR VESSEL

Valve	Flow Coefficient, Cv Full Open Valve
RVHV01 (downcomer)	120
RVCV01 (RVVV)	32

A safety relief valve and rupture disc assembly was located just above the heated section.

3.2 HOT LEG PIPING

This system consisted of the piping and associated hardware and instrumentation from the junction of the hot leg-reactor vessel outlet to the primary inlet at the upper head of the steam generator. The piping was comprised of sections of 3" Schedule 160 stainless steel and Inconel 600 pipe.

A general arrangement of the hot leg piping is shown in Figure 3-6. From the hot leg-reactor vessel outlet at elevation -23", the hot leg extended horizontally about 17", then made a vertical upturn through a special pipe section with a radius of curvature of 14-7/8". The hot leg extended vertically to an elevation of about 794". The piping then started a bend to form the hot leg U-bend (HLUB), with a radius of curvature of 14-7/8". The HLUB spillover was located at 807-1/2". The HLUB radius of curvature was selected to scale the HLUB volume while maintaining the same hot leg pipe inside diameter of 2.626". From the HLUB the piping ran vertically downward to the steam generator. A high point vent (HPV) was located on the top of the HLUB. The details of the hot leg piping design are shown on B&W drawing 9553E.

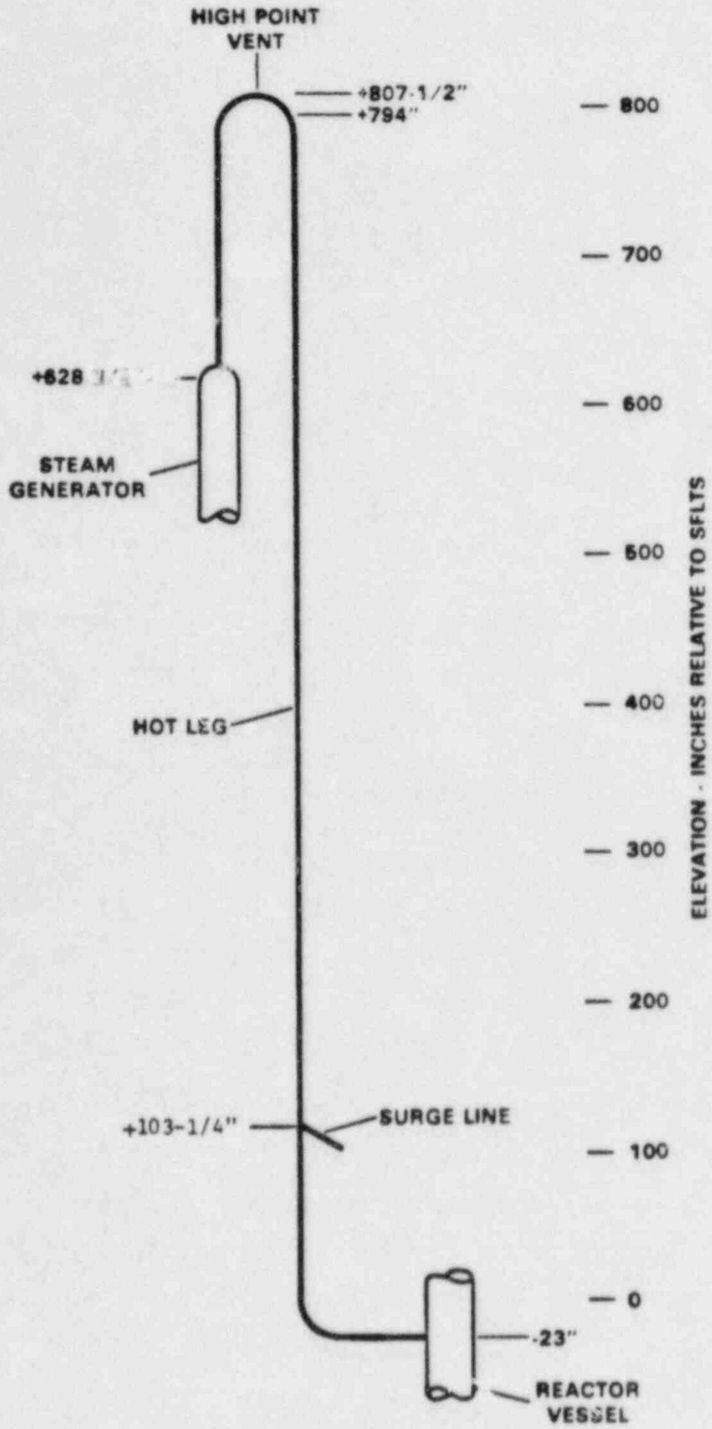


Figure 3-6 Hot Leg Piping General Arrangement

Hot leg instrumentation is identified on Figures 3-7 and 3-8. Resistance temperature detectors (RTDs) were located near each end of the hot leg piping. Fluid temperatures from thermocouples were measured just above and below the surge line connection on the hot leg, and at approximately 10' intervals along the hot leg. Conductivity probes, for phase detection, were located at approximately 4' intervals between the 444" elevation and the inlet to the steam generator. Below this elevation, the probes were placed further apart. There were three ΔP measurements along the hot leg -- from the hot leg-reactor vessel nozzle to the HLUB, from the HLUB to the steam generator inlet, and from the hot leg-reactor vessel nozzle to the steam generator inlet. These measurements are identified in Figure 3-8. There were two viewports located on the hot leg that allowed visual observation of the fluid inside the pipe. One viewport was located in the vertical hot leg, approximately at elevation +420", while the other was located at the HLUB. A video camera was located at each viewport. The cameras were connected to a video recorder through a special effects generator that allowed the flow visualization data at each viewport to be recorded simultaneously.

The hot leg was guard heated over its entire length. Guard heaters were divided into eight (8) control zones, each approximately 132" long. In each zone there was a ΔT measurement used for controlling the guard heaters and a ΔT measurement that was recorded on the data base for monitoring the performance of the guard heaters. The two ΔT measurements were at the same axial location, 180° apart. The elevation of the hot leg guard heater zones and control thermocouples are given in Table 3-6. The operation of the guard heaters is discussed in Section 4.6.

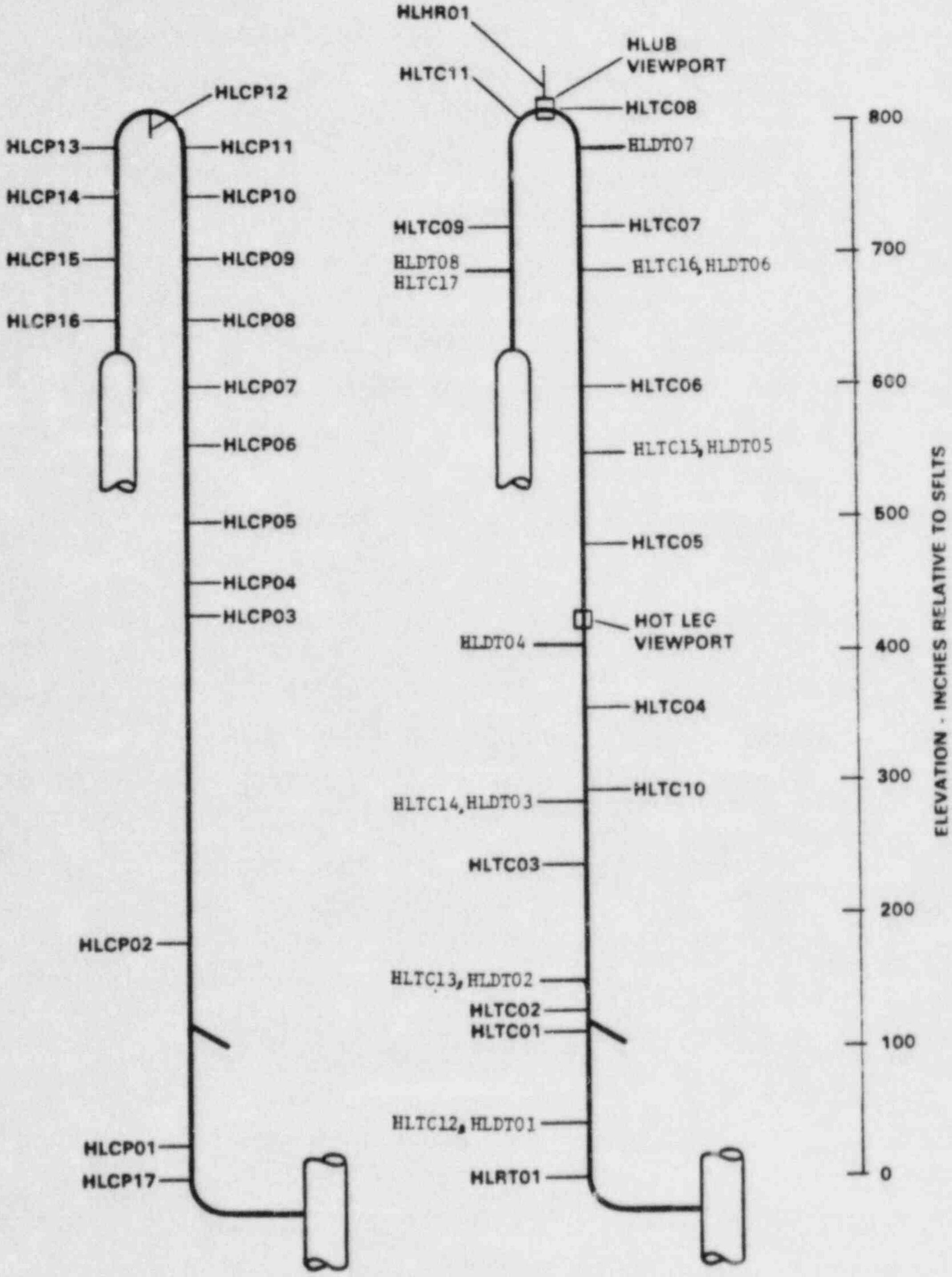


Figure 3-7 Hot Leg Instrumentation - Thermocouples, RTDs, Conductivity Probes and Viewports

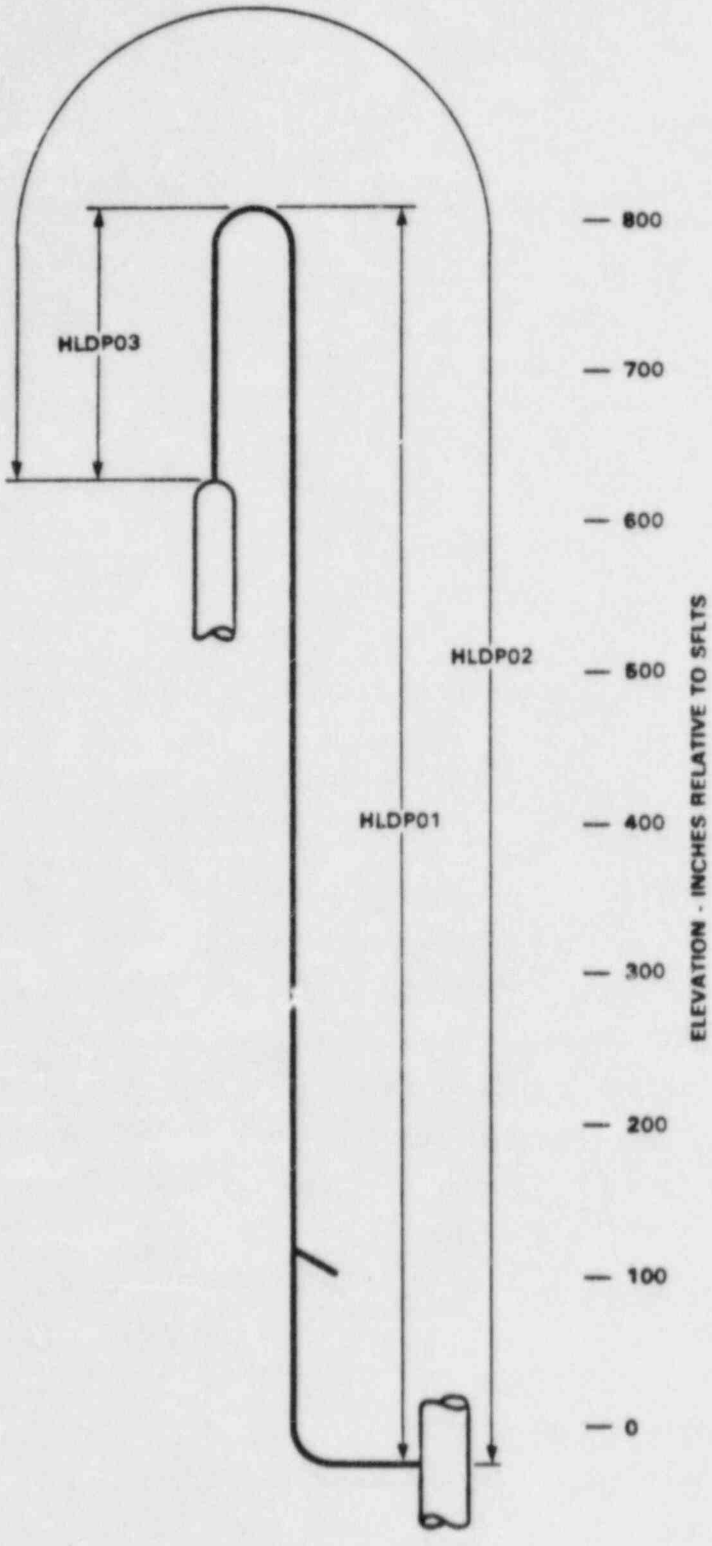


Figure 3-8 Hot Leg Instrumentation - Differential Pressure Measurements

Table 3-6

ELEVATION OF HOT LEG GUARD HEATER ZONES AND CONTROL THERMOCOUPLES

Zone No.	Elevation Covered by Zone Heater (Inches Relative to SFLTS)	Control TCs Designation for Zone	Elevation of Control TCs (Inches Relative to SFLTS)
1	- 23 to + 86	HLDT01	+ 26
2	+ 86 to +218	HLDT02	+157-1/2
3	+218 to +350	HLDT03	+295
4	+350 to +482	HLDT04	+408
5	+482 to +612	HLDT05	+559
6	+612 to +746	HLDT06	+695
7(1)	+746 to +734	HLDT07	+786
8	+734 to +635	HLDT08	+692

(1) This zone crosses over HLUB (elevation +807-1/2)

3.3 STEAM GENERATOR

An existing 19-tube Once-Through Steam Generator (OTSG) was used in OTIS. The OTSG was a single pass, counterflow, tube and shell heat exchanger. It consists of 19 Alloy 600 tubes with an outside diameter of 5/8 inch spaced on a triangular pitch of 7/8 inch on centers. The tube bundle was enclosed in a hexagonal shell 3.935 inches across flats and was held in place by 16 carbon steel tube support plates (TSPs) spaced at approximately 3 foot intervals. The distance between the secondary face of the lower and upper tubesheets was full length, approximately 52'-1-3/8". The 19-tube OTSG is illustrated in Figure 3-9. The TSPs were 1-1/2" thick and were drilled in a manner to simulate the broached pattern of a full-size OTSG TSP. This is illustrated in Figure 3-10.

In the OTSG, primary flow enters at the top, flows downward through the tubes, and exits at the bottom. The main feedwater enters the steam generator at the bottom, boils on the outside of the tubes, and exits at the top. For OTIS, both a high and a low auxiliary feedwater (AFW) injection location were available. The high AFW injection location was selected so that the distance from the nozzle to the first TSP below the nozzle in the model was the same as in the Oconee III

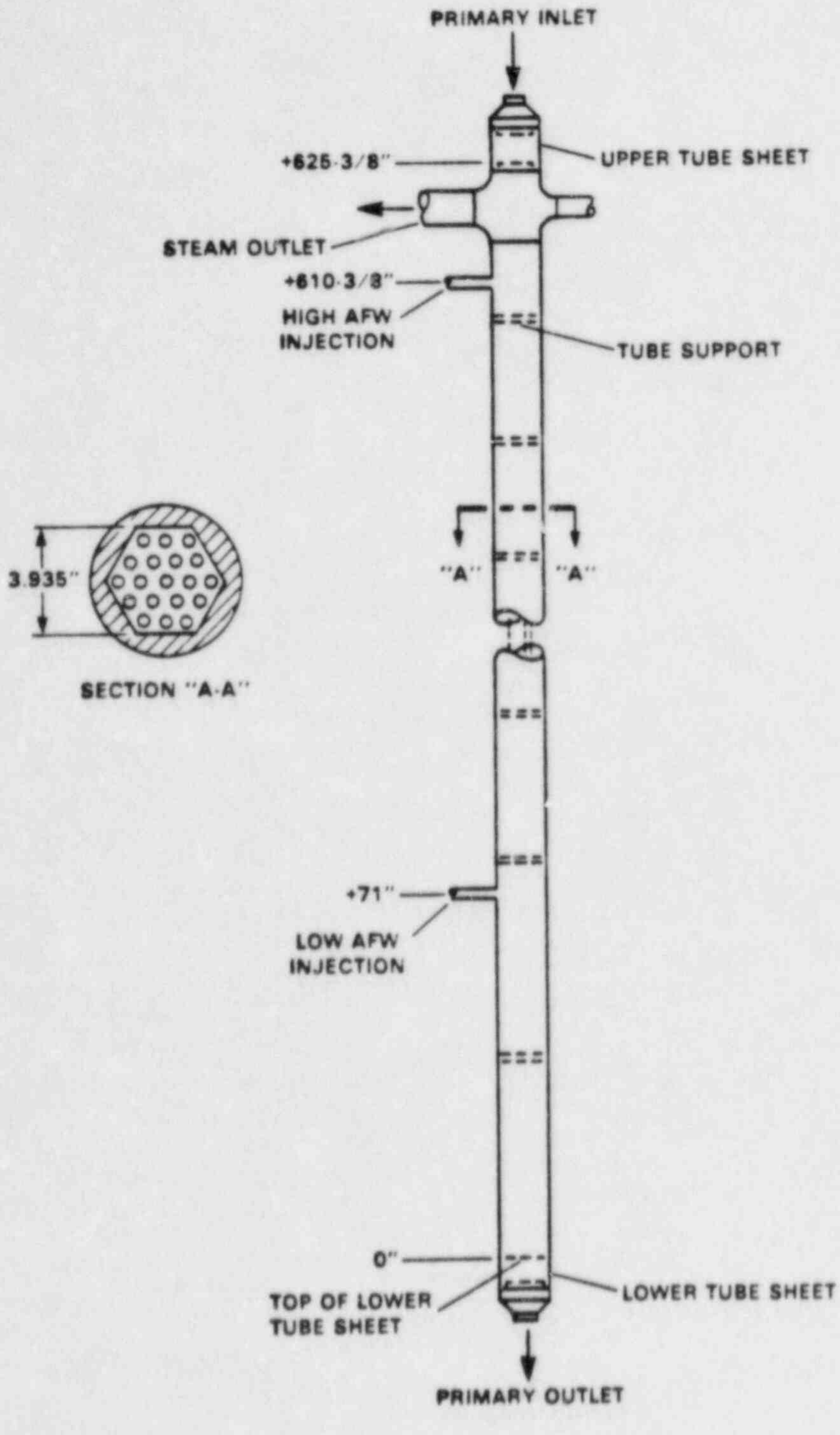
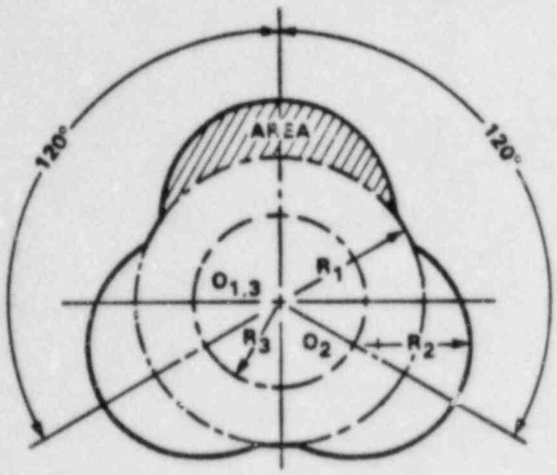


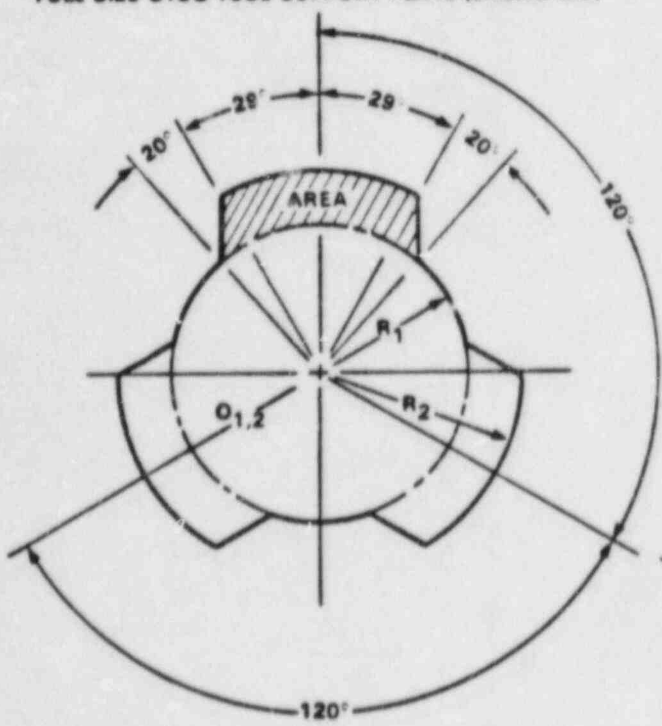
Figure 3-9 19-Tube Once-Through Steam Generator

19-TUBE OTSG TUBE SUPPORT PLATE (DRILLED)



R_1 (IN.)	R_2 (IN.)	R_3 (IN.)	AREA (IN.)
0.32031	0.250	0.1907	0.051518

FULL SIZE OTSG TUBE SUPPORT PLATE (BROACHED)



R_1 (IN.)	R_2 (IN.)	AREA $(IN.)^2$
0.323	0.430	0.051866
0.320	0.430	0.053075
0.320	0.427	0.051445
0.323	0.427	0.050233

Figure 3-10 Comparison of 19-Tube and Prototypical OTSG Tube Support Plates

type OTSGs. The low AFW injection location should have been located at 6'-5-1/16" (relative to the SFLTS) to exactly match the MK elevation, however, this elevation was too close to the second TSP in the model OTSG to allow the shell penetrations to be made. The low AFW injection was located at 5'-11". These AFW injection locations are shown on Figure 3-9.

The pressure boundary between the primary and secondary circuits was established by carbon steel tubesheets placed at the top and bottom of the generator with a distance of 52'-1-3/8" between the secondary faces of the tubesheets. Each tubesheet was clad with Inconel on the primary side. The tubes pass through the drilled tubesheet and were welded at the primary face. The upper and lower tubesheets were 3 and 24 inches thick, respectively. The details showing the assembly of the steam generator are presented on B&W drawing 10710E7.

To measure the overall performance of the steam generator, RTDs were located in the inlet and outlet plenums. These are identified on Figure 3-11. Primary and secondary-side pressures and differential pressure measurements are shown in Figure 3-12.

The OTSG was instrumented, during fabrication (in 1968), with internal thermocouples to provide primary fluid, secondary fluid, and tube metal temperatures. However, due to time and use, many of the thermocouples have failed. Replacement of the primary fluid and tube metal thermocouples was not possible. The primary, secondary. and metal thermocouples used during the OTIS program are shown in Figure 3-11, along with their elevation relative to the SFLTS. The tubes in which the primary fluid thermocouples were located are identified in Figure 3-13. The primary fluid thermocouples were positioned at the center of the identified tube. Metal thermocouples were located on the tube OD at the position identified in Figure 3-13. The secondary fluid thermocouples were positioned in either of two locations:

- between the shell and the first row of tubes (peripheral cell)
- in the unit cell between the first and second row of tubes (bundle cell)

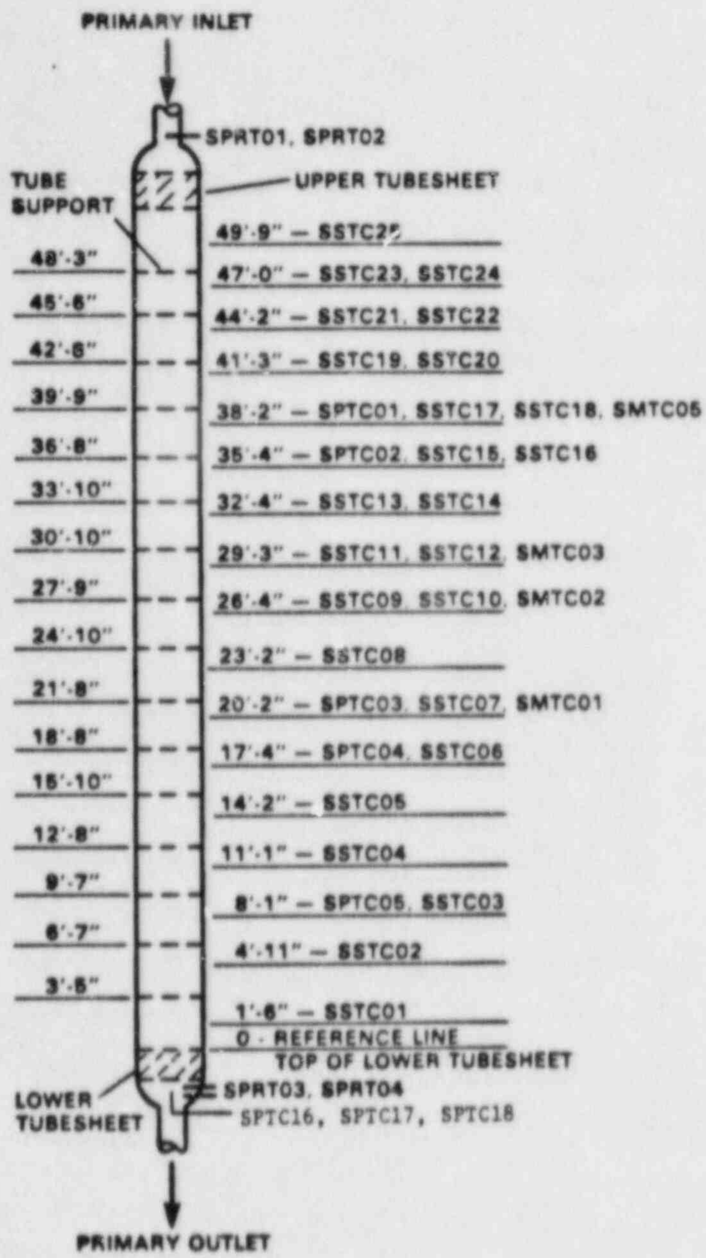


Figure 3-11 OTSG Temperature Measurements and Tube Support Plate Elevations

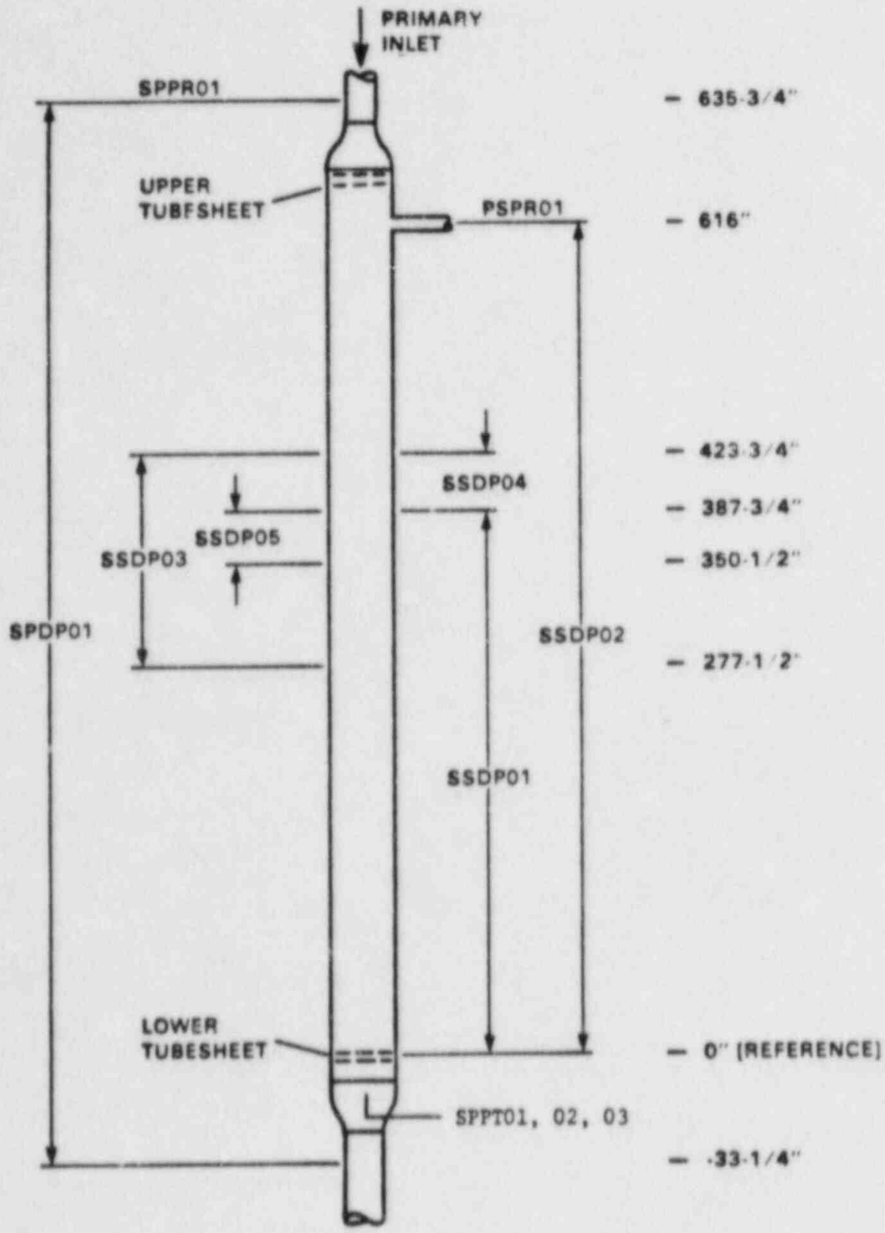
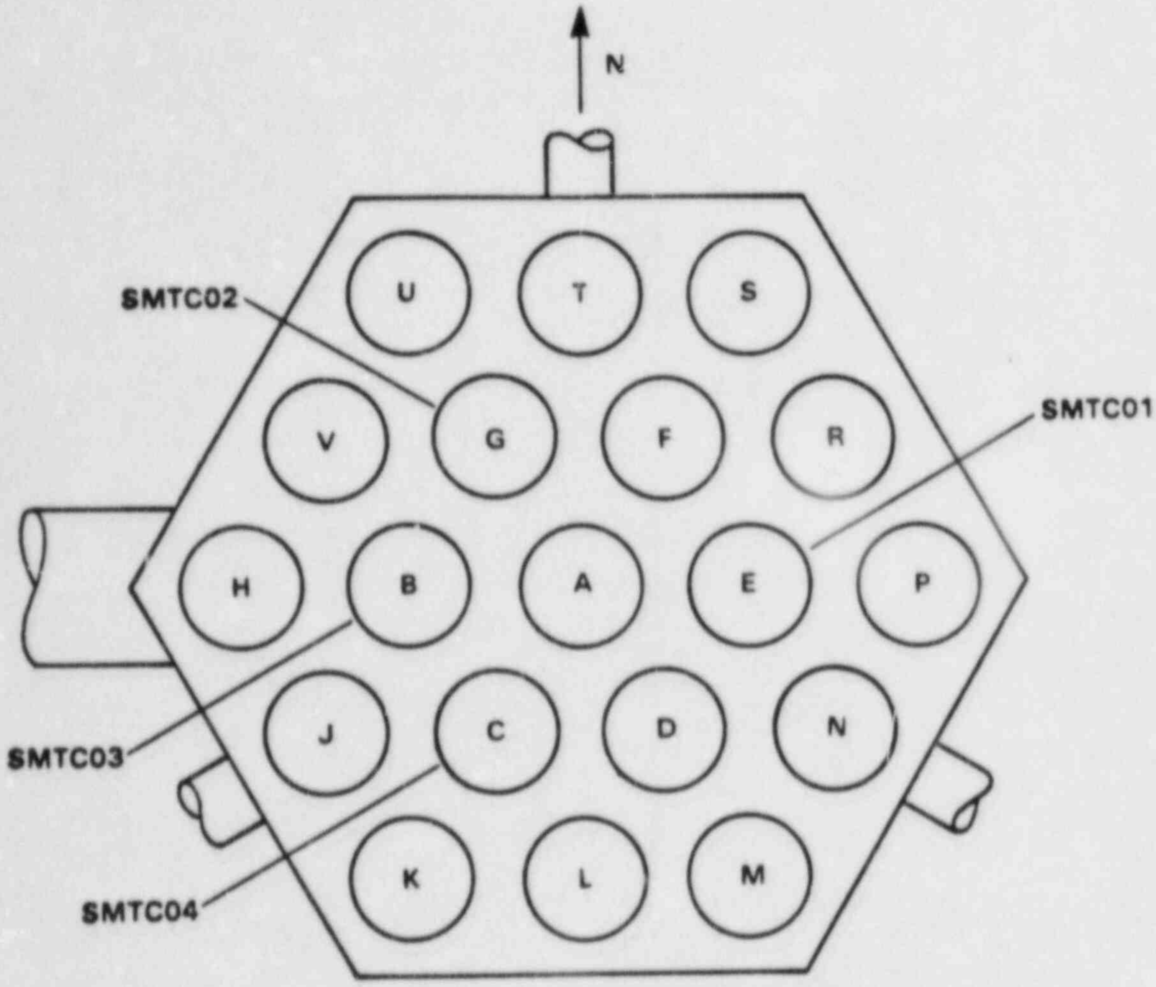


Figure 3-12 OTSG Pressure and Differential Pressure Measurements



PRIMARY FLUID THERMOCOUPLES	TUBE IDENTIFICATION
SPTC01	E
SPTC02	B
SPTC03	F
SPTC04	R
SPTC05	U

Figure 3-13 Radial and Circumferential Location of Primary Fluid and Metal Thermocouples

A map showing the circumferential and radial location of the secondary fluid thermocouples is given in Figure 3-14.

Additional instrumentation was added to the steam generator for the GERDA and OTIS program. A specially fabricated multi-junction thermocouple was installed into one tube. This tube is identified in Figure 3-15. The multi-junction thermocouple had ten (10) thermocouple junctions in a single 1/8" diameter sheath. The thermocouples were positioned at an elevation to measure the effect of high elevation AFW injection on the heat transfer process. These elevations, along with the thermocouple designation are given in Table 3-7. Pitot tubes were installed at the exit plane of the lower tubesheet in three selected tubes. The pitot tubes were used to provide a relative flow indication between the tube instrumented with the multi-junction thermocouples and one uninstrumented tube. Each pitot tube was equipped with a thermocouple for measuring temperature at the same point as differential pressure in the fluid stream. The steam generator tubes instrumented with a pitot tube are identified in Figure 3-15. The details of the additional instrumentation ~~was~~ arrangement in the existing steam generator is shown on B&W drawing 9527E.

Table 3-7

ELEVATION OF MULTI-JUNCTION THERMOCOUPLE JUNCTIONS

VTAB Designation SPTC**	Elevation of TC Junction Relative to SFLTS
06	23' - 1-3/8"
07	30' - 1-3/8"
08	35' - 1-3/8"
09	39' - 1-3/8"
10	43' - 1-3/8"
11	47' - 1-3/8"
12	49' - 1-3/8"
13	50' - 1-3/8"
14	50' - 7-3/8"
15	51' - 1-3/8"

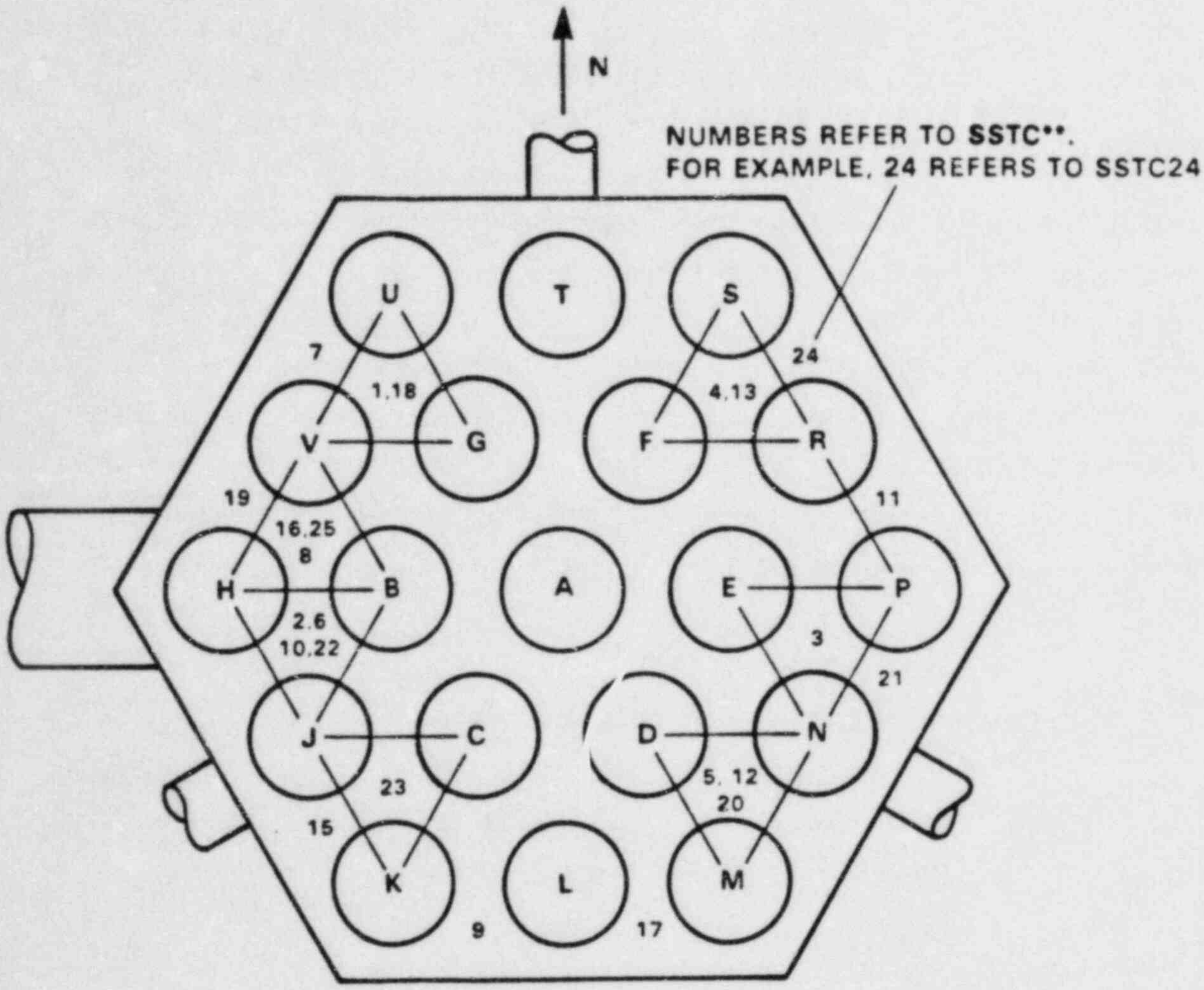
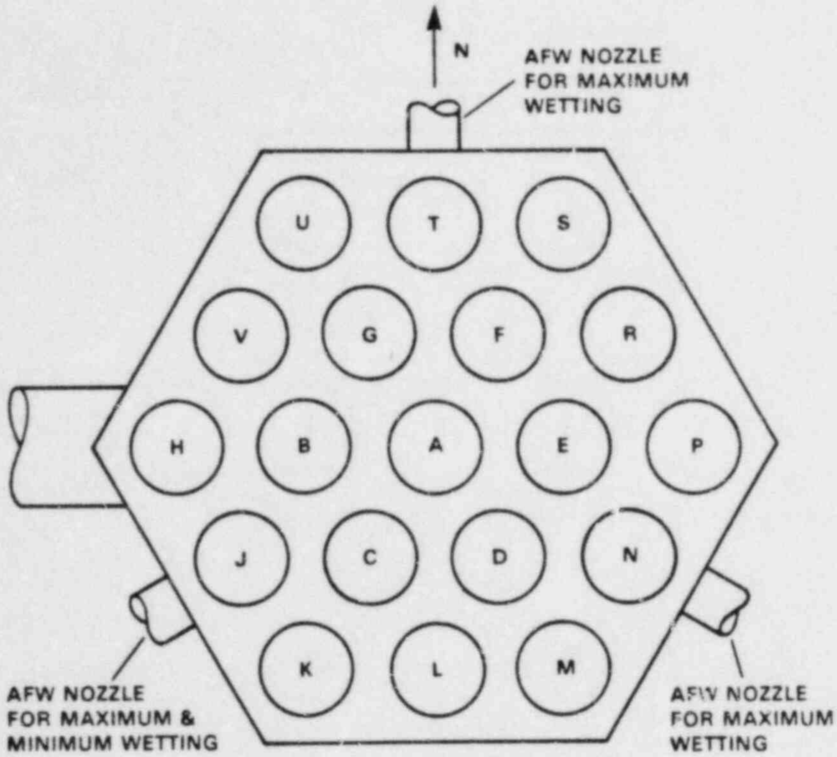


Figure 3-14 Radial and Circumferential Location of Secondary Fluid Thermocouples



INSTRUMENT (VTAB DESIGNATION)	TUBE IDENTIFICATION
MULTI-JUNCTION TC #1 (SPTC06 - SPTC15)	J
PITOT TUBE #1 (SPPT01) , TC SPTC16	J
PITOT TUBE #2 (SPPT02) , TC SPTC17	R
PITOT TUBE #3 (SPPT03) , TC SPTC18	N

Figure 3-15 Location of Multi-Junction Thermocouples, Pitot Tubes, and AFW Nozzles

Conductivity probes were installed in the steam generator to measure the secondary level swell anticipated during some transients. The thirteen (13) active conductivity probes were concentrated between the 29' to 36' elevation in the generator (the normal GERDA test operating level in the steam generator was about 26'). These probes were spaced approximately 6" apart and were staggered around the circumference of the generator. The steam generator reference probe was located at the 20' elevation. The details showing the location and installation of the steam generator conductivity probes are given on B&W drawing 9548E.

Auxiliary feedwater injection in OTIS could simulate either a high or low elevation AFW injection plant. Additionally, nozzles for AFW were used that allowed either maximum or minimum wetting of the tubes in the model OTSG. These maximum and minimum wetting nozzles were used during the GERDA secondary heat transfer and natural circulation tests to evaluate the importance of spray pattern on the heat transfer process and natural circulation.

The configuration of the AFW nozzles for maximum and minimum wetting was determined using a plastic model of the 19-tube OTSG[4,5]. The maximum wetting configuration consisted of a 0.187 inch ID tube with a 0.063 inch OD cross insert located on three sides of the hexagonal shell. The minimum wetting configuration consisted of a single 0.430 inch ID tube located on one side of the hexagonal shell. The circumferential location where the maximum or minimum wetting nozzles were installed is identified on Figure 3-15.

3.4 COLD LEG PIPING AND PRIMARY FORCED CIRCULATION SYSTEM

The cold leg piping was scaled based on phenomena and elevation. Phenomenological scaling set the pipe size to a 3" Schedule 160 pipe. The cold leg piping extends from the 5" x 3" concentric reducer at the outlet of the steam

[4] Auxiliary Feedwater Benchscale Tests, LR:81:5168-05:01, D. P. Birmingham and A. L. Miller to Distribution, March 15, 1981.

[5] Auxiliary Feedwater Benchscale Tests-Effects of Tube Material on Wetting Characteristics, LR:81:5168-05:02, D. P. Birmingham and A. L. Miller to Distribution, April 15, 1981.

generator, through a flanged orifice assembly (bore diameter is 1.110 inches), to the cold leg low point (spillunder) at elevation -76-7/8". The pipe turned 90° to a short horizontal run prior to the upbend. The horizontal run was at a 45° angle to the reactor vessel/steam generator centerline. The cold leg then ran vertically for about 24", where it was reduced from 3" Schedule 160 pipe to 1-1/2" Schedule 160 pipe. The 1-1/2" pipe then turned 90° to the horizontal, then 90° again to a vertical run. This vertical run of 1-1/2" Schedule 160 pipe, of approximately 39 inches, was included for the cold leg ultrasonic flowmeter. The ultrasonic flowmeter was found to be an unacceptable technique for measuring flow rates in GERDA and was not used for GERDA and OTIS test data. However, the associated piping did remain as part of the cold leg piping. After passing through this section of pipe, the cold leg returned to a 3" Schedule 160 pipe, and continued vertically upward to the simulated reactor coolant pump (RCP) spillover resistance. From the RCP spillover the cold leg sloped downward and connected with the downcomer at elevation -23". The routing of the cold leg piping and the key elevations are illustrated in Figure 3-16. Details of the cold leg piping are shown on B&W drawing 9542E.

There were two high pressure injection (HPI) locations in the cold leg -- one at the cold leg low point on the upstream side of the cold leg spillover, and the other in the sloping section on the downstream side of the cold leg spillover. HPI fluid was injected on the bottom side of the pipe normal to the axis of the pipe. The HPI nozzle was sized to preserve the ratio of cold leg to HPI momentum for one HPI pump discharging to one injection location. Details showing the HPI connections to the loop are illustrated on B&W drawing 9572E.

There were two simulated leak sites in the cold leg -- one at the cold leg low point on the upstream side of the cold leg spillover, and the other in the sloping section on the downstream side of the cold leg spillover. The leak sites were located on the bottom side of the pipe. These leak sites are shown in Figure 3-17. Effluent from the leaks was directed to the single-phase venting system (discussed in Section 3.7).

The instrumentation associated with the cold leg is also shown in Figure 3-17. There were five (5) thermocouples located in the cold leg, three (3) on the upstream side and two (2) on the downstream side of the cold leg spillover. An

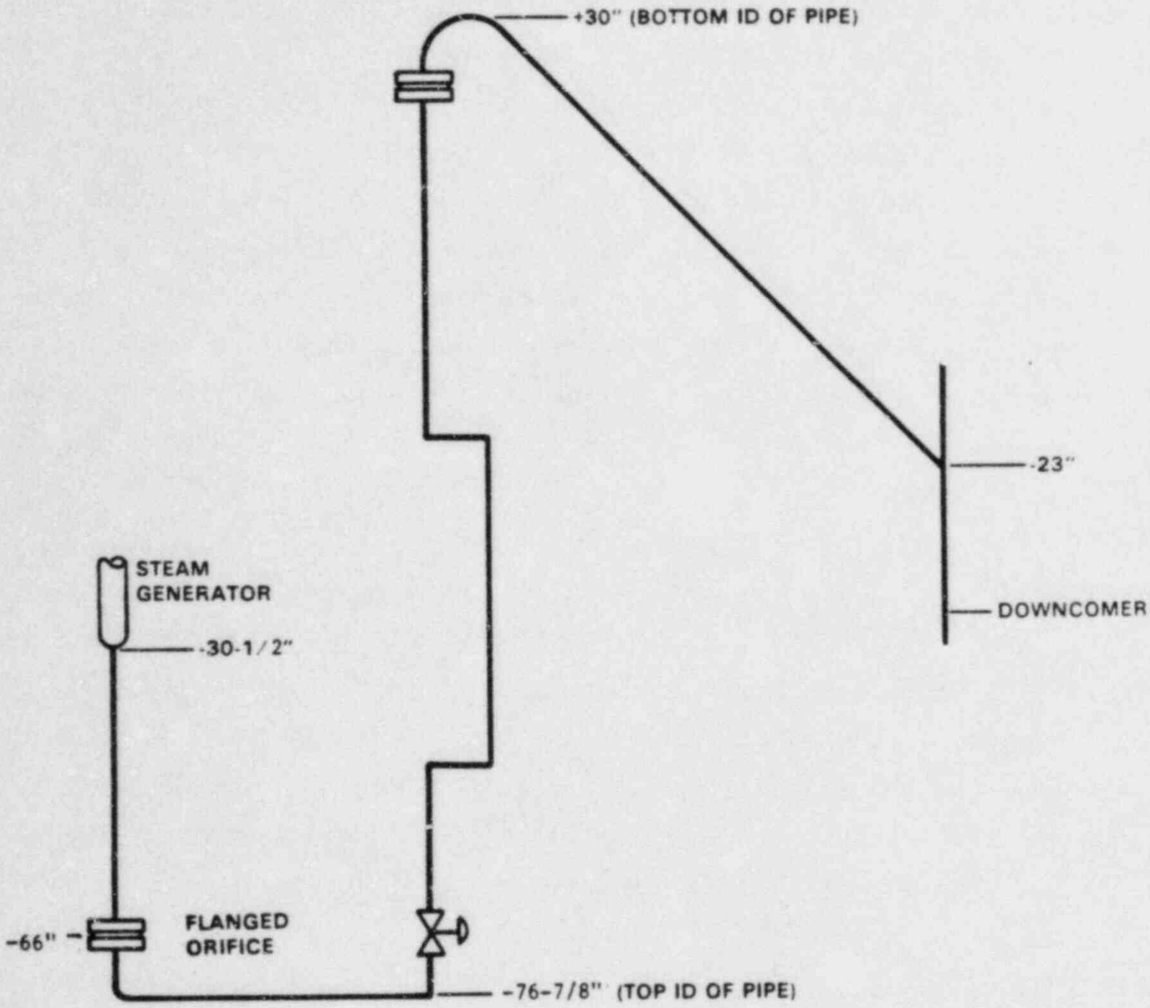


Figure 3-16 Cold Leg Piping - General Arrangement

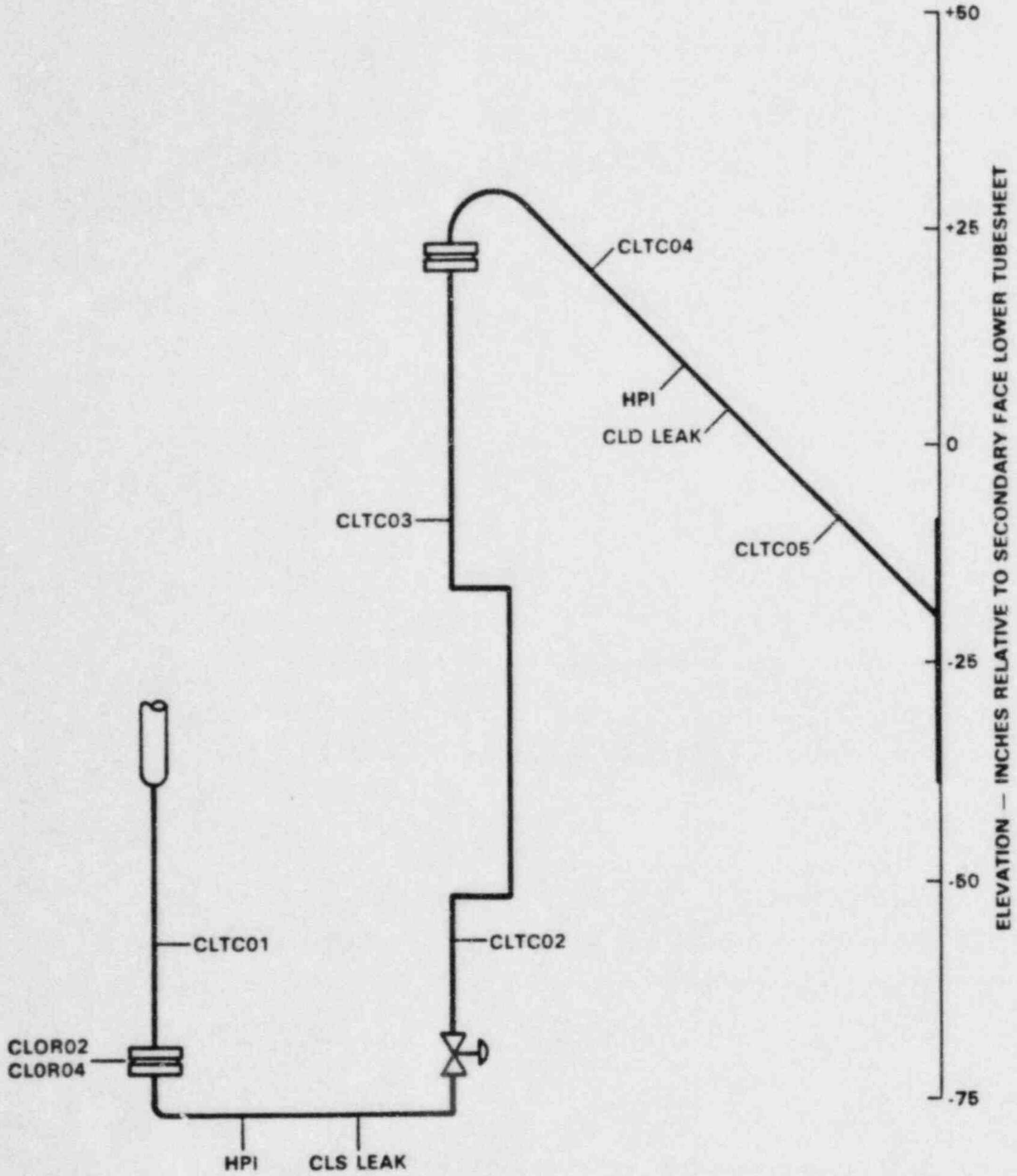


Figure 3-17 Cold Leg Piping - Temperature and Flow Measurements, Location of High Pressure Injection and Cold Leg Leaks

orifice was located near the bottom of vertical run from the steam generator to the spillunder. A high range and low range ΔP transmitter was used to calculate the flow rate from this orifice. The calibration of this orifice is discussed in Section 4.8. The differential pressure measurements around the cold leg are shown in Figure 3-18.

A Chempump Model GET was used in OTIS for providing forced circulation. The Chempump was a canned-rotor pump with a design head of 250 feet at a flow of 250 GPM. The pump was cooled using city water. The circulating pump was used during facility start-up. The pump was located in a loop parallel to the "natural circulation" flow path through the cold leg. Its location is illustrated in Figure 3-19.

The Primary Forced Circulation Loop started at the tee connection in the cold leg low point just before the vertical upturn. A 2-1/2" isolation valve was downstream of the tee section and just upstream of a 4" Schedule 160 straight section to the suction side of the pump. The straight section contained a flanged strainer assembly. The pump discharged vertically upwards through a 3" pipe. After passing through a concentric reducer, the flow passed through an isolation valve located in a 2-1/2" pipe downstream of the pump. The Primary Circulation Loop connected back into the cold leg piping at approximately an elevation of -58-3/4".

The pump-by-pass valve, CLCV01, was full open during natural circulation tests. During forced circulation operation, the isolation valves around the pump were opened and CLCV01 was throttled to give the desired flow rate. As CLCV01 was closed down, more flow was forced through the primary loop. With CLCV01 full open (flow coefficient, Cv, of 110) and the isolation valve on the discharge side of the pump, PCHV02, opened 3-1/2 turns, a flow rate of about 7500 lb/hr was obtained with cold water. This was the normal alignment during loop start-up. The pump was interlocked so it could not be started unless the pump by-pass valve was full open. This was to prevent forcing a large amount of flow through the loop and possibly damaging instrumentation. Pressure gages and thermocouples were located upstream and downstream of the pump. This instrumentation was not recorded as test data, but used for loop operation. Details of the forced circulation system are shown on B&W drawing 9542E.

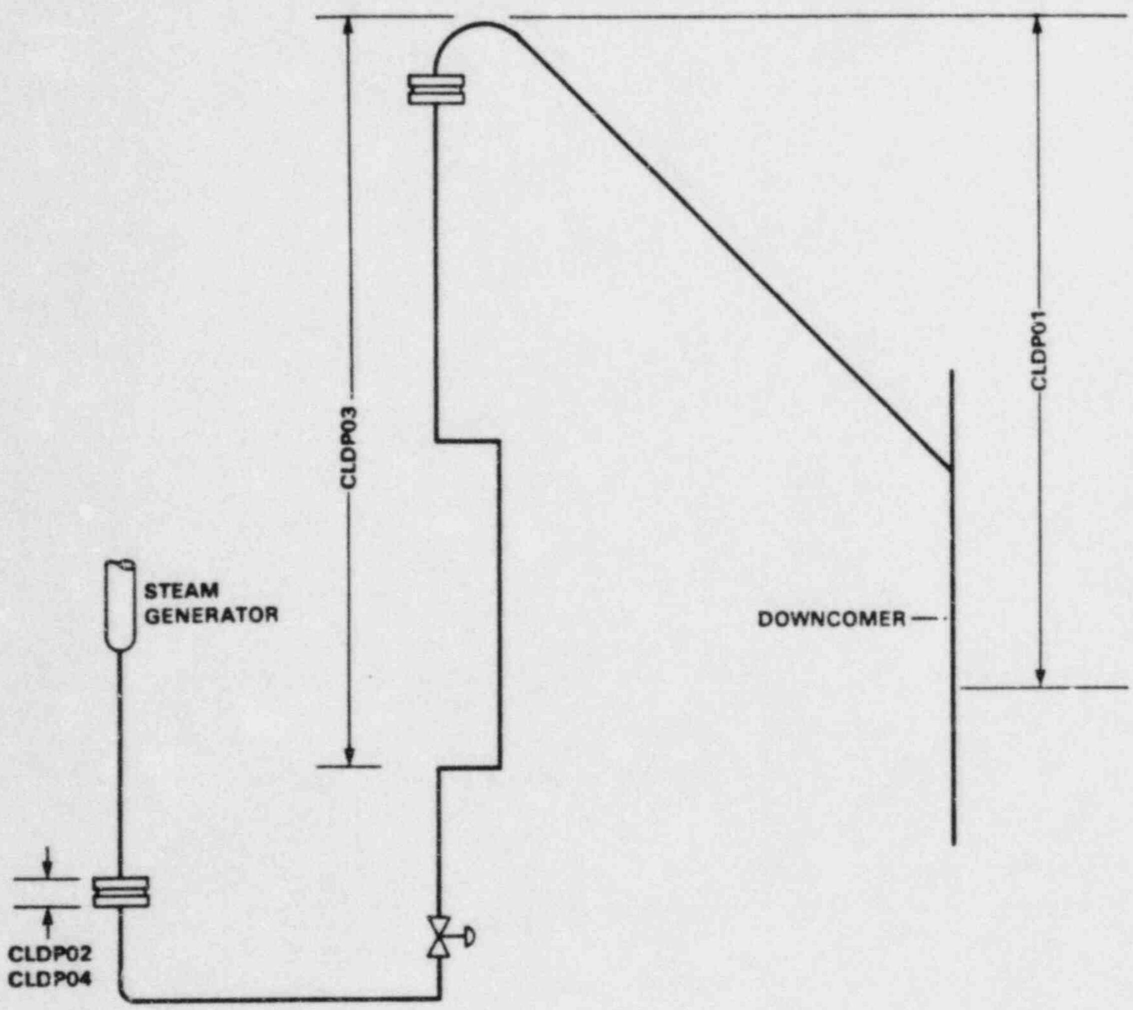


Figure 3-18 Cold Leg Piping - Differential Pressure Measurements

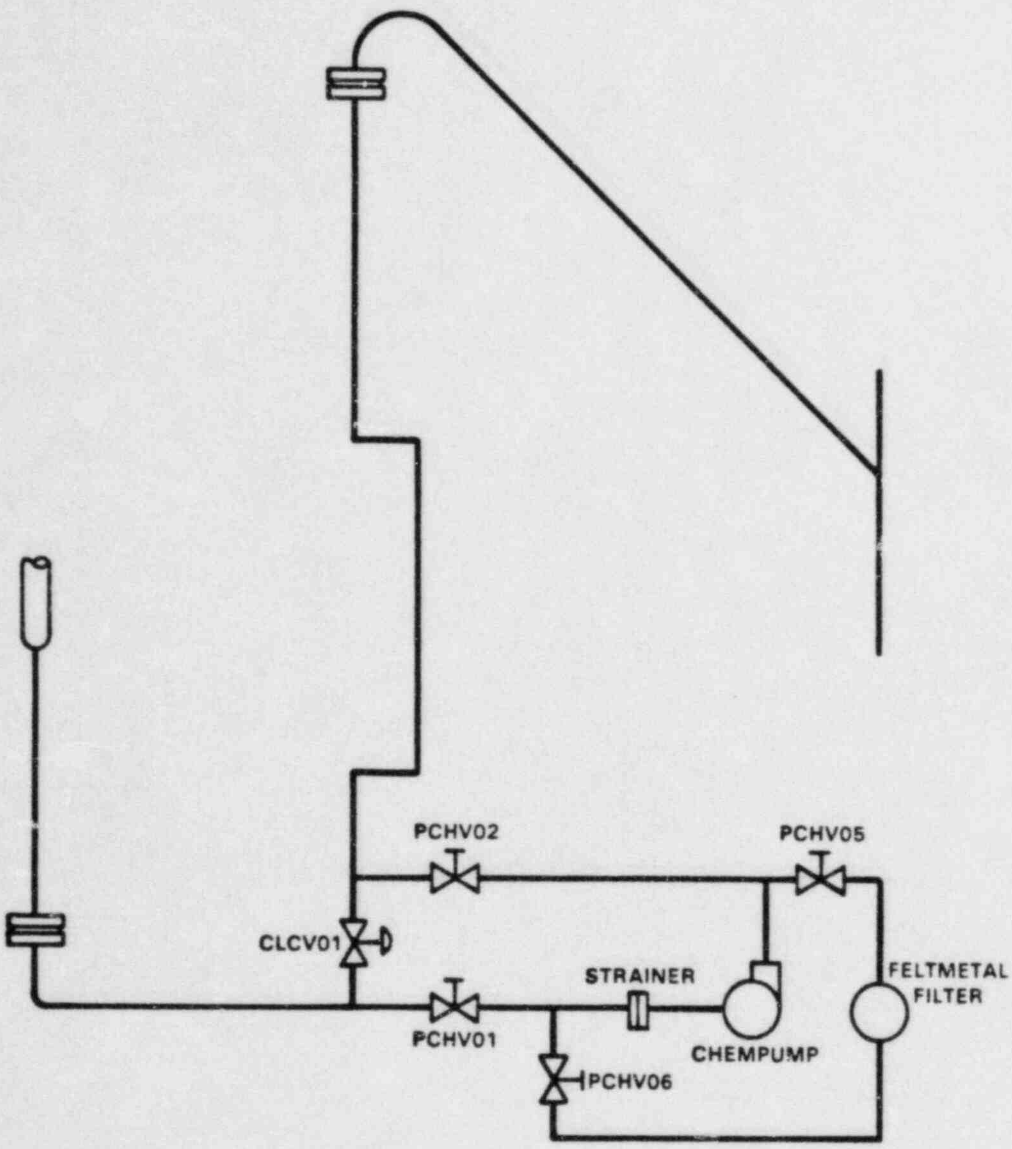


Figure 3-19 Primary Forced Circulation Loop

The forced circulation pump in OTIS was not intended to match the head/flow or coastdown performance of the plant RCP, but only to provide forced circulation. The coastdown time for the OTIS forced circulation pump was determined during GERDA testing to be about 5 seconds based on flow measurements before and after pump trip.

During facility startup and when the suspended solids in the primary fluid exceeded the desired level, a portion of the primary fluid was directed through a 0.6 micron Feltmetal filter. The Feltmetal filter consisted of interlocked metal fibers which were sintered to produce metallic bonds at all points where the fibers touch each other. This porous structure enabled filtration to 0.6 microns. The filter was tubed into a by-pass loop around the Chempump, and is shown in Figure 3-19. Instrumentation w s provided around the filter to measure the pressure drop across the filter, flow rate, and pressure. These measurements were used for loop operation and not for test data.

3.5 PRESSURIZER

The pressurizer vessel was fabricated from a 3" Schedule 160 stainless steel pipe. The volume of the pressurizer was scaled to that of MK, as was the elevation of the bottom of the vessel. The length of the pressurizer was approximately 20" shorter than that of the MK plant to preserve the volume scaling. The surge line was fabricated from 1" Schedule 80 stainless steel pipe. Surge line volume was approximately scaled to MK as were the elevations of the hot leg-to-surge line connection the surge line sloping-to-vertical interface, and the surge line low point. These elevations and volumes for OTIS are compared to MK scaled parameters in Section 3.0.

A schematic illustrating the pressurizer and surge line is shown in Figure 3-20. A layout of the surge line is shown in Figure 3-21. The pressurizer could be isolated from the hot leg by two (2) manually operated valves, PRHV01 and PRHV02. A simulated pilot operated relief valve (PORV) was located at the top of the pressurizer. A spray connection to the pressurizer (from the cold leg) was provided through a remotely operated valve, PRCV01. The facility water supply system was connected to the pressurizer through PRCV02. Provisions for degassing (during heat-up operation) the pressurizer and for providing a gas blanket on the

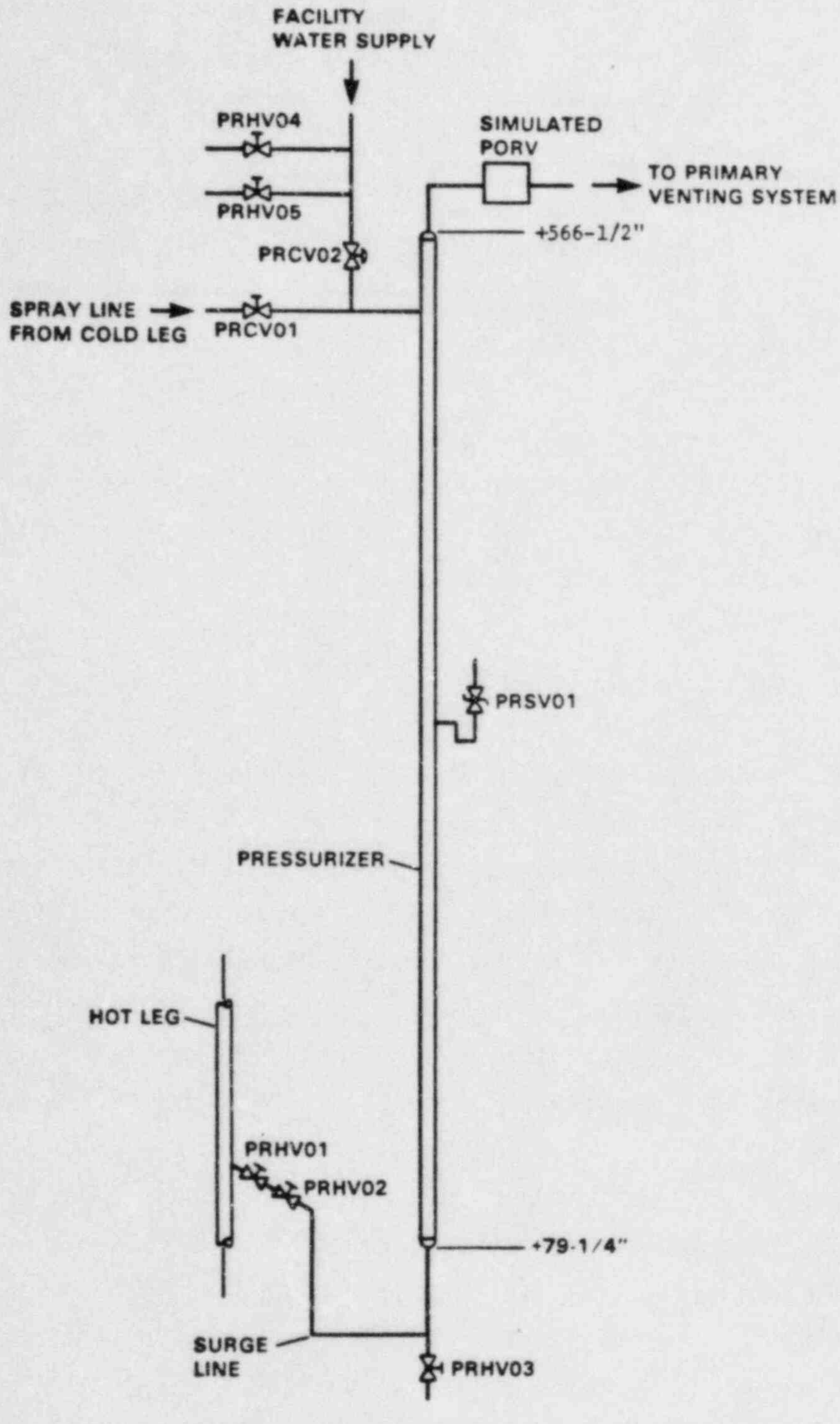


Figure 3-20 Pressurizer - General Arrangement

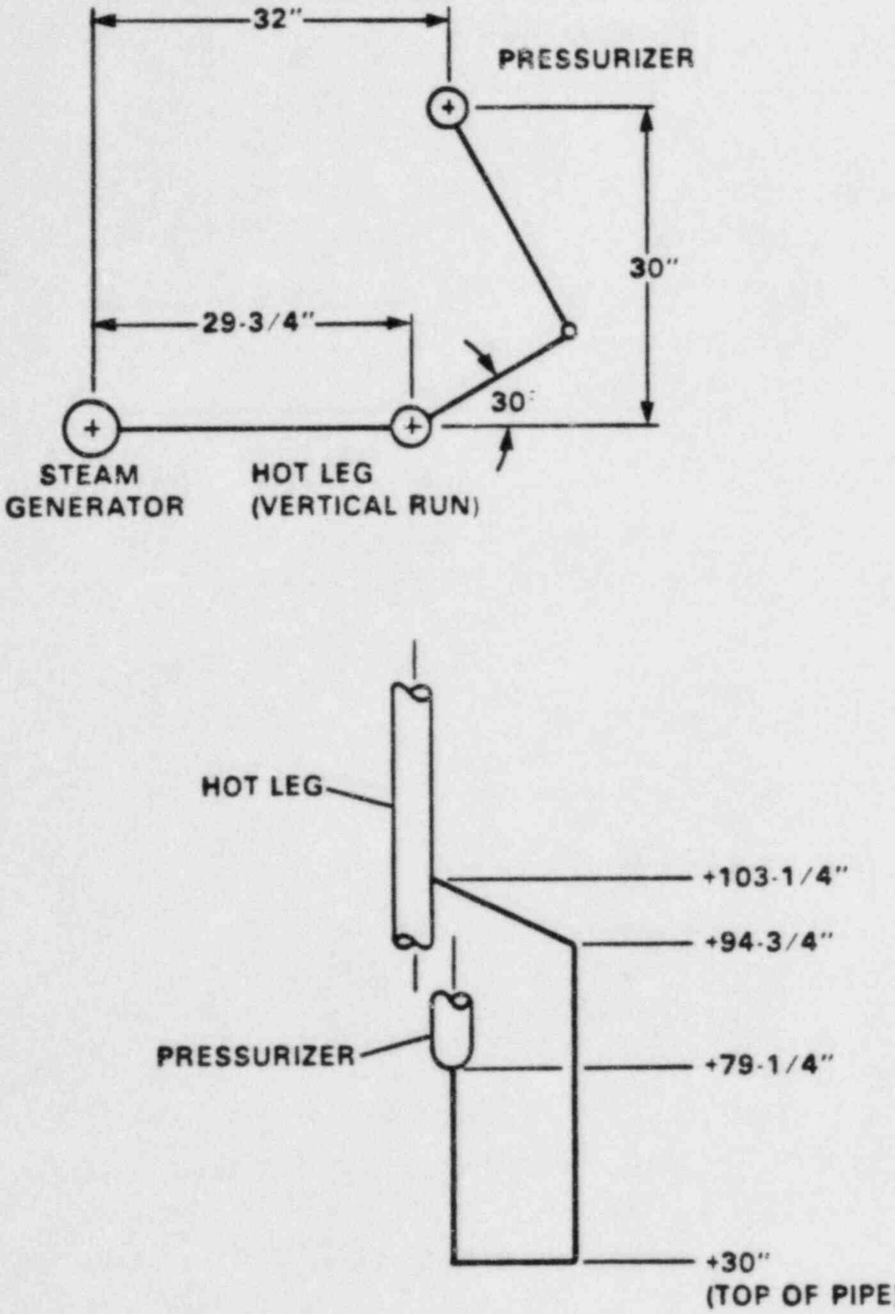


Figure 3-21 Surge Line Layout

pressurizer (used during fill operation) were provided through PRHV04 and PRHV05. A drain valve, PRHV03, was located at the bottom of the surge line. A safety valve and rupture disc assembly was located near the middle of the vessel. The details of the pressurizer and surge line design are contained in B&W drawing 9518E and 9549D.

All the valves on the pressurizer (except the code safety valve and drain valve) were sealed stem valves to preclude leakage of NCGs. The safety valve/rupture disk assembly and drain valve had a water trap upstream of the valve to isolate NCGs from the potential leak path. The flow coefficient, Cv, for the valves in the flow path are given in Table 3-8.

Table 3-8

MANUFACTURERS' SPECIFIED FLOW COEFFICIENT
FOR VALVES IN THE PRESSURIZER

Valve Designation	Flow Coefficient, Cv Full Open Valve
PRHV01	1.2
PRHV02	1.2
PRCV01	1.0

The simulated PORV was located at the top of the pressurizer in a section of 3/8" tubing. This simulation consisted of two (2) sealed stem automatically actuated valves, and a flow control orifice upstream of these valves The flow control orifice was sized to provide the desired relieving capacity of the PORV. The valves in the PORV simulation were controlled to open at a set point pressure of 2300 psia and then to close at 2250 psia. These dual set point pressures were adjustable The valves could also be opened manually. The operation of the PORV is discussed further in Section 3.7, Primary Venting Systems.

The pressurizer was heated externally using band heaters. The main heaters had an installed capacity of about 1.4 KW (MK scaled power was 1.12 KW) and were located over the lower 18" of the vessel. Pressure was controlled with the main heaters during steady-state operation. The heaters were tripped at the start of the SBLOCA transient, and remained off during the entire test. In addition to the main heaters, guard heaters were used over the remaining 40' length of the vessel and over the surge line. The guard heaters were used to minimize the heat loss from the pressurizer and surge line. The guard heater concept was described in Section 2.0.

The pressurizer guard heaters covered approximately 40' of pipe. A single controller was used to control guard heater output. For all tests before April 3, 1984, the control was based on the (arithmetic) average of three (3) sets of control thermocouples (ΔT measurements). The control thermocouples were located near the bottom (146-3/4"), middle (325-3/4"), and top (513") of the pressurizer vessel. A single guard heater was used for the surge line. After April 3, 1984, control was based only on the thermocouples near the pressurizer top (513"). A single controller was used to control guard heater output using one (1) set of control thermocouples. The control thermocouples were located on the vertical section between the surge line low point and the hot leg at an elevation of 37-1/4" above the SFLTS. As with the hot leg guard heaters, two sets of ΔT measurements were made for each of the three pressurizer and the surge line control zones, one for controlling the heater, and the other for test data. These two sets of measurements were at the same elevation, but 180° apart.

Much of the OTIS testing simulated a time during the SBLOCA transient where the pressurizer (in the plant) would already have drained and tripped its main heaters. To better simulate the nearly adiabatic plant pressurizer during this period, a series of tests were run in GERDA to determine the pressurizer guard heater control settings that would maintain a constant pressure with the main heaters off. This control setting, or bias, was obtained for several pressures. For reference, the results of the GERDA tests are shown in Figure 3-22. This curve was used for tests performed before April 3, 1984. After this date, a bias setting of 0.07 to 0.08 was used. GERDA tests were also conducted that allowed the pressurizer heat loss to be calculated. These tests were completed with the pressurizer isolated from the hot leg. The results of these tests are discussed in Section 4.5.

The instrumentation associated with the pressurizer and surge line is shown in Figure 3-23. Fluid temperatures (PRTC01 - PRTC03) and metal temperatures (PRTC04 - PRTC06 and PRTC08 - PRTC10) were measured along the length of the

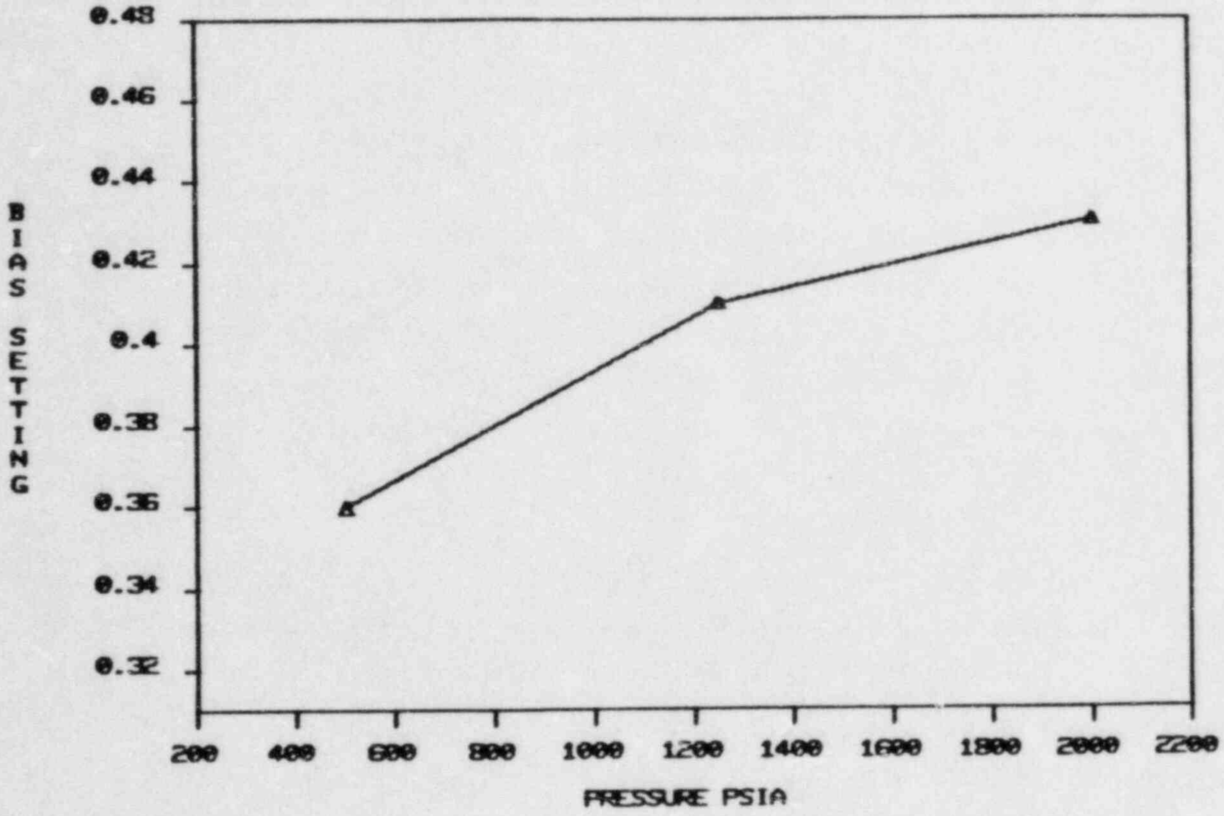


Figure 3-22 Pressurizer Guard Heater Bias for Adiabatic Pressurizer for Tests Prior to April 3, 1984.

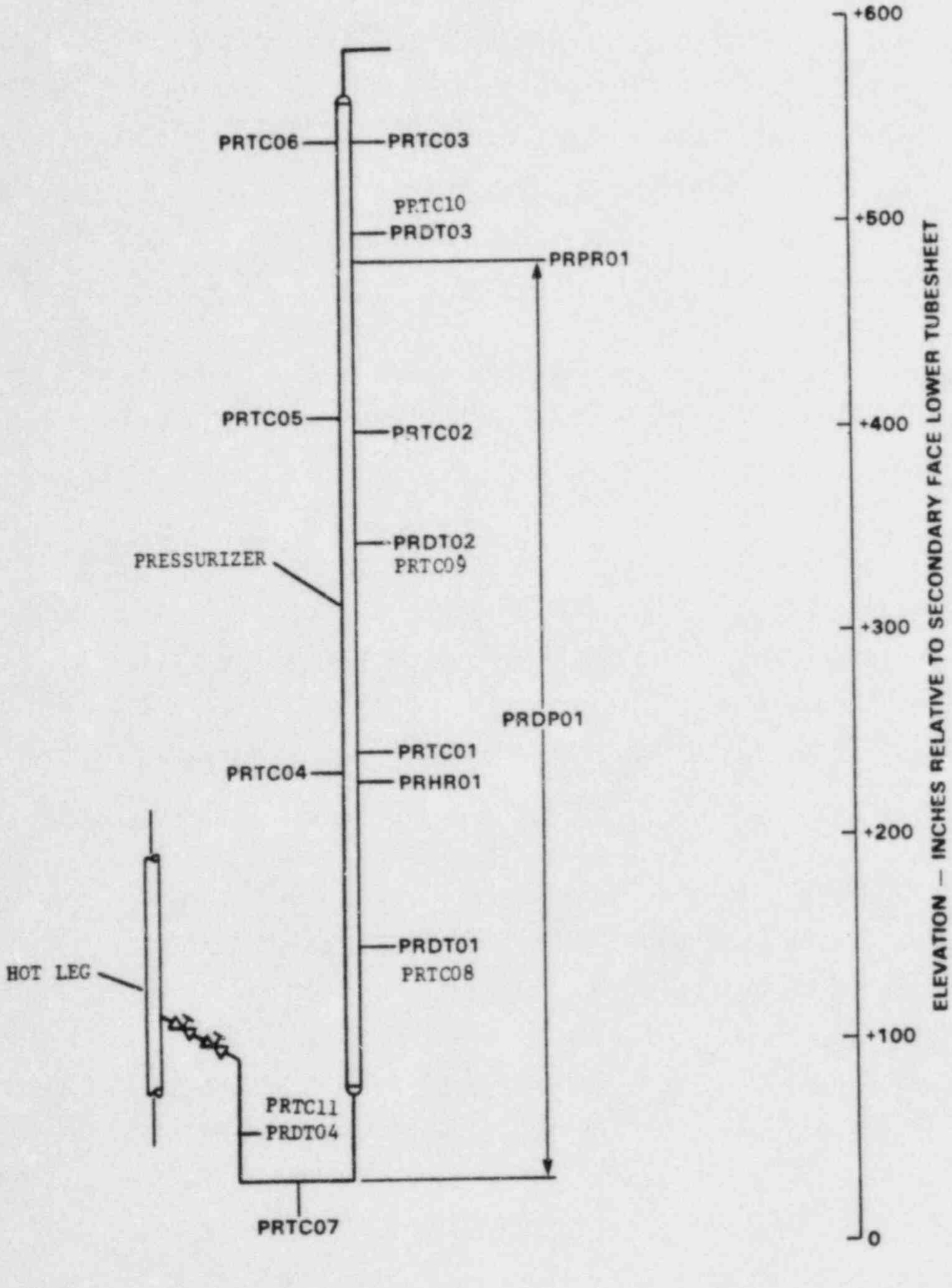


Figure 3-23 Pressurizer Instrumentation

pressurizer. Pressure, differential pressure, and guard heater ΔT measurements were also made and recorded as test data. The surge line metal temperature and the guard heater ΔT measurement were made in the vertical leg of the surge line as shown by Figure 3-23. A second metal temperature (PRTC07) was positioned at the surge line low point. Additional instrumentation was included for loop operation but was not recorded as test data. These included high temperature and high pressure trips for the heaters, current meters for the main and guard heaters, a pressure gage, and an indication of pressurizer level.

3.6 HIGH PRESSURE INJECTION AND FACILITY WATER SUPPLY AND CLEAN-UP SYSTEM

A high pressure injection (HPI) system was included in OTIS that provided the scaled head-flow characteristics of the plant HPI pumps. The system was capable of providing flows up to about 3 GPM.

A John Bean pump, ~~which is~~ a three piston positive displacement pump, was used to provide the scaled HPI flows. Output from this pump was controlled to simulate the desired head-flow characteristics. The system was capable of simulating either low ($\sim$1700 psi) or high ($\sim$2500 psi) shut-off head plant systems. Control of head-flow was through a Research Incorporated Model 5110 DATA-TRAK.

The DATA-TRAK Programmer was an electro-mechanical instrument designed to position the shaft of a rotary output device in accordance with variations in a preplotted program attached to a rotating drum. The preplotted program was a X-Y plot of the head-flow characteristics to be simulated. Pressure was plotted as the X-coordinate and flow as the Y-coordinate. The pressure signal was from RVPR01 (reactor vessel pressure) and the flow signal from HPTM01 (total HPI flow turbine meter). Each was plotted in terms of 0 to 100% of full range output. As the drum rotates to track the pressure variation, the sensor probe follows the etched line in accordance with the head-flow curve. The output device signal was varied in an amount proportional to the prescribed flow. As the demand for flow was changed, the position of the HPI by-pass valve, HPCV03 in Figure 3-24, was varied.

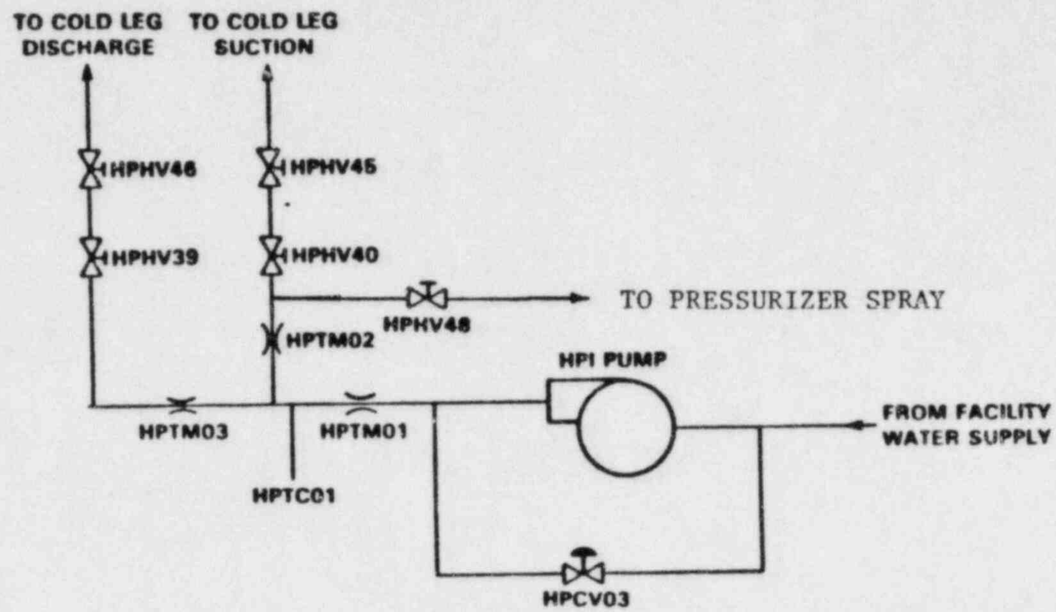


Figure 3-24 High Pressure Injection System

To verify the operation of the head-flow controller, a test was run during the GERDA program where the loop pressure was varied from about 200 psia to just above the MK shut-off head of 1863 psia, and then back to 200 psia. The head-flow curve for 4 scaled MK HPI pumps was simulated. The results of this test, shown in Figure 3-25 verified the ability of the controller to match the HPI shut-off head and the head-flow curve.

In the OTIS test program a simulation of LPI was provided with the John Beam pump by including the LPI head-flow characteristic of interest on the HPI curve tracked by the DATA-TRAK. Figure 3-26 shows this concept for the OTIS "Nominal" HPI/LPI head-flow characteristic. The ability of the control system to track the LPI portion ~~of the control system to track the LPI portion~~ of this characteristic is shown by the inset for Test 2202BB. As indicated by comparison of the experimental data (Δ) to the expected characteristic (solid line) two observations are noted:

1) The pressure for LPI actuation (240 psia) is missed during actual operation by about 10 psia. The major source of this error results from the uncertainty in the pressure measurement, (about +/- 7 psia) and comparable error in aligning the DATA-TRAK sensing head.

2) A significant data scatter and hysteresis is present during LPI actuation that directly relates to the error (sensitivity and response characteristics) present in the HPI control system. The existing HPI system shown in Figure 3-24 and controls were not designed to track the LPI head-flow characteristic.

HPI supply was from the facility water supply system (to be discussed later in this section). The desired head-flow could be delivered to either the HPI location on the suction side or discharge side of the simulated RCP spillover. Each line contained a manually adjustable flow control valve, HPHV45 and HPHV46 so that the HPI could be divided, as desired between the suction side and discharge side of the RCP spillover. Turbine meters were installed in each branch, in addition to the turbine meter upstream of the split. This is illustrated in Figure 3-24. Check valves were installed in each branch line to prevent backflow in the HPI lines.

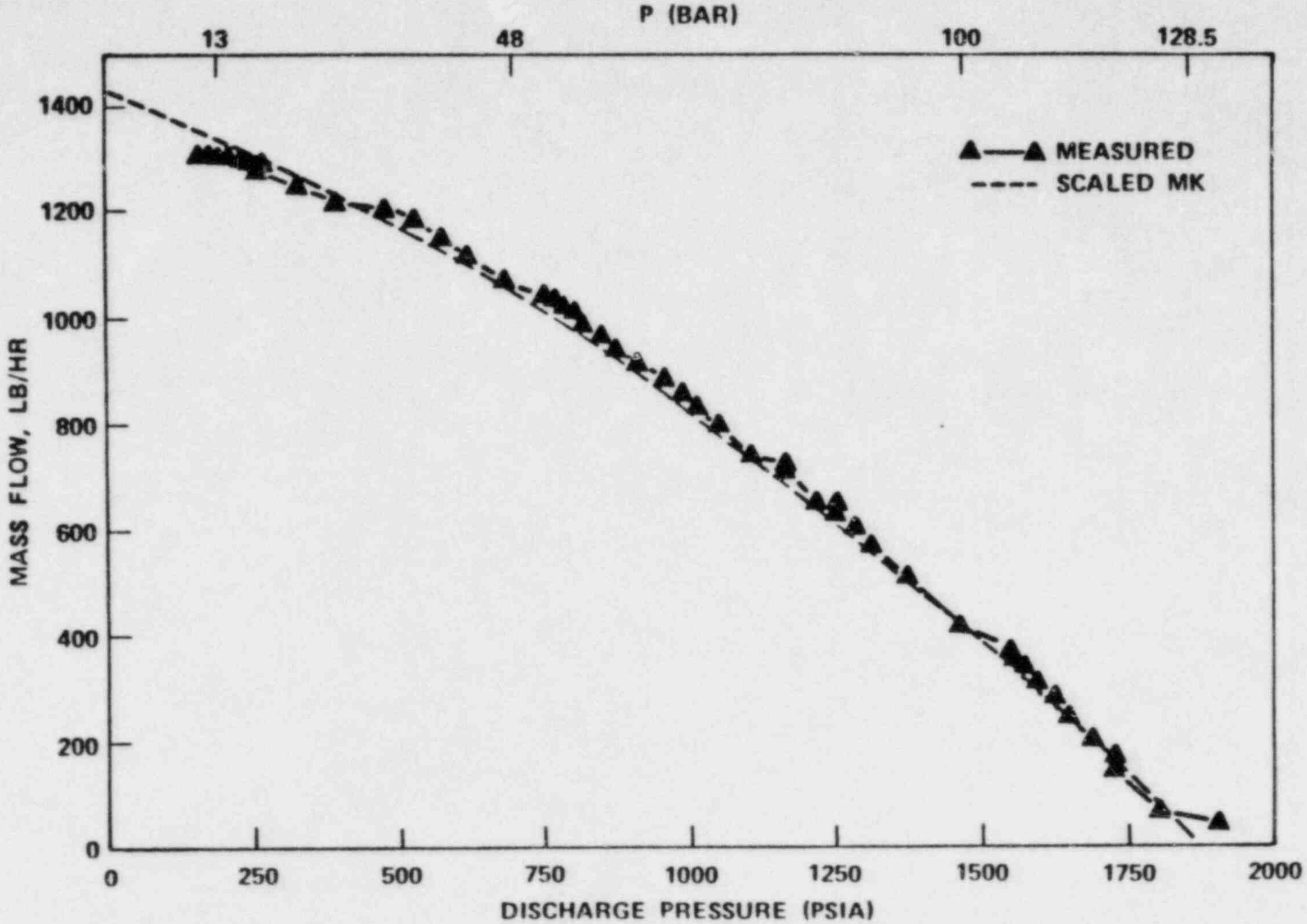


Figure 3-25 GERDA 4 Pump HPI Head-Flow Curve

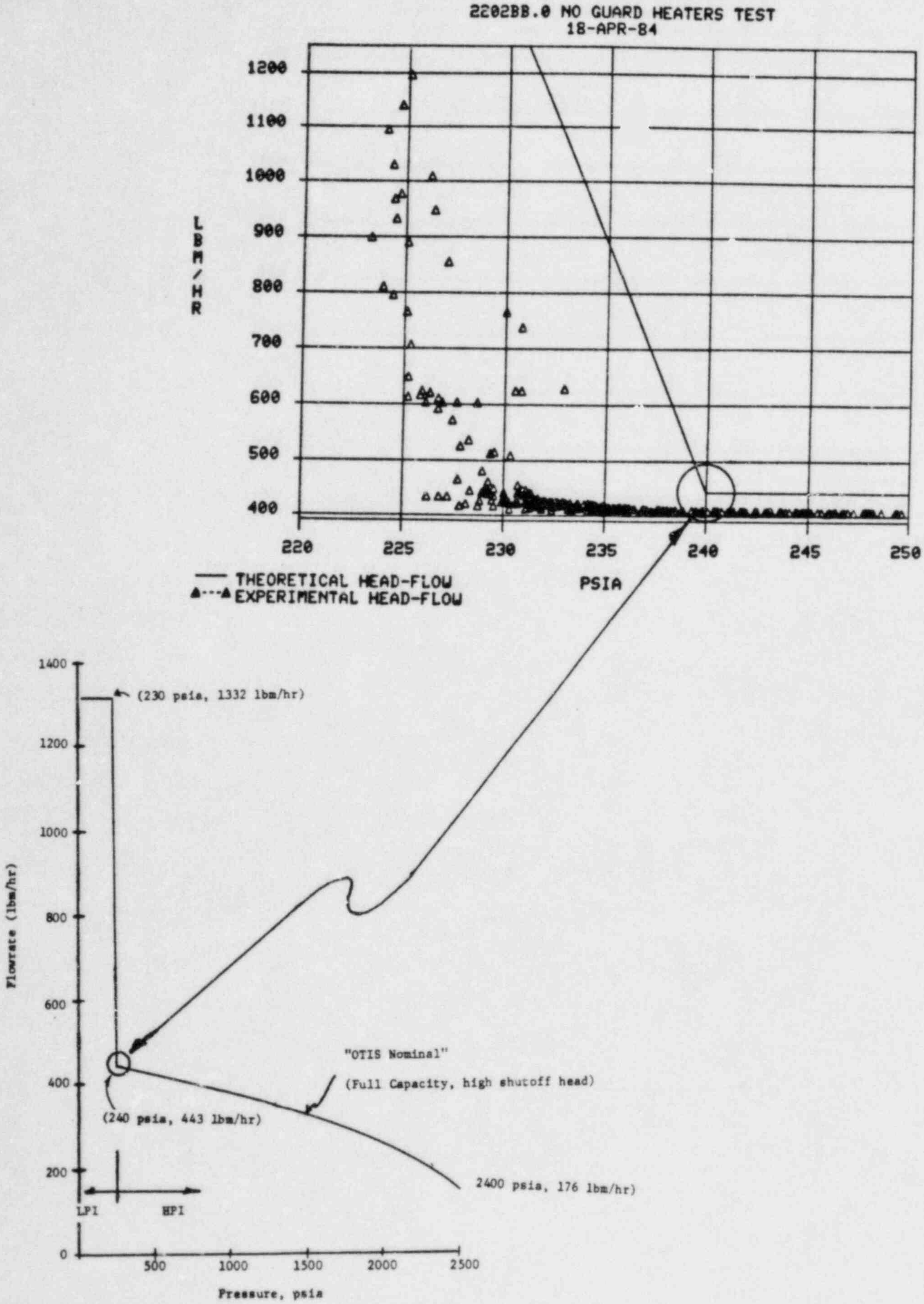


Figure 3-26 OTIS "Nominal" HPI/LPI Head-Flow Characteristic

The HPI system was supplied by the Facility Water Supply and Clean-Up System. This system, illustrated in Figure 3-27, provided high-purity deaerated water for initial filling of the primary and secondary loops, for leakage makeup, for removal of NCGs from the loop, and for HPI supply.

Demineralized water from the plant reverse osmosis system was passed through a Continental demineralizer, then to an Epicor vacuum deaerator. The deaerator was operated at a fluid temperature of 110°F and a pressure of 3 inches mercury to provide deaerated water (<10 ppb oxygen) at flows up to 3 GPM. Flow from the deaerator could be supplied directly to the loop, either through the HPI system or through a Sprague pump. The Sprague pump, which is a single piston air driven pump, was primarily used for making chemical additions to the loop and for small amounts of makeup water. Water from the deaerator could also be stored in a 1000 gallon storage tank. In this storage tank, the demineralized water was kept at ambient temperature with a small gas overpressure. The conductivity of the water in the tank was adjusted to that in the loop to minimize the (conductivity) dilution effect during high pressure injection. Also, the gas overpressure was selected to be either nitrogen or helium depending on which species was being used in the loop. Water stored in this tank could be routed back to the deaerator so that degassed water could be supplied to the loop. Upon completing a NCG test, the water in the loop was routed back to the Facility Water Supply and Clean-Up System, where it was degassed, and then returned to the loop using the HPI system.

3.7 PRIMARY VENTING SYSTEMS

The function of the primary venting system was to provide a controlled leak for the release of primary fluid, and to provide a means of measuring the rate and total mass of fluid exiting the loop through the leak site. In OTIS there were six (6) leak sites - four (4) defined as single-phase region leaks, and two (2) defined as two-phase region leaks. Independent systems were used to control and meter the fluid from the single-phase and two-phase leak regions. The single-phase venting system will be discussed first.

There were four controlled leak sites in the single-phase region - two (2) in the cold leg, one on the suction side of the simulated RCP spillover and one on the discharge side of the RCP spillover, one controlled leak at the bottom of the

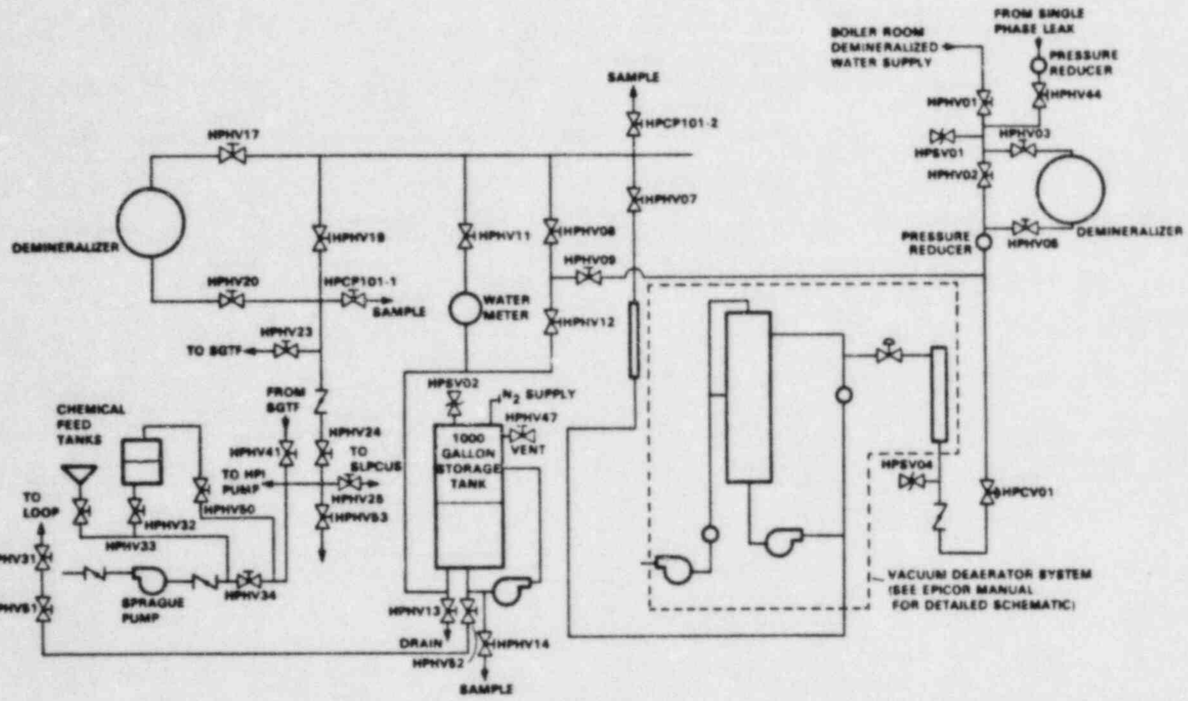


Figure 3-27 Facility Water Supply and Clean-Up System

lower plenum of the reactor vessel, and one controlled leak at the top of the top plenum of the reactor vessel. These four leak sites tied into a common point, after which they shared a heat exchanger and a leak measuring system. The cold leg suction leak site was branched into four lines, each having a leak orifice. This arrangement avoided loop cooldowns for cold leg suction (CLS) leak orifice changes. This system is illustrated in Figure 3-28.

Remotely actuated leak control valves were located just downstream of the leak control orifice. (The orifice assembly was discussed in Section 2.0.) The control valves and control orifice were located in 3/8" tubing. The control valves were 3/8" NUPRO "U" series sealed stem valves, which have a flow coefficient, Cv, of 1.0. After passing through the control valve, the fluid was cooled using a single pass, tube-in-shell heat exchanger. The heat exchanger had sufficient cooling capacity to handle single-phase leaks up to a scaled 50 cm^2 break. Downstream of the cooler the effluent could be sampled to determine the amount of dissolved gas prior to being collected in a collection tank. An accumulating flowmeter, V1AC01, was used to measure the mass of fluid exiting through the leak site. Leak rate was computed (by the data acquisition system) based on the accumulating flowmeter reading and the time interval between data acquisition scans. Fluid temperature was measured downstream of the meter. The collection tank was mounted on a weigh scale to allow cross checks on total inventory leaked from the loop. Details of the single-phase leak system are given on B&W drawings 9574E and 9539D.

There were two (2) leak sites in the two-phase region of the loop - a high point vent (HPV), located on top of the HLUB, and a simulated pilot operated relief valve (PORV), located on the top of the pressurizer. The effluent from these leaks was cooled, stripped of NCGs (if present), then the liquid and NCG mass flows were measured. A schematic illustrating the two-phase venting system is shown in Figure 3-29. Details of the two-phase venting system are given on B&W drawings 9559D, 9562D, 9563D, 9564D, and 9565D.

The HPV leak control valves, which were two 3/8" NUPRO "U" series sealed stem valves, were located upstream of the leak control orifice assembly, After passing through the orifice the steam-water-NCG mixture was condensed, cooled, and the gases were separated from the condensate. A centrifugal separator was used to

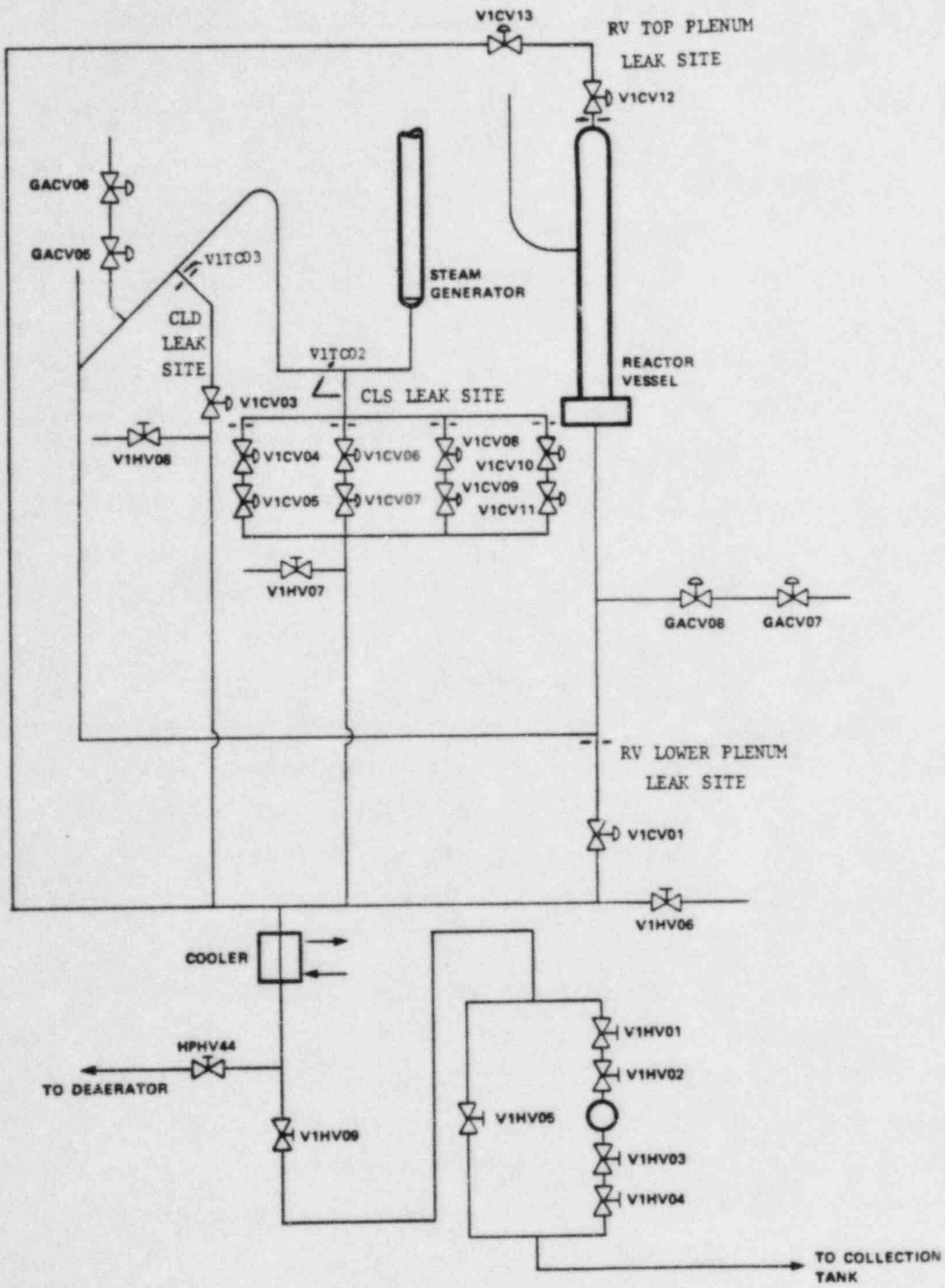


Figure 3-26 Single-Phase Venting System - General Arrangement and Instrumentation

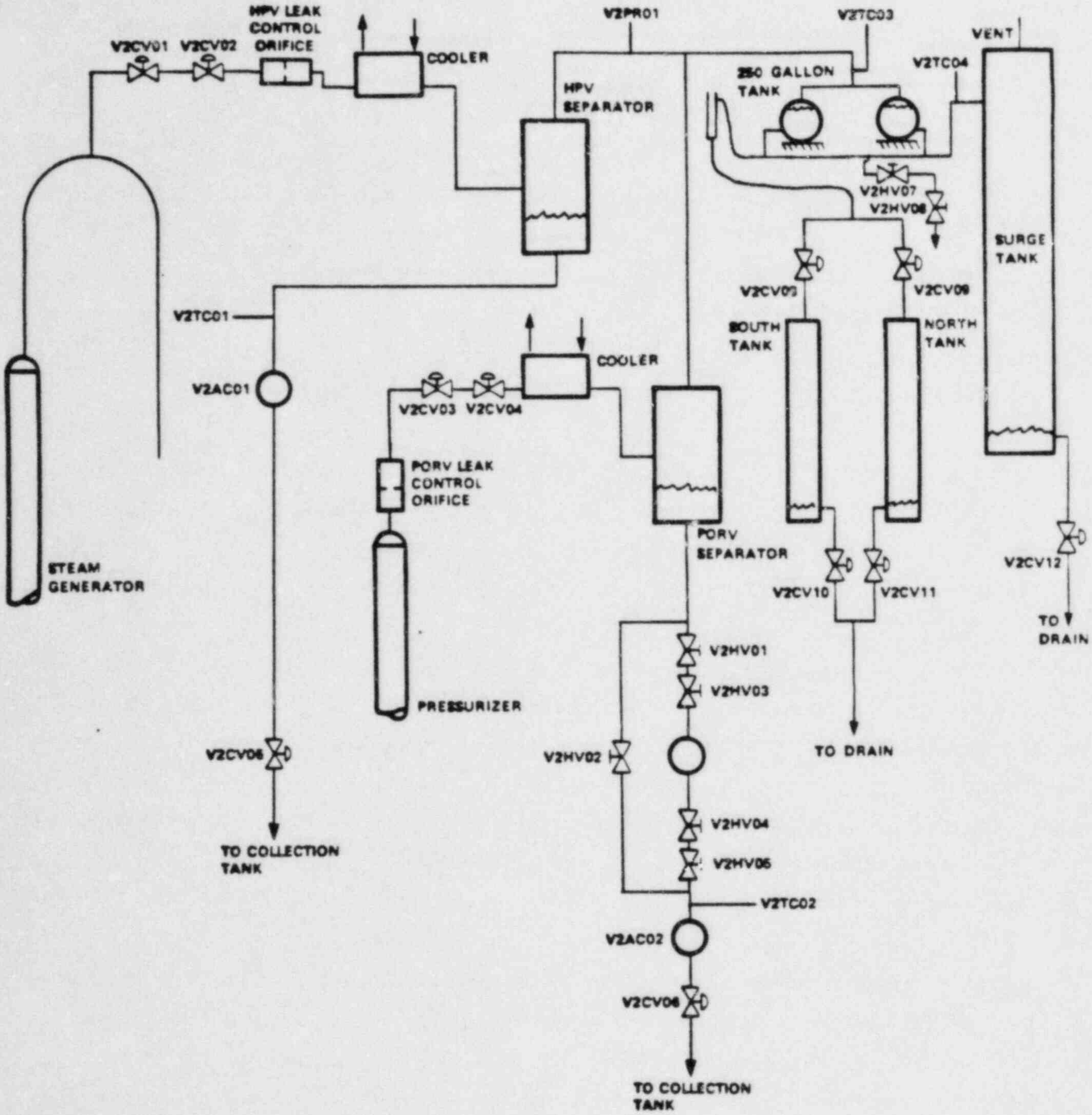


Figure 3-29 Two-Phase Venting System - General Arrangement and Instrumentation

separate the liquid and the gases. The liquid level in the separator was maintained at a nearly constant level using a flow control valve, V2CV05, and the separator differential pressure. The differential pressure measurements associated with this system are shown in Figure 3-30. An accumulating flowmeter, V2AC01, was used to meter the mass of steam-water removed through the HPV. The NCGs flowed from the top of the separator to the two 250 gallon tanks. When the internal pressure of the separator was sufficient to raise the water level in an overflow leg to its discharge elevation, water from the 250 gallon tank would spill over into either the North or South accumulator tank (whichever one was selected by the operator). The level in the accumulator tank was calculated from the differential pressure measurement, V2DP03 or V2DP04. The volume of gas released through the HPV was then computed from this level change.

The PORV leak control valves were located downstream of the leak control orifice assembly. As with the HPV a double isolation valve was used. After the mixture from the PORV was cooled and the gases were separated from the condensate, the liquid mass and gas volume were measured in a manner similar to the HPV.

A Surge tank was used in parallel with the two accumulator tanks (North and South tanks). The purpose of the Surge tank was to provide a means of pressure relief for the system as well as to measure water displaced from the tanks. In the event a large quantity of gas was released, the lines to the North and South tanks may not be able to handle the resulting water flow rate without building up a backpressure. The large line to the Surge tank would provide a path to relieve the pressure and a means to measure this large gas release.

The instrumentation associated with the two-phase venting system are shown on Figures 3-29 and 3-30. Included are limit switches on the HPV and PORV flow control valves; accumulating flowmeters to measure steam-water removed through both the HPV and PORV; thermocouples located in each separator, on the water side of the 250 gallon tanks, and at the Surge tank, a pressure transmitter, and the differential pressure measurements shown in Figure 3-28. All these measurements were recorded as test data. 30

A test to verify the ability of the two-phase venting system to accurately meter gas removed through the HPV and PORV was performed as part of the GERDA

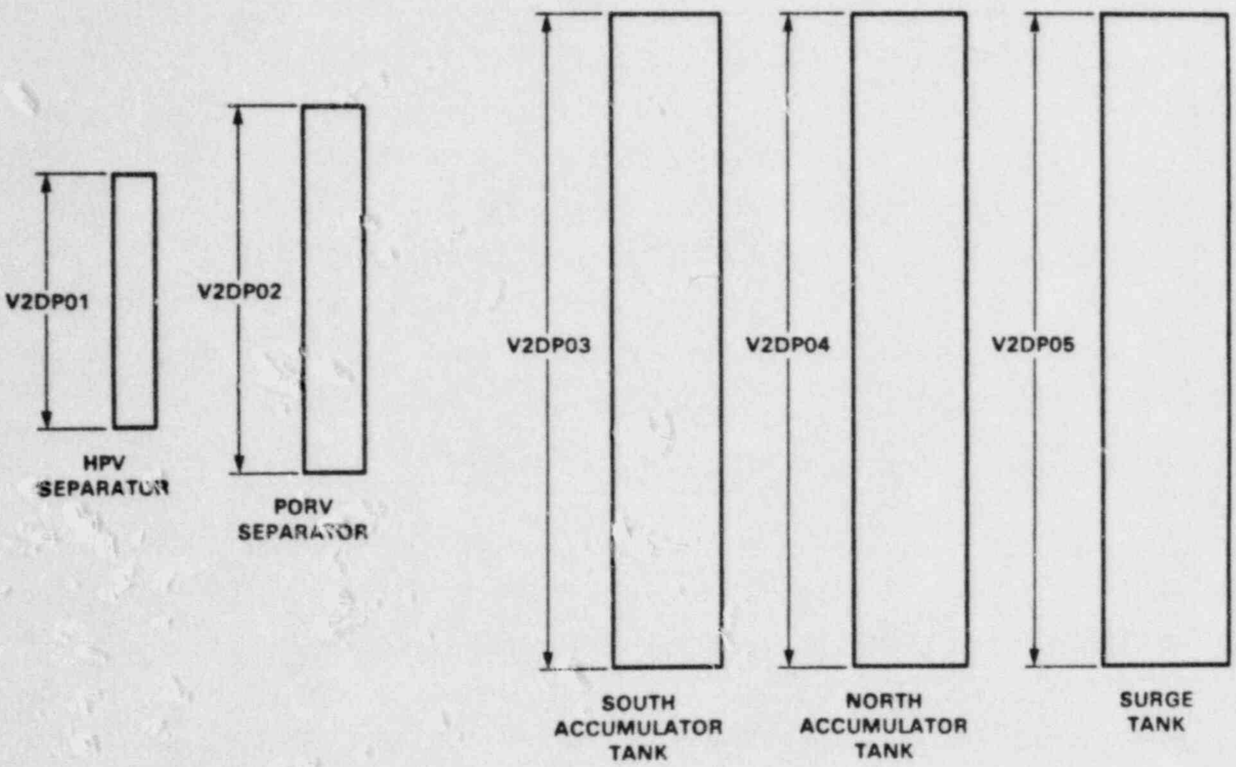


Figure 3-30 Two-Phase Venting System-Differential Pressure Measurements

program. This will be discussed in Section 4.3. The response time for the HPV and PORV flow control valves, V2CV01 through V2CV04 on Figure 3-28, was measured. The total time required for the valve to move close-to-open or open-to-close was less than one second.

3.8 SECONDARY FORCED CIRCULATION SYSTEM AND FEEDWATER HEATERS

The purpose of the secondary forced circulation system was to provide feed flow to the 19-tube OTSG at flow rates from approximately 0.2 to 2.5 gpm (represents plant scaled flow rate of 340 to 4210 gpm) and at supply pressures from approximately 100 to 1300 psia. To supply the desired flow rates and pressures, an existing Sundyne LMV-311 centrifugal pump was used. The Sundyne pump was rated at 27 gpm at a developed head of 1600 psia. The arrangement of the pump in the secondary forced circulation system is shown in Figure 3-31. This arrangement allowed proper operation of the pump by returning most of the flow back to the hot well while passing the desired flow to the steam generator. The flow split between the steam generator and the hot well was varied by positioning the pump discharge valve, SFCV01, the by-pass valve, SFCV02, and the flow control valve, SFCV03 or SFCV04.

The hot well was used as an accumulator tank for the secondary side of the loop. The hot well was located to provide the required net positive suction head (NPSH) for the Sundyne pump and was used to collect condensate from the condenser. Since most of the pump flow was by-passed back to the hot well, a system was required to remove the pump heat from the fluid in the hot well. This system will be discussed in Section 3.11. Chemical additions to the secondary loop were made into the hot well. A slight nitrogen overpressure was maintained on the hot well at all times.

A feedwater heater was included in the OTIS loop. This vessel was constructed using six (6) parallel and interconnecting 4" diameter pipes. A 20 KW electrical heater, Chromalox Model MTS3180AXX, was located in each of the interconnecting pipes. With the installed capacity of 120 KW, it would be possible to heat the feedwater from 100° to 500°F for flows up to 1.5 gpm. In the

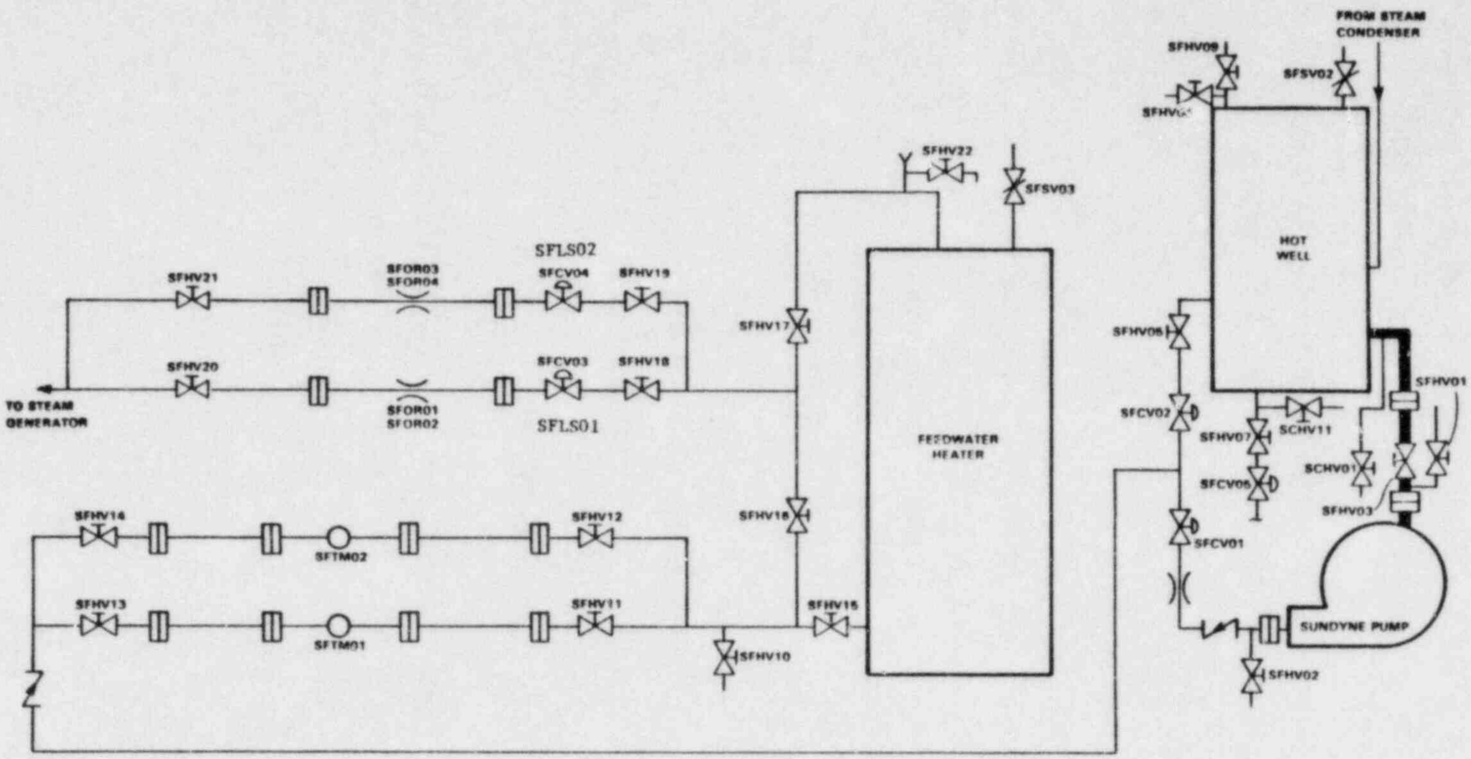


Figure 3-31 Secondary Forced Circulation System - General Arrangement and Test Instrumentation

OTIS test matrix, feedwater temperature was specified as about 100°F for all tests; consequently, the feedwater heaters were not used. Hand isolation valves were provided that allowed by-passing the feedwater heater.

Parallel flow control and flow measurement circuits provided for a high feedwater flow path and a low feedwater flow path. Each path contained a flow control valve and a flow orifice. The flow control valves were Annin Series 94 valves with flow coefficients, Cv, of 0.075 and 0.55 for the low and high flow path, respectively. These valves are identified in Figure 3-31 as SFCV03 and SFCV04. Each of these control valves was instrumented with a limit switch (SFLS01 and SFLS02) for positive indication of a closed valve. The flow orifices, manufactured by Fluidic Techniques Incorporated were installed downstream of the flow control valves in a flanged spool piece. The orifices had a bore diameter of 0.207 and 0.312 for the low and high flow orifices, respectively. The meters had corner taps for the differential pressure measurement. The calibration of these meters is discussed in Section 4.9.

High and low range turbine meters were installed in parallel flow paths, upstream of the feedwater heaters. These turbine meters were used as the standard for calibrating the steam and feedwater flowmeters. The details of this system are shown on B&W drawings 9501E, 9502E, and 9503E.

The test data instrumentation associated with the secondary forced circulation system included the ΔPs across the flow orifices. A high (0 - 100" H_2O) and low (0 - 20" H_2O) range ΔP was used on each orifice. The remaining instrumentation in this system was for loop operation and protection and was not recorded as test data.

For the domestic raised loop plants considered, i.e., Davis-Bessee (DB) and Tennessee Valley Authority (TVA), AFW flow is injected at a rate such that the steam generator secondary water level increases at a rate of not more than 3 feet per minute. In OTIS, the feedwater valve positions were determined so that the 3 feet per minute level increase was obtained at about 1000 psia. These valve positions are given in Table 3-9.

Table 3-9

FEEDWATER VALVE POSITION FOR 3 FEET PER MINUTE LEVEL INCREASE

Valve Designation	Valve Position (% Open)
SFCV01	93
SFCV02	55
SFCV03	60.5

During some of the OTIS tests, it was necessary to approximate the head-flow characteristic of the DB plant AFW pumps. The OTIS scaled AFW head-flow curve for the mentioned plant is illustrated in Figure 3-32. The feedwater valve positions were found at various pressures to approximate this head-flow curve. The positions are given in Table 3-10 for DB simulation.

Table 3-10

FEEDWATER VALVE POSITIONS FOR SIMULATING THE DAVIS-BESSEE AFW HEAD-FLOW CURVE

Pressure, psia	200	400	600	800	900	1000	1100	1200	1250	1300
Flowrate, lb/hr	900	900	900	893	803	691	554	392	281	108
SFCV01, % Open	93	93	93	93	93	93	93	93	93	93
SFCV02, % Open	55	55	55	55	55	55	55	55	55	55
SFCV03, % Open	71	74	80	89.5	88	84.5	79	65.5	55	30.5

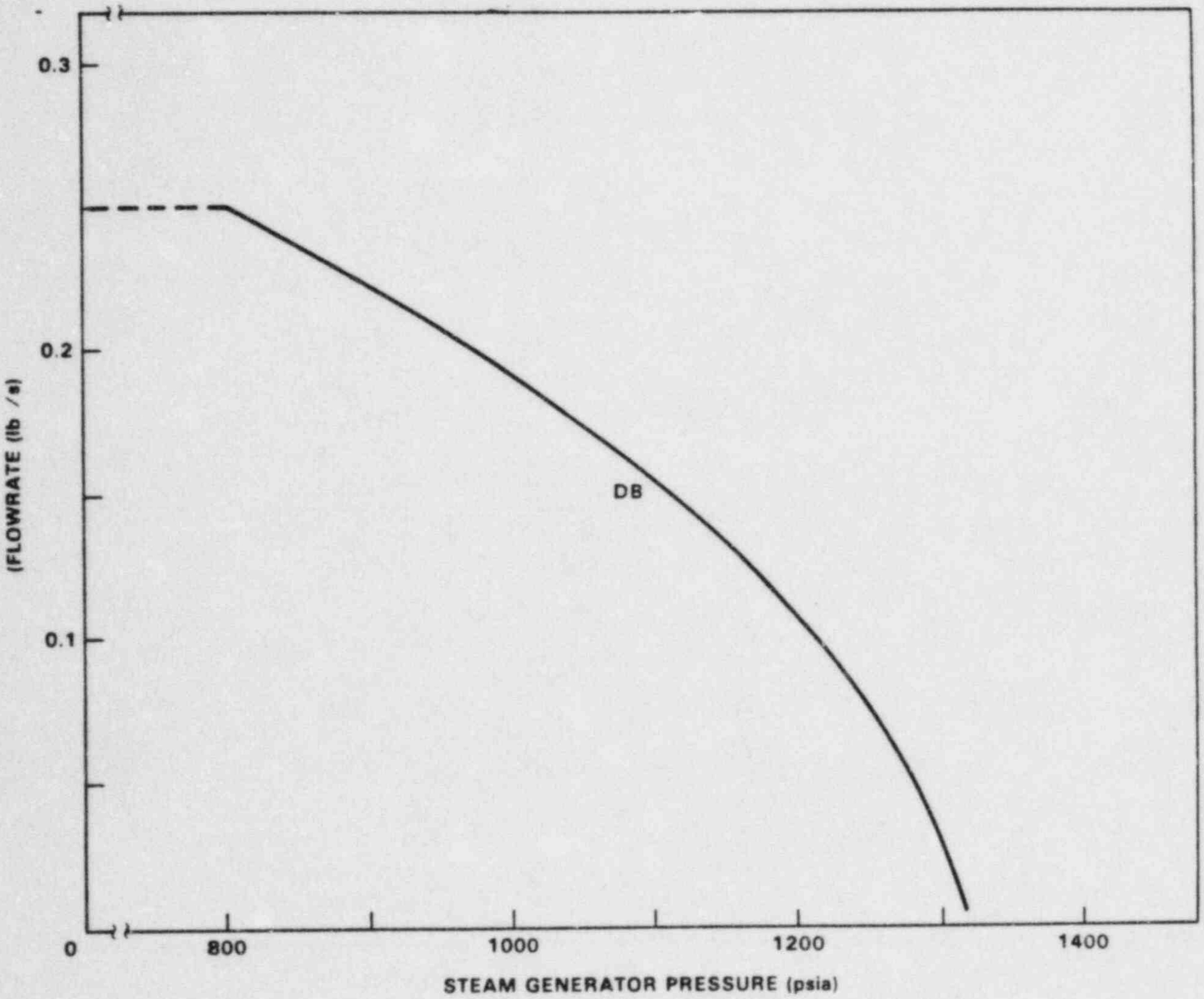


Figure 3-32 Auxiliary Feedwater (AFW) Scaled Head-Flow for the Davis Bessee Plant.

3.9 FEEDWATER PIPING

This system extended from just downstream of the feedwater flow measurements (in the secondary forced circulation system) to the feedwater injection locations on the steam generator. This is illustrated in Figure 3-33.

There were three (3) feedwater injection locations on the 19-tube OTSG; a high AFW location typical of that used on some 177FA OTSGs a low AFW location typical of that used on 205FA OTSGs, and an injection location just above the lower tubesheet. The two locations that simulated AFW injection were discussed in Section 3.3. These locations were used for testing. The inlet just above the tubesheet was used periodically to flush out the "dead leg" below the low AFW site. This inlet also served as a drain point for the steam generator.

The instrumentation associated with the feedwater piping included a Resistance Temperature Detector (RTD) in each line and a thermocouple upstream of the split (to the three locations). The feedwater lines were arranged so that one feed path could be selected while the other paths were isolated. A remotely actuated control valve, with a response time less than 1 second, and a manually operated valve were located in each line. The two lines simulating AFW injection supplied a header arrangement that allowed either maximum or minimum wetting of the steam generator tubes. This was discussed in Section 3.3. The details of the feedwater piping and this header are shown in B&W drawing 9550E.

3.10 STEAM PIPING

The steam piping system extended from the outlet of the steam generator to the piping upstream of the hot well. A schematic illustrating this system is shown in Figure 3-34.

Steam exited the steam generator at elevation 619-3/8" centered on a point on the hexagonal generator adjacent to tube "H". A cross-section of the generator at this elevation is illustrated in Figure 3-35. After leaving the steam generator, steam passed through either a low flow or high flow path for steam pressure control and flow measurement, through a water cooled condenser, through

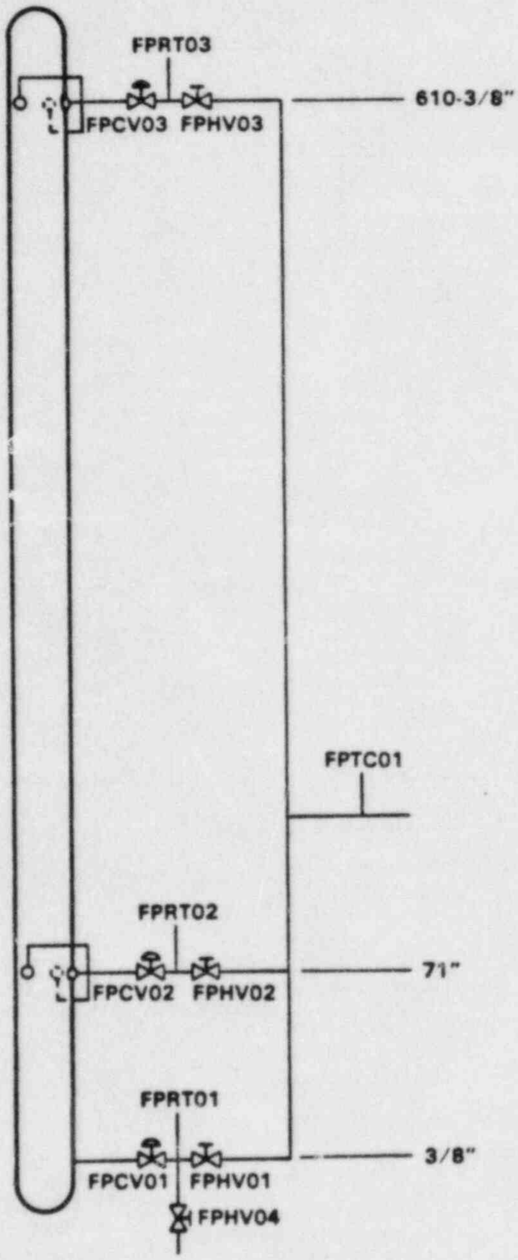


Figure 3-33 Feedwater Piping System - General Arrangement and Instrumentation

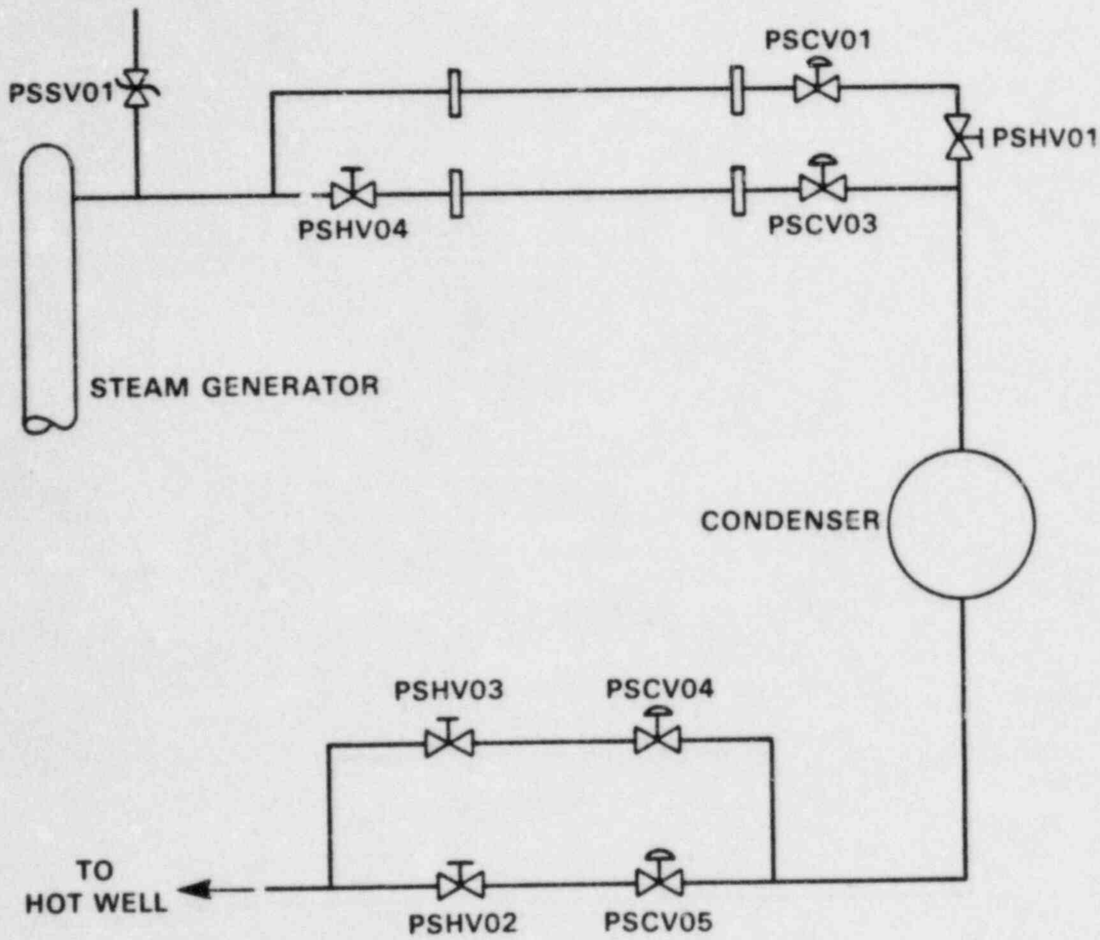


Figure 3-34 Steam Piping - General Arrangement

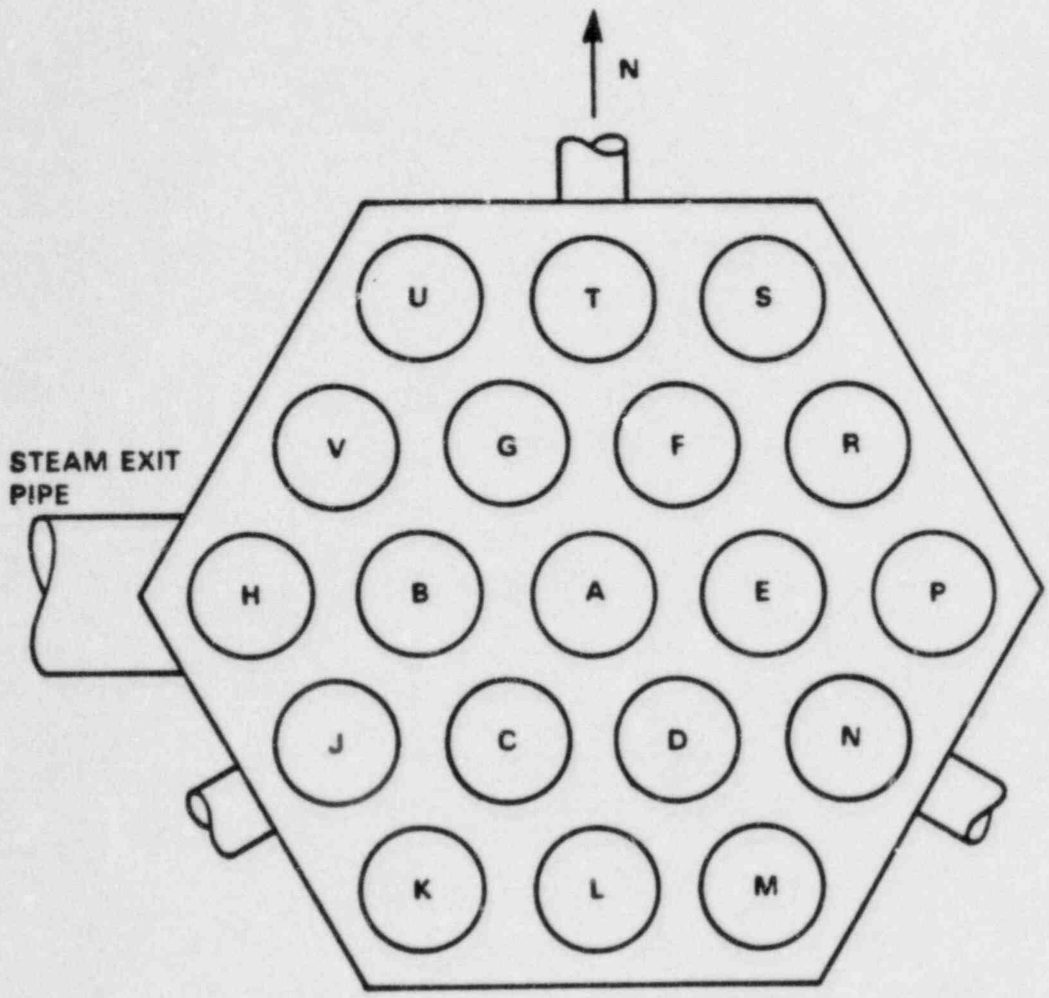


Figure 3-35 Location of Steam Exit Pipe on OTSG

either a low flow or high flow path condensate backpressure valve, and then to the hot well. The piping from the outlet of the generator to the hot well was 1" Schedule 80 carbon steel pipe.

Parallel steam pressure control and flow measurement was provided for a high and low steam flow path. The circuits were capable of measuring steam flows in the range of 100 to 1200 lb/hr (represents plant scaled flow rates of 0.17 to 2.02 x 10^6 lb/hr) over a range of pressures from 100 to 1300 psia. The high flow path steam pressure control valve, PSCV01, was a Fisher 1" DBQ with a 3/8" microform trim. The low flow path control valve, PSCV03, was an Annin Model 9460 with a 1.0 L (linear) trim. Each of these control valves was instrumented with a limit switch (PSLS01, PSLS02) for positive indication of a closed valve. A flow orifice, manufactured by Fluidic Techniques, Incorporated, was installed in each flow path. The low flow path orifice had a bore diameter of 0.296" while the high flow path bore diameter was 0.441". The steam meters utilized corner taps for the differential pressure measurement. The calibration of the steam flowmeters will be discussed in Section 4.9. The meters were installed in the steam pipe in a flanged spool piece section.

The response time of the steam pressure control valves to go close-to-open and open-to-close was measured during the GERDA program. The results are shown in Table 3-11. The delay time was the time from actuation until the stem began to move. Ramp time is the total time from actuation to full closed (or opened) position.

Table 3-11

STEAM CONTROL VALVES RESPONSE TIME

Valve Identification	Close to Open	Open to Close	Delay Time (Seconds)	Ramp Time (Seconds)
PSCV03		X	1.2	5.5
PSCV03	X		1.6	5.1
PSCV01		X	1.2	6.0
PSCV01	X		1.2	5.9

Note: Loop pressure was 25 psia, loop temperature was 90°F and instrument air pressure was 92 psi.

The steam condenser was a single pass, tube in shell, counterflow heat exchanger. Steam was on the tube side, inside a 1-1/2" Schedule 80 pipe, while shell side coolant was enclosed in a 3" Schedule 40 pipe. The heat exchanger was about 78' long with about 30 ft^2 of cooling surface available. The condenser was capable of removing about 335 kw of heat input. Tower water from the plant's main tower provided cooling water for the condenser. Downstream of the condenser were two Micropak 1" control valves (one for the high flow circuit and one for the low flow circuit). These valves were intended to backpressure the steam control valve and thereby extend the range for steam pressure control. The valves had a trim of 0.25 L and 0.04 L for the high and low flow circuits, respectively. Details of the steam piping system are shown on B&W drawings 9513E, 9514E, 9515E, and 9516E.

The instrumentation associated with the steam piping is shown in Figure 3-36. The measurements recorded as test data included the thermocouple and RTD just outside the steam generator, and the thermocouple in each flow measuring branch, steam pressure, and the differential pressure across the steam flowmeter. Dual range ΔPs were used for each steam flowmeter, a low range (0 - 125" H_2O) and a high range (0 - 500" H_2O). The other instrumentation shown in Figure 3-36 was used for loop operation and not recorded as test data.

Automatic control of steam pressure was available for either constant pressure control or pressure ramp control. For constant pressure control, the output from a pressure transmitter provided the signal to modulate the steam pressure control valve to the desired set point. The process line for steam pressure was located near the steam exit from the generator at elevation 619-3/8". During the course of a SBLOCA, the plant operator initiates loop cooldown by decreasing steam pressure at some rate. In OTIS, this steam pressure ramp control was simulated using a Leeds & Northrup 1300 Process Programmer. The cooldown rate was keyed into the programmer as a series of linear segments of pressure (saturation) and time. A test was conducted during the GERDA program that verified the operation of this controller for a 50°F per hour ramp from 700 to 200 psia.

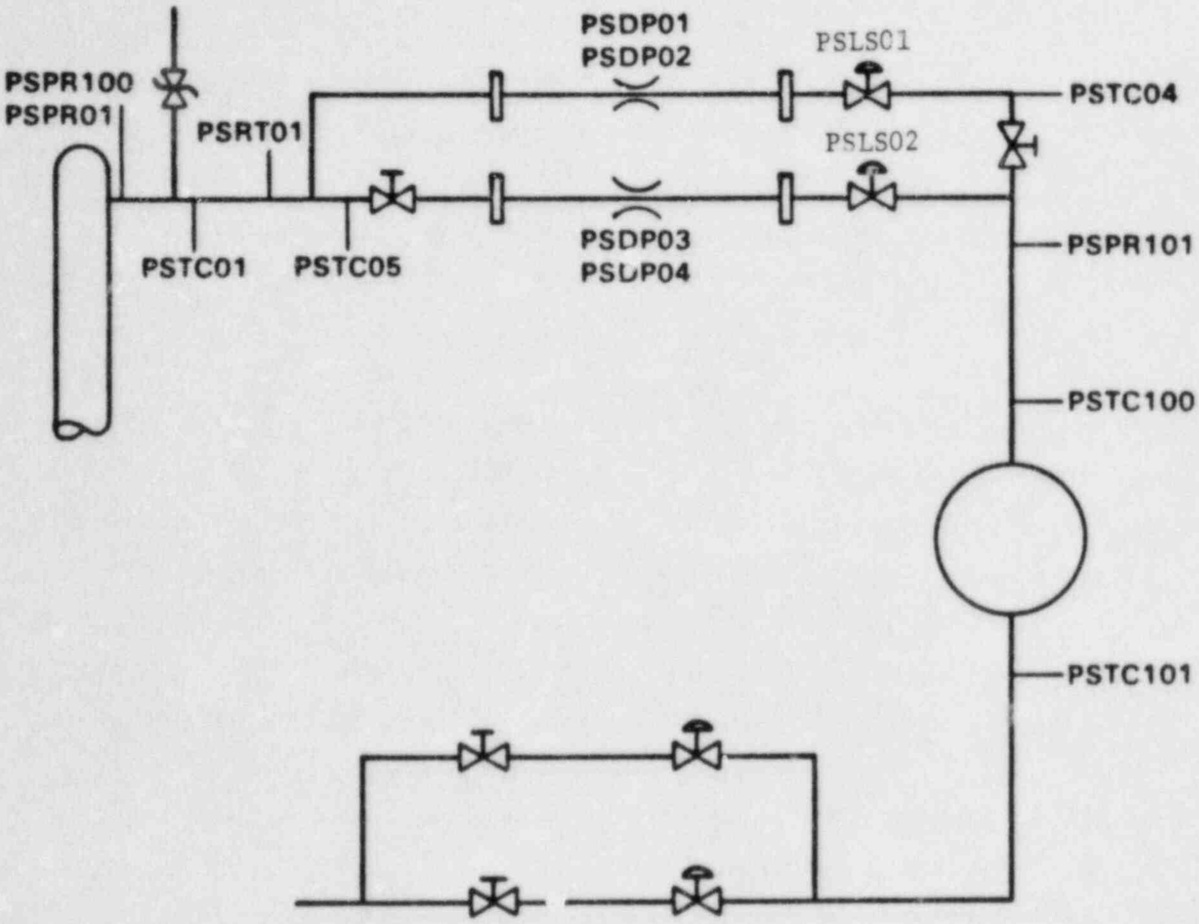


Figure 3-36 Steam Piping Instrumentation

3.11 SECONDARY LOW PRESSURE CLEAN-UP SYSTEM (SLPCUS)

The purpose of the Secondary Low Pressure Clean-up System (SLPCUS) was two-fold. One was to remove heat added to the secondary-side fluid by the main secondary forced circulation pump and the second was to remove suspended and dissolved contaminants from the secondary-side fluid. This was accomplished using the hardware and instrumentation shown on Figure 3-37.

The subsystem hardware was arranged so that a Worthington D512 pump takes suction from the hot well to provide a flow of approximately 20 gpm through a counterflow heat exchanger. The counterflow heat exchanger was sized to remove heat from the secondary fluid added by the secondary forced circulation pump. The heat exchanger was used to maintain the feedwater temperature less than or equal to 120°F.

Downstream of the heat exchanger the flow was split by valves SCHV04 and SCHV05 and either returned to the hot well or passed through the clean-up system. Approximately 4 gpm was passed on to the clean-up system while the remaining flow was returned to the hot well. The 4 gpm flow was directed through a CUNO 5 CD1 filter with a 5 micron filter cartridge to remove suspended contaminants and through a CUB S-300 demineralizer with NH_4OH resin to remove soluble contaminants. After passing through the demineralizer the flow was returned to the hot well.

All of the instrumentation shown on Figure 3-37 was required for loop operation. As such, the output from these instruments was monitored to insure proper operation of the system but was not recorded as test data.

3.12 NONCONDENSIBLE GAS ADDITION

The function of the noncondensible gas (NCG) addition system was to add a known quantity of NCG into the primary loop. The NCG was added as a batch addition.

Batch addition of a known quantity of NCG was performed by expanding the gas at an initial pressure and temperature from a known volume into the primary loop. A schematic of the NCG addition system is shown in Figure 3-38. The source of NCG

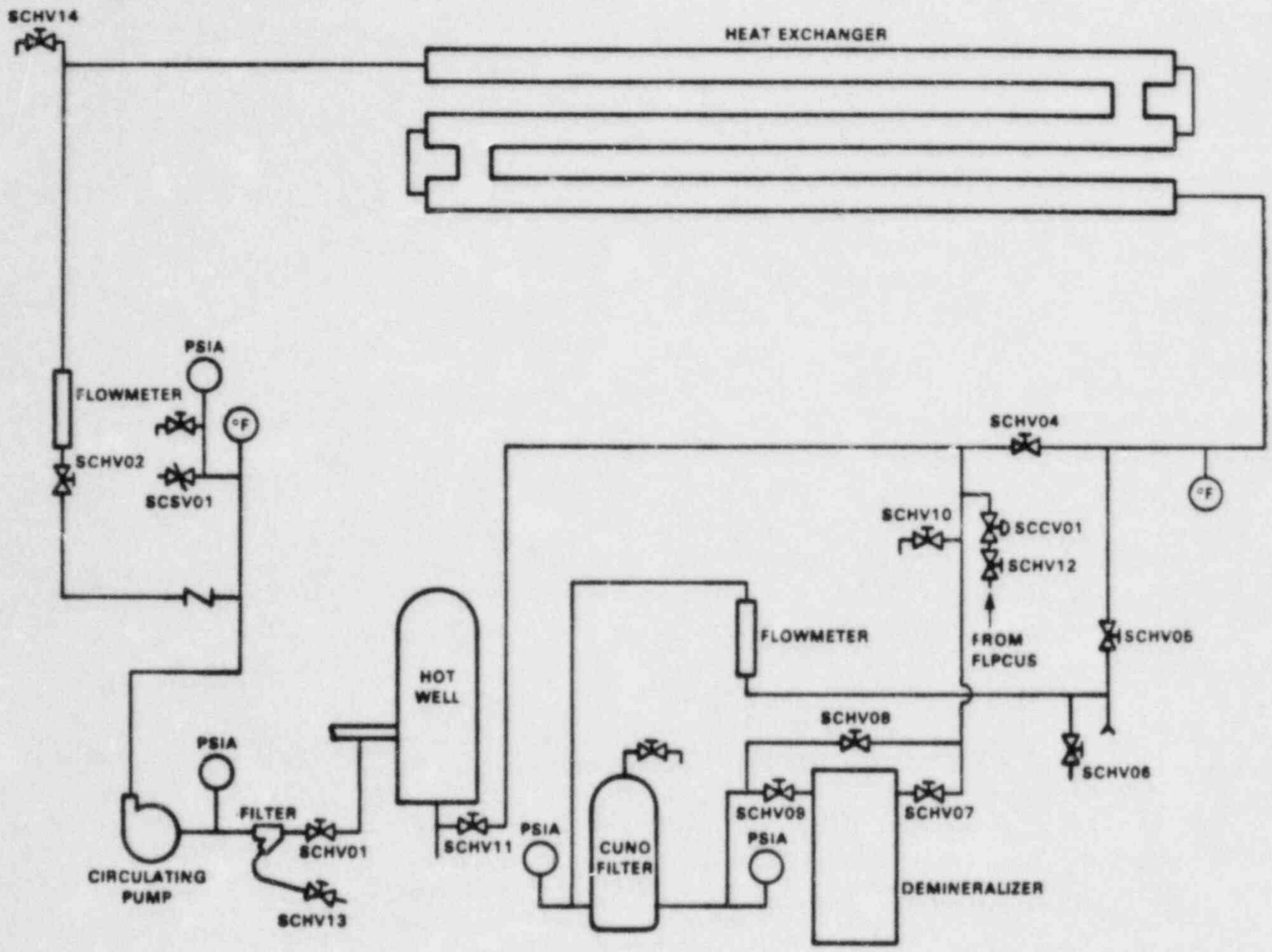


Figure 3-37 Secondary Low Pressure Clean-Up System General Arrangement and Instrumentation

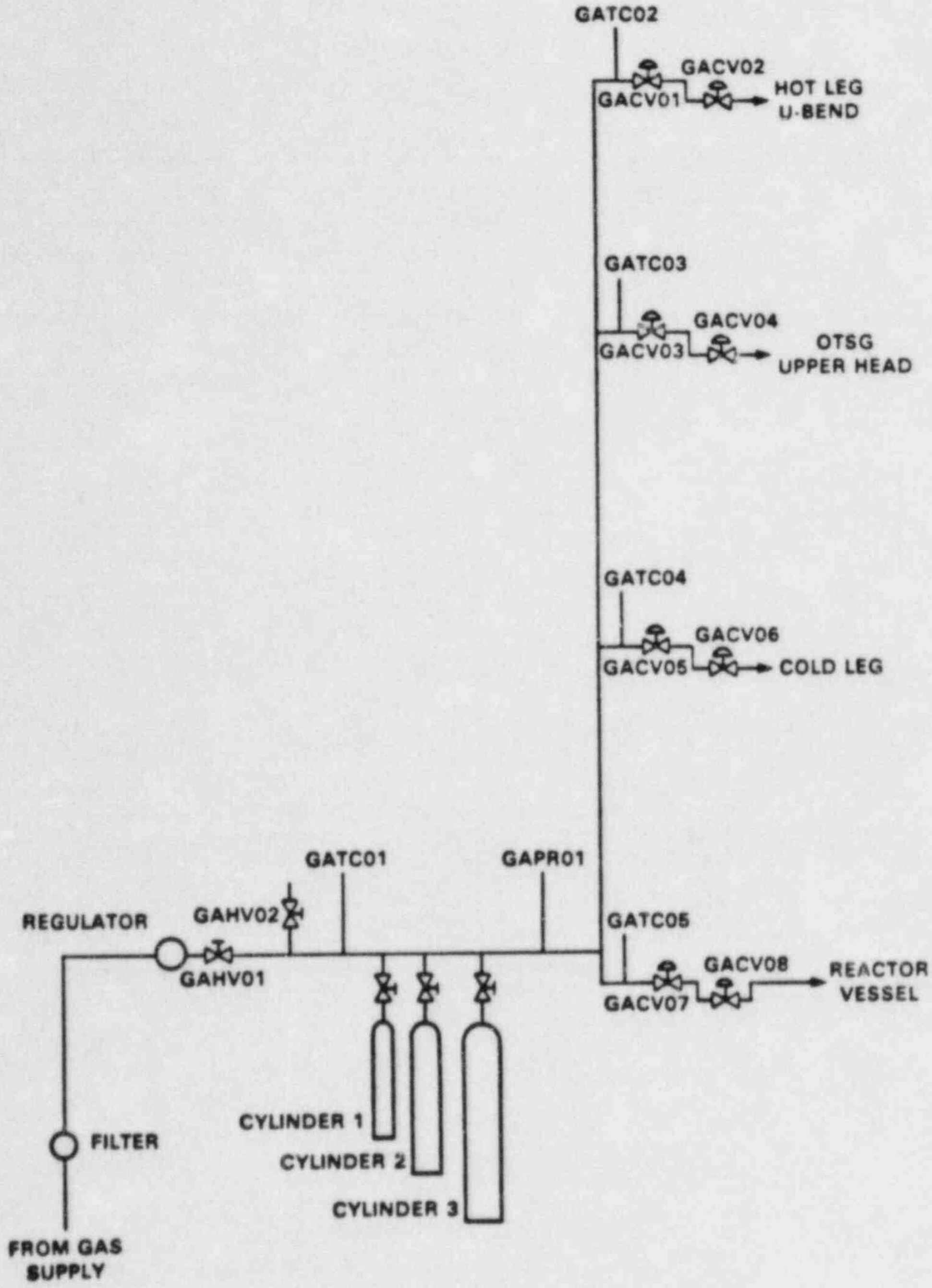


Figure 3-38 Gas Addition System - General Arrangement and Instrumentation

was a standard size 2500 psia gas bottle. Nitrogen (N_2) was used during OTIS testing. There were three reservoirs available for gas addition. One or more reservoirs were selected based on the quantity of gas to be added and the loop pressure. A computer program, GASADD, was used to select the appropriate reservoir(s) and/or tubing volumes and the initial pressure to which this volume should be pressurized to make the desired addition. The volume of the reservoirs and tubing is included in Table 3-12.

Table 3-12

GAS ADDITION RESERVOIR VOLUMES

Reservoir	Volume in^3
Tubing (T) only	40.14
T + cylinder 1	107.81
T + cylinder 2	177.24
T + cylinders 1 and 2	244.91
T + cylinder 3	394.92
T + cylinders 1 and 3	462.59
T + cylinders 2 and 3	532.02
T + cylinders 1, 2, and 3	599.69

Prior to adding gas to the loop, the gas supply was isolated, the active volumes and gas pressure were checked, then the gas was added through the appropriate isolation valves. There were two isolation valves, NUPRO "U" Series sealed stem bellows valves, at each gas addition location. These valves were remotely operated from the control room.

There were four locations in the primary loop where NCG could be added. They were:

- Lower plenum of the reactor vessel
- Cold leg piping, downstream of RCP spillover
- Top of steam generator
- Top of HLUB

These locations are illustrated in Figure 3-39.

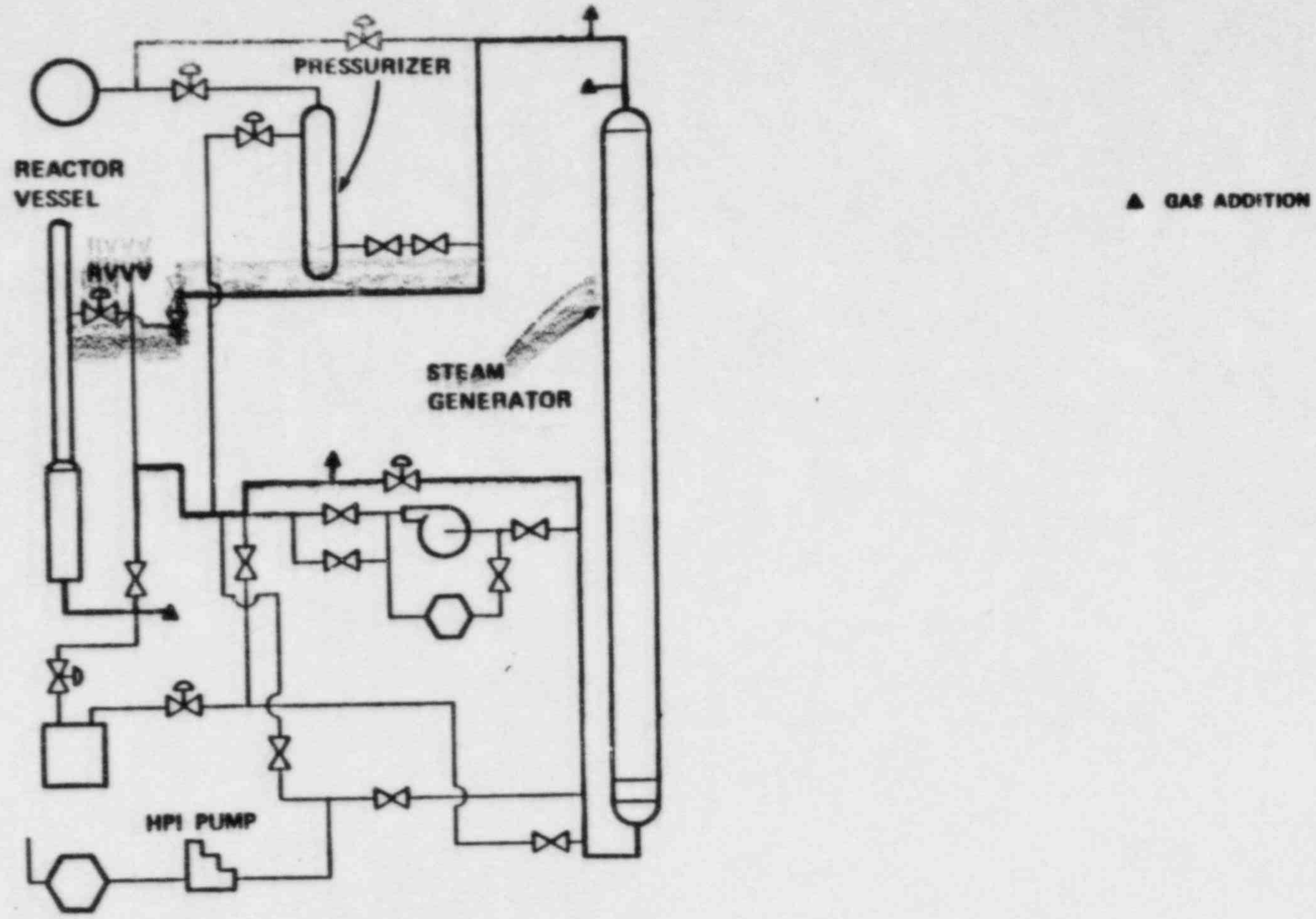


Figure 3-39 Gas Addition Locations

3.13 DATA ACQUISITION SYSTEM (DAS)

The OTIS facility had a Digital Equipment Corporation (DEC) PDP[6] 11/34 minicomputer and Analogic ANDS5400 data acquisition system dedicated to the facility for data acquisition and on-line data processing. A number of input/output devices were attached to the PDP 11/34 for user communication to the DAS and prompting of data display options. In addition, a DECnet[7] link from the PDP 11/34 to the existing VAX[6] PDP 11/780 computer at the Alliance Research Center was used for direct communications with this computer. The system architecture that make the OTIS DAS is shown in Figure 3-40.

An Analogic ANDS5400 was used to acquire analog voltage, digital, and frequency data from the test instrumentation. The architecture of the Analogic was such that analog voltages were input to one of three card types depending on the full scale range of the input. Analog inputs in the millivolt range to a maximum of 10.0 volts were digitized by the Analogic system. Sixteen bit, bipolar (hence, 15 bits plus sign) data acquisition rates of about 10,000 readings per second were obtained. Table 3-13 summarizes the Analogic's resolution and accuracy for three full scale DC voltage inputs.

Table 3-13

ACCURACY AND RESOLUTION OF THE ANALOGIC ANDS5400

Full Scale Input	Resolution (μv)	Accuracy	Typical Inputs
+/-40 mv	1.2	0.05%/20 μv	Thermocouple
+/-1.25 V	38	0.05%/625 μv	RTD
+/-10.0 V	305	0.05%/5.0 mv	Pressure and differential pressure transmitters, watt transducer, conductivity probe (analog)

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[6]PDP and VAX are trade names for families of DEC minicomputers.

[7]DECnet is a hardware/software communication link for interconnecting compatible computers.

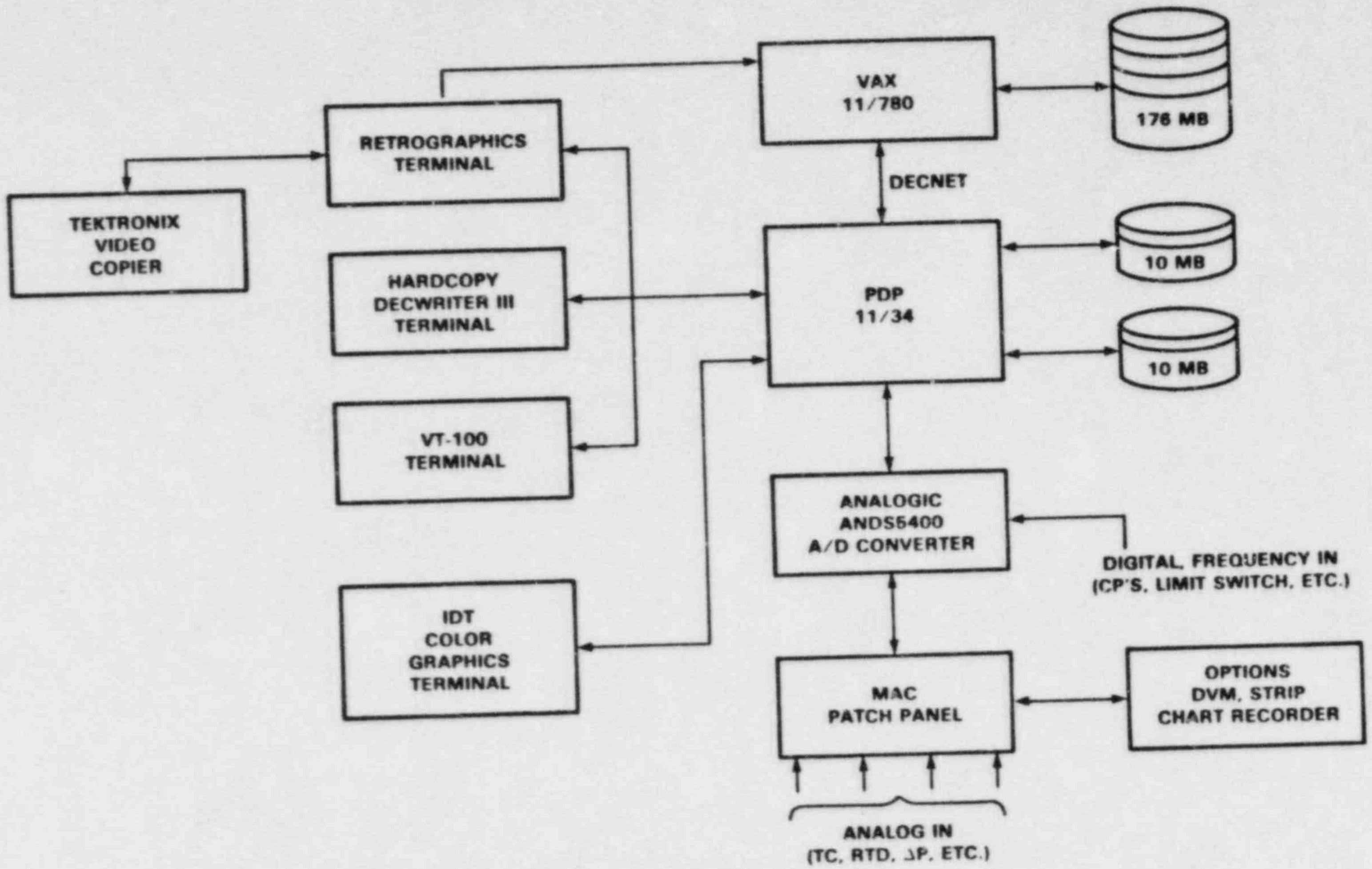

Figure 3-40 OTIS Data Acquisition System

The filter on each of the Analogic voltage input channels attenuated the amplitude of an analog voltage input such that an additional 0.05% full-scale input error was present at a frequency of 0.12 Hz. For analog voltage inputs with frequency contents greater than 0.12 Hz, the error caused by the filter increased to approximately 30% at 5 Hz.

Raw signal data from a thermocouple (HLTC08), a differential pressure transmitter (HLDP01), and a pressure transmitter (RVPR01) were recorded on magnetic tape as well as by the OTIS DAS for the first 1.5 hours of an OTIS test. The magnetic tape data was analyzed to:

- determine frequency content from OTIS instrumentation raw signal data,
- estimate the effect of the Analogic input filters on data acquisition, and
- evaluate the ability of the OTIS DAS sampling method to record SBLOCA phenomena of interest.

~~The detailed report is given in~~[8]. The analysis[8] showed that the transient data was tracked well by the OTIS DAS. Spectral analysis of the raw signal fluctuations showed that fluctuations were less than 5 to 10 Hz, and typically of low magnitude. Errors introduced through the filter characteristics of the Analogic and by sampling at OTIS DAS rates (0.2 Hz) were found to be negligibly small in most cases. It ~~is~~ was concluded that the application of the acquired OTIS data for code benchmarking exercises on a macro scale ~~does~~ did not warrent reducing the scan frequency to more accurately acquire the data on a micro scale.

Measurement accuracy of a frequency input (such as from a turbine meter) was conservatively set at +/-0.1 Hz for frequency inputs from 1 to 100 Hz and +/-0.1% of the reading for inputs of 100 to 5000 Hz. No error was associated with the input and handling of a digital input. Digital inputs resulted from limit switches and from the conductivity probes when first processed by the Creare

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[8]"OTIS Signal Analysis," RDD:84:4091-30-01:01, H.R. Carter to Distribution, September, 1984.

electronics and microprocessor Similarly, no error was associated with measuring the counts obtained from the output of the accumulating flowmeters at their output frequency during operation.

Calibration checks of the Analogic ANDS5400 were achieved by substituting a specially configured MAC patch panel in place of the panel used during test data acquisition. This panel wired all analog voltage input cards of the same full scale input in parallel so that a single connection of a calibration standard allowed the whole series of channels to be simultaneously checked. The calibration check was performed periodically, depending upon past history and stability of the Analogic.

Control of the Analogic DAS and data processing was through the PDP 11/34 minicomputer controlled under a real time (RSX-11M, Version 4) operating system. User software was written in Fortran IV Plus with software instructions stored in the 11/34 memory (256 K bytes) and/or on disk. Data in raw and/or engineering units was transferred to one of the two 10 mega-byte disks for temporary storage during data acquisition.

Between tests when data acquisition was not required the PDP 11/34 disk records were transferred over the DECnet to much larger disk drives (176 mega-bytes) on the VAX 11/780 computer for conversion to engineering unit data and permanent archival on tape. In addition, the VAX computer was connected to the computer center at UPGD via a telephone link and thereby provided a data transfer means to UPGD. The flow of data from the PDP 11/34 to UPGD will be discussed later in this section.

A MAC patch panel was used to provide a flexible interface between transducer inputs to the DAS and the Analogic and PDP 11/34. The MAC panel could interface up to 1088 3-wire connections. Because of the desired flexibility when routing input channels to the Analogic and the parallel capability to route any input channel to a secondary data acquisition device (such as a magnetic tape recorder, pen-type strip chart recorder, digital voltmeter, etc.), the actual capacity of the MAC panel was reduced to about 350 input channels.

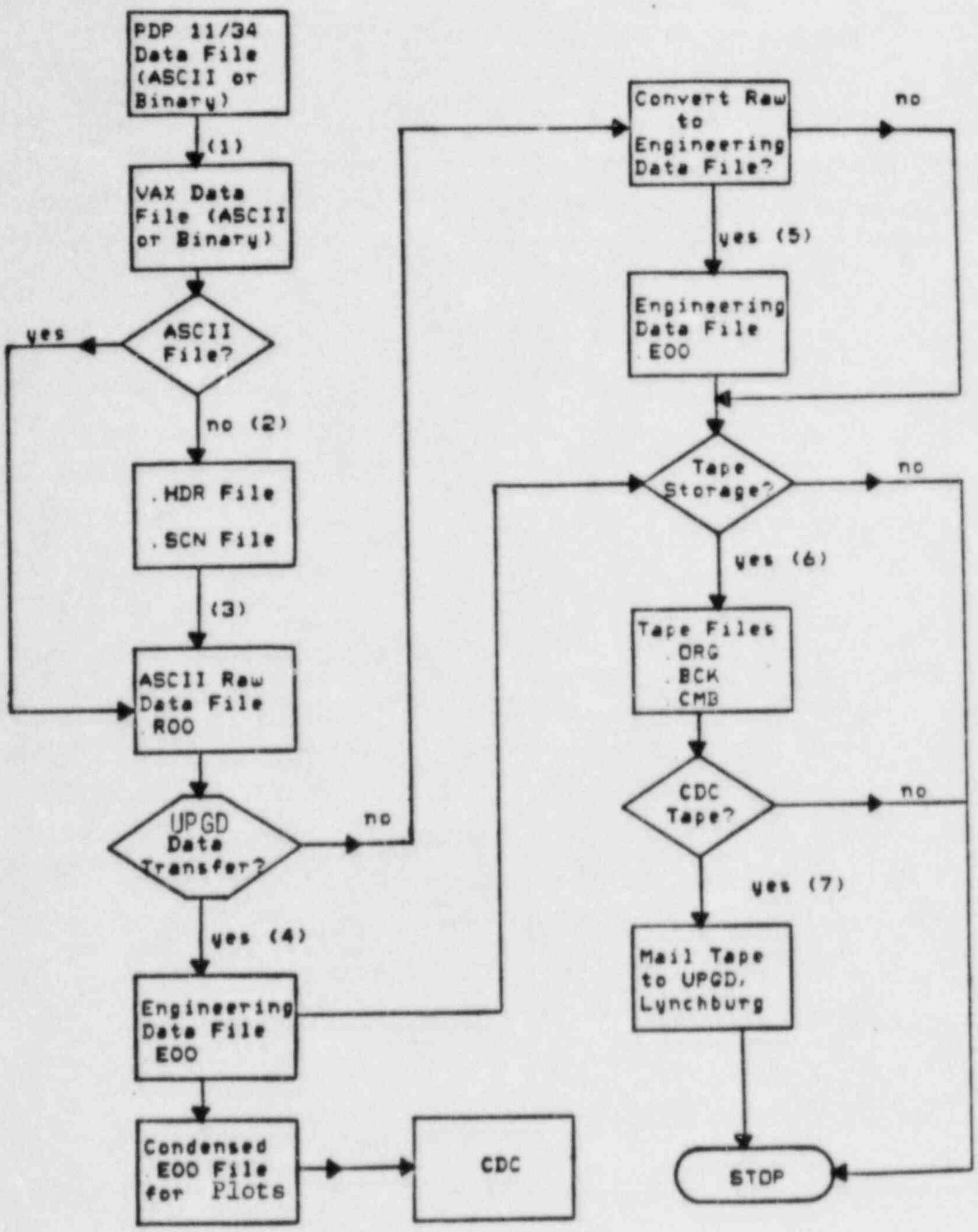
User communications with the PDP 11/34 and 11/780 computers were through the four terminal devices as shown on Figure 3-40. A DECWRITER III terminal was available for hardcopy listings of data, source listings, or system error messages from either the PDP 11/34 or the VAX 11/780. A VT-100 DEC terminal with the RETROGRAPHIC option was connected to the PDP 11/34 and VAX 11/780 computers and was used for software development and display of test data in graphical format during data acquisition. A second VT-100 DEC terminal was used to display test data and/or loop operating parameters. An Industrial Data Terminals (IDT) Model 2000 color graphics terminal was available for color graphic display of the OTIS test loop and selected test parameters during the test program. Color graphical displays of loop parameters such as the water level temperatures, pressures, flow rates, etc., provided important real-time visual feedback of the loop behavior during transient tests. The graphical displays of the RETROGRAPHICS terminal could be recorded in black and white hardcopy form using a TEKTRONIX Model 4632 video copier with enhanced grey scale.

Data acquired on the OTIS data acquisition system resided on the PDP 11/34 disk until the test engineer down-loaded the file to the VAX 11/780 computer for data processing and long term archival. Once on the VAX, additional manual operations were required to ultimately transfer the converted engineering data file to UPGD, Lynchburg, and to archive the data to magnetic tape. In Section 3.13.1 the commands necessary to trace the path of data processing from the PDP 11/34 to the VAX 11/780 with ultimate data transfer to UPGD and data archival to tape will be described. In addition, the routines available for data file revisions or updates and subsequent data processing are defined.

3.13.1 Initial Data File Processing

The initial flow of the data file strictly involved its acquisition and processing to transmit a condensed part of the engineering data file to UPGD for issuance of the Initial Report plots. Once processed at Alliance, the raw and converted engineering data files were archived to magnetic tape for long term storage.

A flowchart illustrating the processing steps for a raw data file is shown on Figure 3-41. A discussion of this flowchart and the routines available at ARC are



(#) # enclosed in parentheses refers to VAX command procedures that are discussed in the accompanying text.

Figure 3-41 Initial Processing of OTIS Raw Data File defined below. Numbers enclosed by parentheses on the flowchart correspond to VAX command procedure data processing routines and are referenced in the following text using the same nomenclature, i.e., the number enclosed in parentheses.

(1) The data acquired on the PDP 11/34 was transferred to the VAX 11/780 using a Digital Equipment Corporation (DEC) file transfer routine called DECnet. The PDP user manually installed the DECnet transfer routines on the PDP by issuing the command @[1,2]NETSTART. Once loaded, the data file could either be sent to VAX while logged on the VAX or logged on the PDP. If logged on the VAX the following command resulted in transfer of the data file:

COPY SBLOCA"SYSTEM SYSTEM"::DL1:[PDP ACC'NT] PDP EXT VAX.EXT

If the user was logged on the PDP and wished to perform the transfer to the VAX from the PDP, the following command was required:

NFT>VAX/USERNAME/PASSWORD//::VAX.EXT=PDP.EXT

The transferred raw data file could be either in binary or ASCII format
(2) at this time depending upon how data save took place as defined by the test engineer. If the file was saved in binary, then two operations must have taken place to convert it to an ASCII format. First, the file was operated on using either the VAX command procedure DAYASC or NITASC depending upon whether day batch or night batch processing, respectively, was required. These routines translated the binary file to ASCII and "split" the raw data file into two parts -- a header section consisting of the legend and VTAB list, and the data portion for each time scan. In so doing, any additional comments to the legend that need to be included to document the completed test prior to its distribution to UPGD could be included at this time. The header section was small enough that the VAX editor can easily be used to add any comments. This was important because with large files it was not possible to edit the header without first separating the header from the remaining data
(3) scans. The second step combined the ASCII header and data scan parts into a single file. Execution of either the command procedure DAYCOP or

NITCOP (depending upon whether day or night batch processing was desired) merged the two files into the single ASCII raw data file. As indicated on the Figure 3-40 flowchart, this raw data file was denoted ".R00", the "R" denoting the "raw" data file and the "00" indicating revision 0 of the file.

(4) To begin the process of making plots for the Initial Reports, the user manually invoked the execution of the command procedure, DATRNS or NITRNS, once again depending upon whether day or night batch data processing was required. This command procedure caused the conversion of selected raw data file scans to their corresponding engineering data file (denoted ".E00" on the flowchart) scans. Raw data scans to be converted to engineering unit scans were selected based upon a user predefined list of significant events during the test transient and corresponding data conversion time steps for each event. If this sorted engineering data file contained more than 260 time scans (the maximum allowed for UPGD plots), then an additional sort took place prior to data transmission to UPGD that limited the data file to 260 scans. In addition, this data file contained only those VTABs previously defined by UPGD as needed for the Initial Report data analysis and presentation. Hence, the data file contained only a portion of the data base VTABs and a maximum of 260 time scans.

(5) In the event that electronic data transfer to UPGD was not desired but the converted engineering data file was still required at ARC, a number of conversion routines were available at ARC to create the engineering data file and provided additional listings of the legend part of the data file and/or a listing of the entire header (legend plus VTAB listing). This conversion was accomplished by executing a VAX command procedure depending upon the information desired and the mode of data processing -- real time, day batch, or night batch. In Table 3-14 these command procedures and their options are summarized.

Table 3-14

COMMAND PROCEDURES FOR ENGINEERING DATA FILES

Command Procedure	Batch	Legend and Chrono Files	Data to UPGD
CNVRE	no - real time	no	no
CNVRT	no - real time	yes	no
BCNVRT	yes - day batch	yes	no
NCNVRT	yes - night batch	yes	no
DATRNS	yes - day batch	yes	yes
NITRNS	yes - night batch	yes	yes

At this time, two data files were resident on the VAX computer, a raw data file, ".ROO", and an engineering data file, ".EOO". These files were stored to tape using command procedures on the VAX. The original (6) raw data file, ".ROO", was saved to tape by executing the command procedure ORIGIN. A backup copy of the raw data file was created by running procedure BACKUP. Finally, the raw data file and engineering data file were saved as pairs on a tape by executing the command procedure COMBIN. These three steps created the data tapes ".ORG", ".BCK", and ".CMB", respectively, as shown on the flowchart. As indicated, three copies existed of the original version of the raw data file, ".ROO".

In the follow-up to the electronic data transfer for the Initial Report (7) the complete engineering data file created at ARC was copied to a CDC compatible tape at ARC and mailed to UPGD, Lynchburg. This tape was created using the VAX command procedure ENGR.

3.13.2 Post Processing of the Data File

After processing and transmitting the data file for the Initial Report, modifications to the data base were needed to remove or correct deficiencies to the data base files. Additional comments to the data file legend and corrections to the data file VTAB listing were required. After implementing these corrections the revised raw data file was converted to engineering units and the engineering data tape mailed to UPGD. The flowchart shown by Figure 3-42 traces the steps required for file handling and the VAX command procedures needed to implement each.

The original raw data file (or most recent revision) was migrated from tape back to the VAX disk. If the raw data file was too large for use of the VAX editor and available user disk space, the user executed the

(1) command procedure DSPLIT or NSPLIT (day or night batch, respectively). These routines operated on the ASCII raw data file and split it into a header portion and a data scan portion. The user could then easily operate on the header portion with the VAX editor -- making the needed additions to the legend and corrections to the VTAB parameters. After

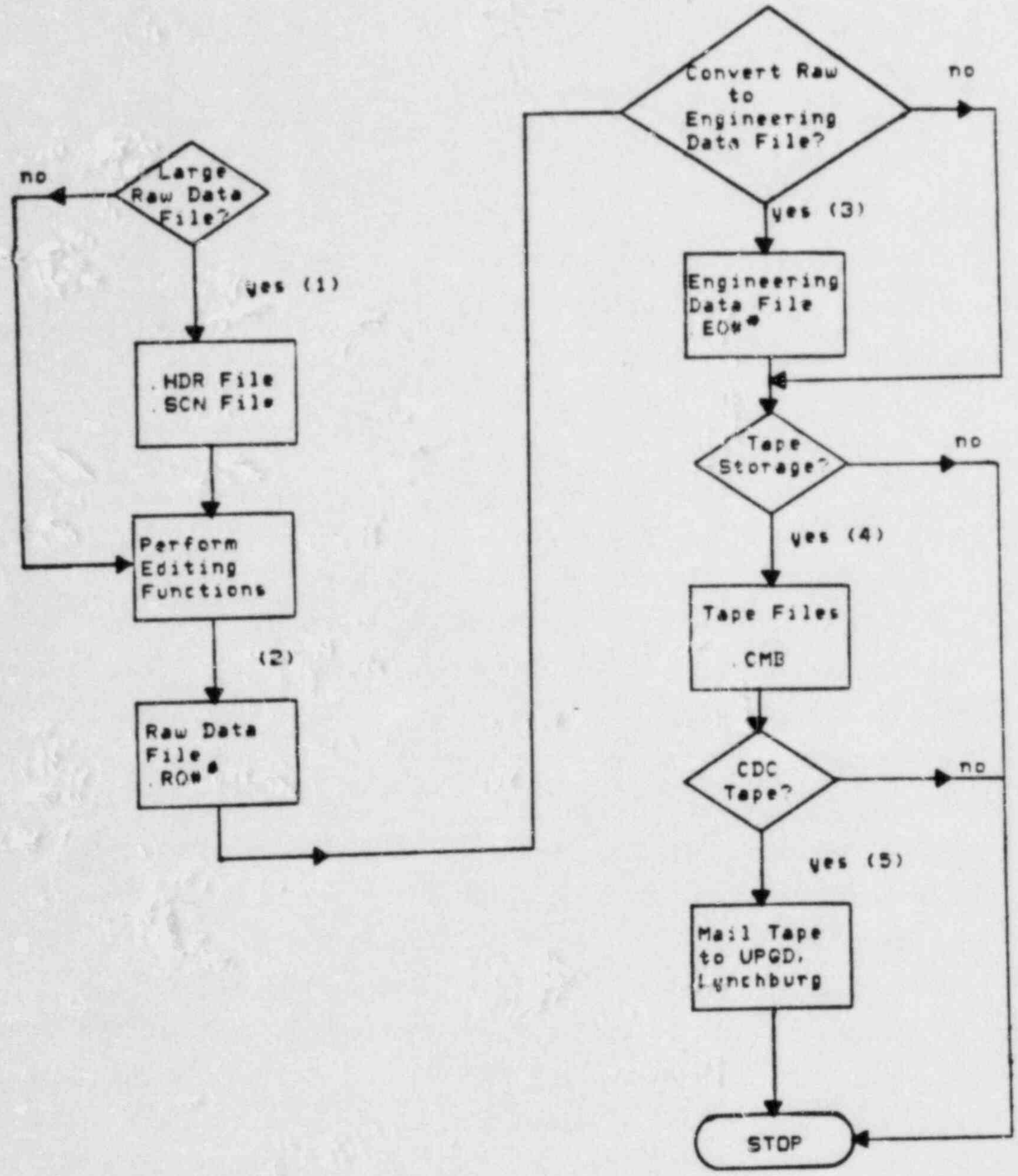
(2) completing the revision to the header file the two were combined to a single revised raw data file by executing the command procedure DAYCOP or NITCOP, described previously. The resulting raw data file is denoted on the flowchart as ".RO#", where the # symbol refers to the raw data file revision number.

With the revised raw data file complete, conversion to the corresponding

(3) engineering data file, ".EO#", was achieved using one of the command procedures previously defined -- CNVRE, CNVRT, BCNVRT, or NCNVRT. Note that neither DATRNS nor NITRNS were used since electronic transfer of data to UPGD was not performed for the revised data files.

(4) The revised raw and engineering data files were archived to tape using the command procedure COMBIN. Backup of the revised data files were periodically performed using VAX system commands to duplicate the magnetic tape.

(5) The complete engineering data file could then be copied to a CDC compatible tape at ARC and mailed to UPGD, Lynchburg, Virginia. This tape was created using the VAX command procedure ENGR.



* # denotes the revision number of the file.

(#) # enclosed in parentheses refers to VAX command procedures that are discussed in the accompanying text

Figure 3-42 Follow-Up Processing of OTIS Raw Data File

Additional information and listings of the command procedures and Fortran source code defining the routines referenced in this document can be found in the QA documents listed in Table 3-15.

3.13.3 User Input For Definition of the OTIS VTABLE Database

The database for the OTIS data acquisition system was designed so the user could define all parameters needed to couple each of the user defined table entries (VTABs) to the available options in the data acquisition software. This information was stored on disk in account DLO: [201,10] with the file name, VTABLE.DAT.

The VTAB generally corresponded to an instrument such as a thermocouple pressure transmitter, conductivity probe, etc. However, the VTAB may have referred to a "non-instrument entry" desired by the user to more appropriately define the output of the instrument. For examp an orifice used for flow measurement was monitored by a differential pressure transmitter that measures the pressure differential across the orifice. It was necessary for the data acquisition system to measure and record this differential pressure but it was also convenient for the operator to have an on-line indication of the flow rate based on this measured differential pressure. The OTIS data acquisition software allowed the user to define a second VTAB which contained the necessary conversion constants and reference VTABs (or instruments) to compute the flow rate through the orifice. This flow rate remained in memory until the next data acquisition cycle. Hence, any on-line calculation for the current data acquisition cycle would have this flow rate available without the need to recompute the flow. This flow rate was also present in the off-line data base for distribution to users outside of ARC.

Table 3-15

QA DOCUMENTS FOR SOURCE CODES AND COMMAND PROCEDURES

Routine	QA Document
DAYASC	QA0102.000
NITASC	
DAYCOP	
NITCOP	
DSPLIT	QA0103.000
NSPLIT	
CNVRE	QA0100.000
CNVRT	
BCNVRT	
NCNVRT	
DATRNS	
NITRNS	
Details Defining the Conversion from Raw to Engineering Units	QA0097.001
ORIGIN	QA0101.000
BACKUP	
COMBIN	
ENGR	

With this introduction, the following options required user input for each VTAB and are summarized below.

- Global definition to the data acquisition software regarding the status of a VTAB, i.e., in or out of service, use for loop alarm indications to the operator, or use for control of the time interval between data acquisition scans.

- Identification of a VTAB for alarm monitoring and the parameters required to define the low and high alarm values, and alarm deadband.

- Identification of a VTAB for rate control of the data acquisition hardware, i.e., based on the rate of change of a VTAB raw data signal or engineering value, the time interval between data acquisition scans is either increased or decreased.

- Definition of the ANALOGIC ANDS5400 "card" (analog, counter-timer, or digital input) and ANALOGIC channel associated with the VTAB.

- Conversion of the raw data signal (voltage, frequency, digital input, count, etc.) to the appropriate value in engineering format or units. This operation requires the following user defined information:

  - Calibration constants and material or test loop geometry constants needed to perform the raw data signal to engineering format conversion.

  - Reference VTABs (or instrument readings in this case) needed to perform the raw data signal to engineering format conversion.

- Definition of the "units descriptor" (ex., DEG F, PSI, LBM/HR) associated with the converted engineering value for each VTAB.

- Definition of the number of significant decimal places that will be associated with the converted raw data signal to engineering value.

- Descriptor associated with each VTAB for user ease in identification of the VTAB.

The parameter order and format for each of the VTAB data cards is contained in Appendix D.

4.0 LOOP CHARACTERIZATION TESTS

The purpose of the loop characterization tests was to debug the mechanical and electrical components, to characterize the operation of important loop systems (such as high pressure injection, guard heaters, etc.) and to calibrate in-place selected instrumentation. For reference, the results of the GERDA Phase 0 tests are documented here as well as in the final revision of the GERDA Loop Functional Specification (RDD:84:5168-01-01:01). The six (6) major test categories, along with the section of this report in which the results are contained, are identified in Table 4-1. A list of the test runs recorded during GERDA and OTIS Phase 0 is included as Appendix E.

4.1 HELIUM LEAK TEST

Tests were completed during the GERDA program to determine the extent of noncondensible gas (NCG) leakage from the primary natural circulation loop. The loop was drained under a helium blanket until the water level was about 72" above the secondary face of the lower tubesheet (SFLTS). This is approximately the elevation of the top of the reactor vessel. The helium pressure was increased to about 1000 psia. Based on the pressure decay with time, a leak rate of about 10^{-2} cc/sec was calculated.

A Matheson gas detector was used to "sniff" around the gas region of the loop to identify where the leakage was occurring. Leakage that produced a full scale deflection of the gas detector, 8×10^{-4} cc/sec ($\sim 1 \times 10^{-4}$ FT^3/HR) or greater, was noted at the following locations:

- hot leg U-bend (HLUB) view port windows both on the north and south side
- conductivity probes, HLCP12 and HLCP04, at the Conax fitting
- hot leg isolation valve, RVHV02[9]

[9] This valve was not present for OTIS testing.

Table 4-1

LOOP CHARACTERIZATION TEST CATEGORIES

CATEGORY		REPORT SECTION CONTAINING RESULTS
I.	DEBUG AND CHECKOUT	
I.1	Component, Instrument, and Control Operation	Not applicable
II.	COMPONENT TESTS	
II.1	Feedwater and Steam Flowmeter Calibration	4.9
II.2	Steam Generator Volume	3.0, 4.12
II.3.A	Discharge Orifices - Vapor and Liquid Region	4.2
II.3.B	Venting with Noncondensible Gas (NCG) - Pilot-Operated Relief Valve (PORV) Site	4.3
III.	COLD LOOP	
III.1	Leakage	4.1
III.2	Primary Volume	3.0, 4.12
III.3.A	Filled NCG	4.10
III.3.B	Valve Response - Cold	3.1,3.9,3.10
III.4	Primary Flow - Cold	4.8
IV.	HEATED LOOP	
IV.2.A	Primary Flow - Hot, Low Flow	4.8
IV.2.B	Heat Loss, Guard Heating, Stored Energy	4.5, 4.6, 4.7
IV.3	Temperatures	4.11
V.	STEAMING (FORCED FLOW)	
V.1	Cooldown	3.10
VI.	ABNORMAL CONFIGURATIONS	
VI.1.B	HPI Head-Flow Curve, LPI Simulation	3.6
VI.2	Reactor Vessel Vent Valve (RVVV) Head-Flow Curve	3.1
VI.3	Reversed Primary Flow	4.4
VI.4.A	Level Indication with Condensation and Guard Heating in a Vapor Region	4.7
VI.4.B	Venting with NCG - High Point Vent (HPV)	4.3

- reactor vessel vent valve, RVCV01

To get a feel how leak tight the loop was, consider how long it would take for helium to escape assuming that:

- The measured leakage all occurred in the hot leg U-bend (HLUB) and the hot leg stub.
  (Volume = .65 FT^3)

- The HLUB and hot leg stub was filled with a 4% volumetric concentration. (Note, a 4% concentration was required in the single tube test[10] to elevate the primary pressure to greater than 2000 psia from an initial pressure of about 900 psia.)
  (Volume He - .026 FT^3 = 736.32 cc)

The time required for the helium to escape would be 66,938 seconds (18.6 hours) at 1000 psi system pressure. Based on these results it was concluded that the loop was leak tight enough to allow testing with NCG's, including helium.

4.2 DISCHARGE ORIFICES - VAPOR AND LIQUID REGION

Scaled leaks up to 77 cm^2 were tested in GERDA. Leaks of 5, 10, 20 and 40 cm^2 were tested in the liquid region (cold leg suction, cold leg discharge, bottom of reactor vessel), and 3, 10, and 77 cm^2 were tested in the vapor region (Hot Leg HPV and PORV).

To characterize the flow for each orifice size up to 40 cm^2, the critical flow rate was measured at pressures of approximately 1000 and 2000 psia for both the liquid and vapor region orifices. Two 5, 10, 20, and 40 cm^2 orifices were calibrated at these pressures in saturated water, and two 3, and 10 cm^2 orifices were calibrated at the same pressures in saturated vapor. These calibrations

[10] Condensation Heat Transfer Inside An Alloy 600 Once-Through Steam Generator (OTSG) Tube, LR:81:2987-07:01, G. C. Rush to J. R. Gloudemans, November 9, 1983.

were performed in the Steam Generator Test Facility (SGTF) pressurizer.[11] ~~The detailed test data for these calibrations is contained in[11].~~

The calibration test results are summarized on Figure 4-1 and Table 4-2. As shown by Figure 4-1, the steam phase critical flows compared well with the predictions of Fauske, Moody, and HEM. For the liquid phase orifices, the measured critical flows were approximately 1-3% greater than predicted by Fauske.

Figure 4-2 illustrates that as subcooling is reduced the critical flow is reduced until the fluid temperature reaches saturation. The flow measured at this plateau was taken as the saturated water critical flow and presented on Figure 4-1 and Table 4-2. The remaining data on Figure 4-2 was generated by increasing the pressure loss upstream of the leak orifice. The increased pressure drop caused the fluid at the orifice inlet to become two-phase. This resulted in a step-change reduction in the measured flow. The flow change (as noted during several orifice tests) was reversible and repeatable.

The critical flow rate for a 77 cm^2 steam phase orifice installed at the GERDA PORV site was also measured.[12] The PORV was opened for about 15 seconds at pressures of 1900, 1700, and 1550 psia, and the vented vapor was measured. The critical flow rate measured compared well with Moody predictions. ~~The detailed results of this test are included in[12].~~

For the OTIS testing, a scaled 15 cm^2 leak control orifice was also used. No characterization tests were performed for this orifice. Interpolation of GERDA leak orifice data was sufficient to characterize this orifice.

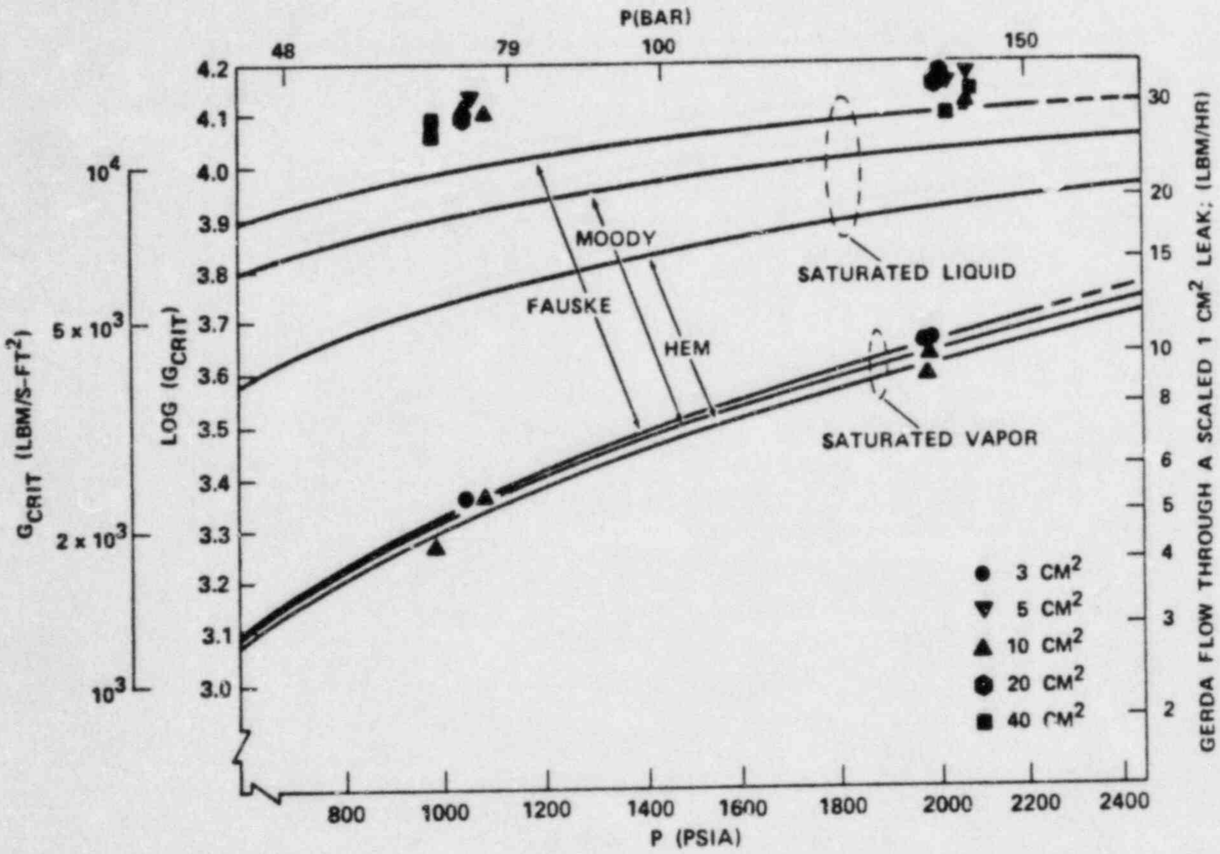
[11] Letter from H.R. Carter to J.R. Gloudemans, Calibration of Leak Flow Orifices, SBLOCA-794, September 27, 1982.

[12] Letter from G.C. Rush to H.R. Carter and J.R. Gloudemans, Test 009910, Venting Through the Pressurizer Relief Valve Without Noncondensibles, SBLOCA-810, October 14, 1982.

Table 4-2

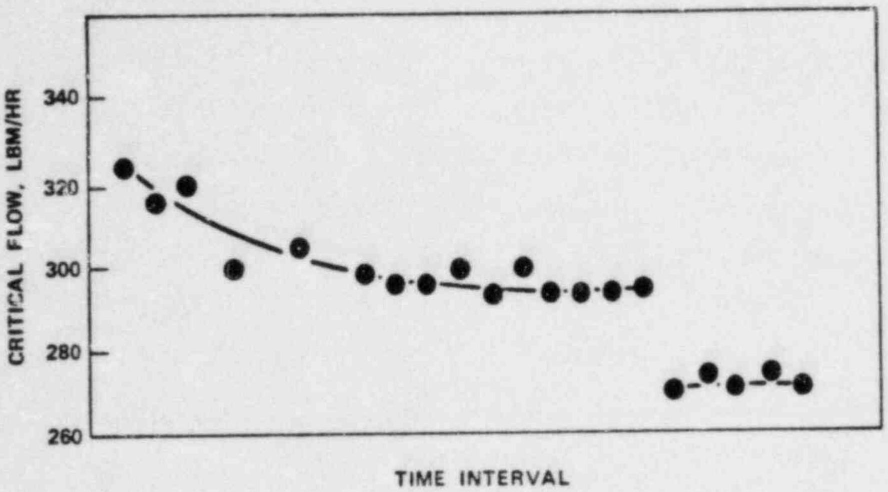
CALIBRATION RESULTS FOR GERDA LEAK FLOW ORIFICES

Orifice Serial No.	Orifice Diameter (in.)	Area (cm^2)	Test Pressure (psia)	Leak Rate (lbm/hr)	Normalized Leak Rate ($lbm/hr\text{-}cm^2$)	Test Pressure (psia)	Leak Rate (lbm/hr)	Normalized Leak Rate ($lbm/hr\text{-}cm^2$)
52	0.0237	4.80	1060	155.3	32.4	2050	162.1	33.8
53	0.0241	4.96	1060	163.6	33.0	2020	173.1	34.9
12	0.0338	9.76	1055	294.7	30.2	2055	302.5	31.0
13	0.0339	8.82	1070	292.5	29.8	2050	300.8	30.6
56	0.047	18.87	1045	580.6	30.8	1995	634.6	33.6
57	0.041	18.95	1050	572.3	30.2	2010	656.9	34.7
58	0.0667	39.16	1000	1145	29.2	2060	1232	31.5
59	0.0675	38.92	1005	1090	28.0	2030	1115	28.7
				SATURATED STEAM				
4	0.0178	2.71	1050	14.2	5.2	1980	27.8	10.3
5	0.0180	2.77	1055	14.1	5.1	1990	27.8	10.3
54	0.0319	8.69	1095	45.9	5.3	1985	87.5	10.1
55	0.0338	9.76	1000	42.0	4.3	1980	88.8	9.1



FAUSKE, MOODY, AND HEM (HOMOGENEOUS EQUILIBRIUM MODEL) CRITICAL FLOW AT SATURATED CONDITIONS. GERDA CRITICAL FLOW IS FOR A SCALED 1 CM^2 LEAK.

Figure 4-1 Measured and Predicted Critical Flows



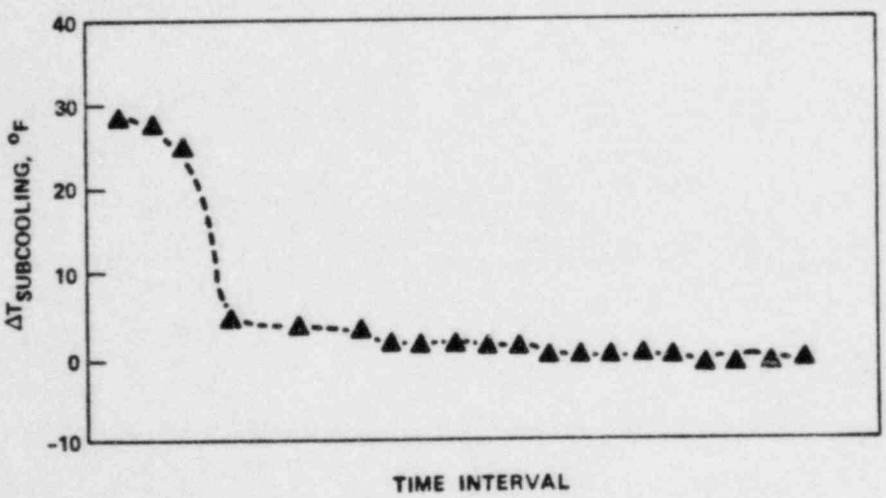


Figure 4-2 Critical Water Flow for a Scaled 9.8 CM^2 Leak

4.3 TWO-PHASE VENTING SYSTEM - CHECKOUT TEST

A GERDA test was completed to verify the ability of the two-phase venting system to effectively separate and meter the NCG's removed through the HPV and PORV. This test was performed at the conclusion of GERDA Test 100145.

During GERDA Test 100145, a total of 37.19 SCF of nitrogen was added to GERDA. Upon completing this test, the two-phase venting system checkout test was performed. The HPV was opened, allowing the NCGs to be vented out as the loop was slowly refilled. Periodically the PORV was cycled to vent any gases present in the pressurizer. The HPV remained open until the loop was refilled and the accumulator tanks indicated no more NCGs were being removed. The primary circulation pump was run after the loop was refilled to help release any trapped gases. After the free gas was removed, several grab samples were taken from the cold leg suction leak site for total gas analysis. The amount of gas removed from the loop was compared with the initial amount of gas in the loop. This is shown below in Table 4-3.

Table 4-3

COMPARISON OF GAS REMOVED WITH INITIAL GAS VOLUME IN LOOP

	Initial Gas Volume, SCF	Volume Removed, SCF
NCG Added	37.19	- - -
NCG Vented	- - -	35.36
NCG Dissolved	0.045	2.86
Total	37.24	38.22

The amount of NCGs removed from the loop compare well with the initial gas content.[13] ~~The detailed results and calculations~~ for this test are included ~~in~~[13] ~~.~~

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[13]Letter from J.E. Blake to H.R. Carter, Two Phase Vent Exercise, Run #009981, SBLOCA-1009, March 11, 1983.

4.4 IRRECOVERABLE PRESSURE LOSS CHARACTERIZATION - FORWARD AND REVERSE FLOW

The GERDA loop irrecoverable pressure drop characteristics must approximate those of the MK plant to obtain similar natural circulation performance. SAVER Code calculations indicated that the GERDA primary loop piping was less restrictive than that of MK. To better match the irrecoverable pressure drop characteristics, orifice plates were added in GERDA. An orifice plate was added near the reactor coolant pump (RCP) site to model the missing stalled RCP, and a venturi for flow measurement in the lower downcomer to match the loss coefficient in the RVVV loop. During OTIS testing the orifice at the pump spillover elevation (used for flow rate measurement) was relocated in the cold leg to the steam generator outlet as shown by Figure 3-16.

GERDA tests were conducted that allow calculation of the irrecoverable pressure drop (Euler number) around the primary loop. These Euler numbers were then compared with the predicted values from the SAVER Code. Since natural circulation pressure drops were too small for comparing measured and predicted Euler numbers, the tests were run with (nearly) isothermal, forced forward flow conditions. GERDA Test 0401CC, with a primary flow rate of about 20,000 lb/hr was used for comparison with the SAVER calculations.[14] The measured ΔPs are given in Table 4-4. Note that CLDP03, from the outlet of the steam generator to the RCP spillover, (including the cold leg orifice) was not recorded. The calibrated range of this transmitter precluded its use while in forced circulation.

The fractional differences between the SAVER predicted and the adjusted measured ΔPs ranged from -64% to +14%. The differences decrease with increasing ΔP. The sum around the loop of measured ΔPs obtains a fractional difference of only -0.5%. ~~Details of the calculations and the test results are included in[14].~~

[14] "GERDA Forced Flow ΔP Prediction," B&W Document No. 32-1127192-00, 2/2/83.

A test was also performed to obtain loss coefficients for reverse flow in the primary piping loop. With a reverse flow of about 1600 lb/hr (~1.67% of full flow) the measured differential pressures were nearly identical (within transmitter accuracy) to the no-flow condition. The conclusion from this test was that for the expected reverse flows, irrecoverable loss was negligible in comparison with the gravity head.

Table 4-4

COMPARISON OF GERDA MEASURED AND SAVER PREDICTED ΔPs

ΔP Transmitted	GERDA "Corrected" Measured ΔP, psi	SAVER Predicted ΔP, psi
HLDP01	0.762	0.426
HLDP02	0.785	0.482
HLDP03	0.156	0.056
SPDP01	1.572	1.682
CLDP01	0.260	0.143
CLDP03	--	10.556
DCDP02	2.092	2.390
RVDP02	0.090	0.038
RVDP04	0.205	0.243
Total (excluding CLDP03)	5.004	4.978

4.5 HEAT LOSS

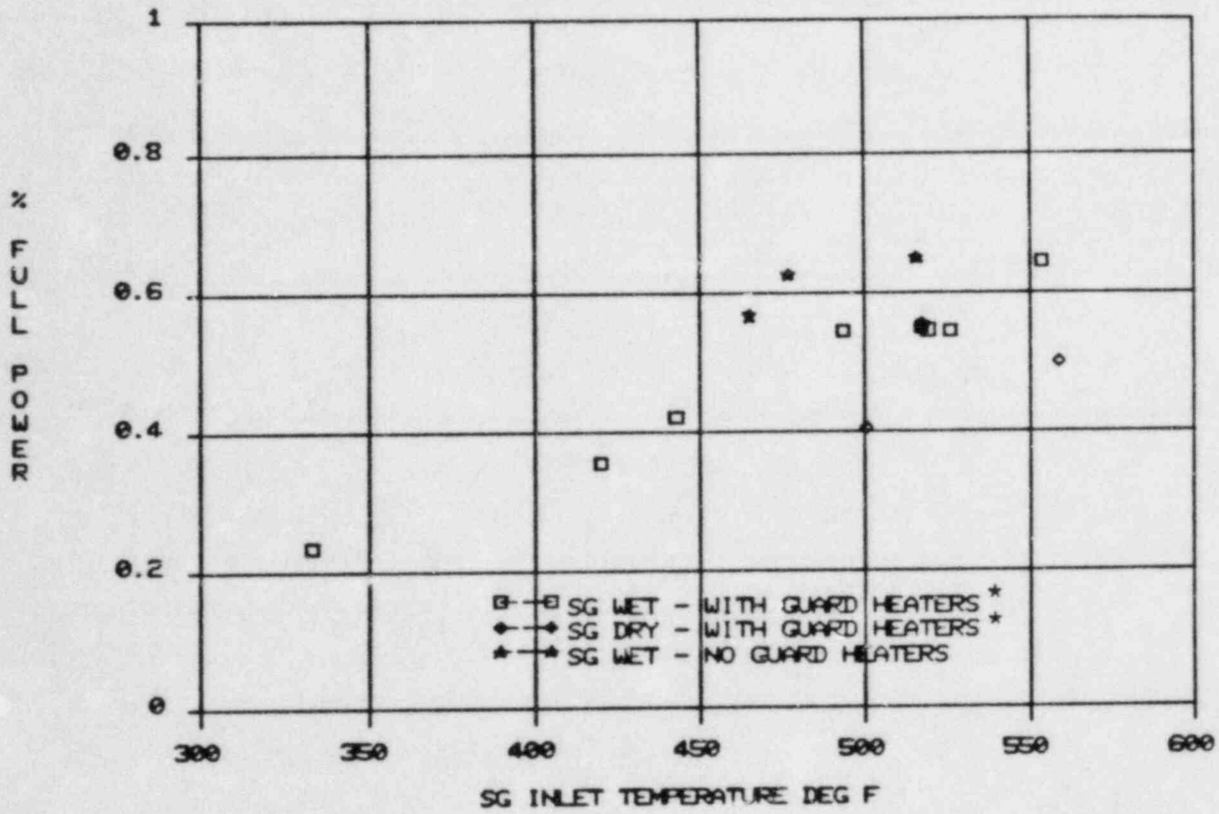
To determine the heat loss characteristics of the GERDA loop, a series of heat loss tests were conducted during GERDA Phase 0 Characterization Testing. From these tests the total loop heat loss and the heat loss from the major components (reactor vessel, hot leg, steam generator, and cold leg) was determined. The heat loss was measured during steady-state conditions under natural circulation flow rates. To assure steady-state conditions, the loop was allowed to soak at least 24 hours prior to taking the heat loss data. Data were taken both with and without the hot leg guard heaters activated (no surgeline or reactor vessel guard heaters were available during these GERDA heat loss tests). Pressurizer heat loss was determined during a separate test in which it was isolated from the loop.

The overall loop heat loss (excluding the pressurizer) equals the core power required to sustain the loop temperature. Thus, loop heat loss was measured directly by the core wattmeter. Heat loss for the major components was calculated based on the fluid enthalpy change between the inlet and outlet of each component. Enthalpy change was based on Resistance Temperature Detector (RTD) measurements located at the inlet and outlet of each component, and on the mass flow rate as indicated by the Venturi meter in the downcomer. The reactor vessel vent valve (RVVV) was closed during all the heat loss tests. During these tests the secondary side of the steam generator was isolated. The water level in the steam generator varied from 0 to 67% during these tests.

The overall loop heat loss, in terms of percent (%) full power versus steam generator inlet temperature, is shown in Figure 4-3. At 500°F with the hot leg guard heaters activated and with a wet steam generator, loop heat loss was about 0.55% of full power (1% of full power equals 22.4KW for GERDA tests). The component heat losses are shown in Figures 4-4 through 4-7 for the steam generator, reactor vessel, cold leg, and hot leg respectively. Steam generator heat loss, shown in Figure 4-4, was insensitive to the secondary-side water level, as long as a level was present. The one data point taken for a dry steam generator shows a lower heat loss than for a wet steam generator at the same temperature.

Hot leg heat loss, shown in Figure 4-7, was taken both with and without guard heaters activated. With the guard heaters activated (bias setting at 0.1), the hot leg was nearly adiabatic up to about 500°F. Above this temperature, the data indicates a net heat loss along the hot leg. At 535°F, the heat loss was about 0.045%.

Pressurizer heat loss was determined while the pressurizer was isolated from the loop. Initially, the pressurizer was at a steady-state condition with the



*Hot leg guard heaters only, bias setting +0.1.

Figure 4-3 GERDA Loop Heat Loss

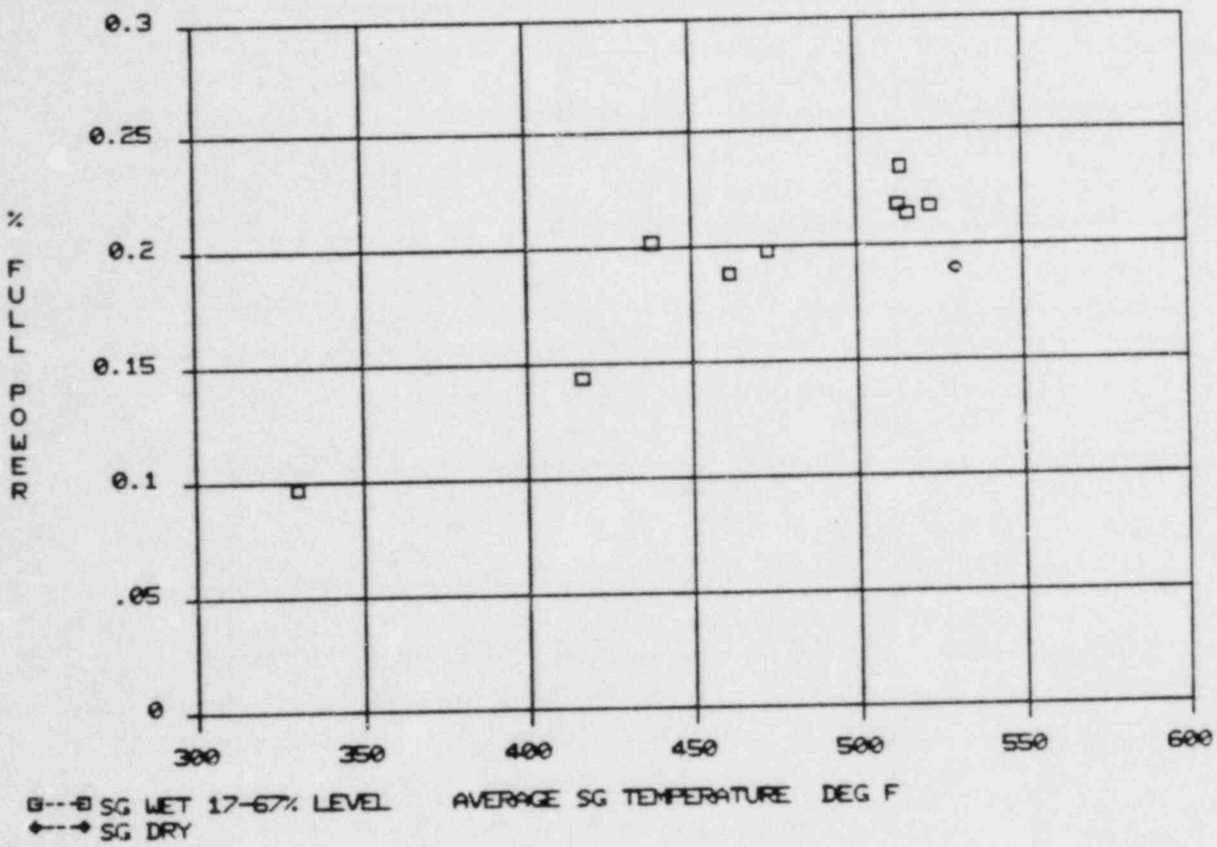


Figure 4-4 GERDA Steam Generator Heat Loss

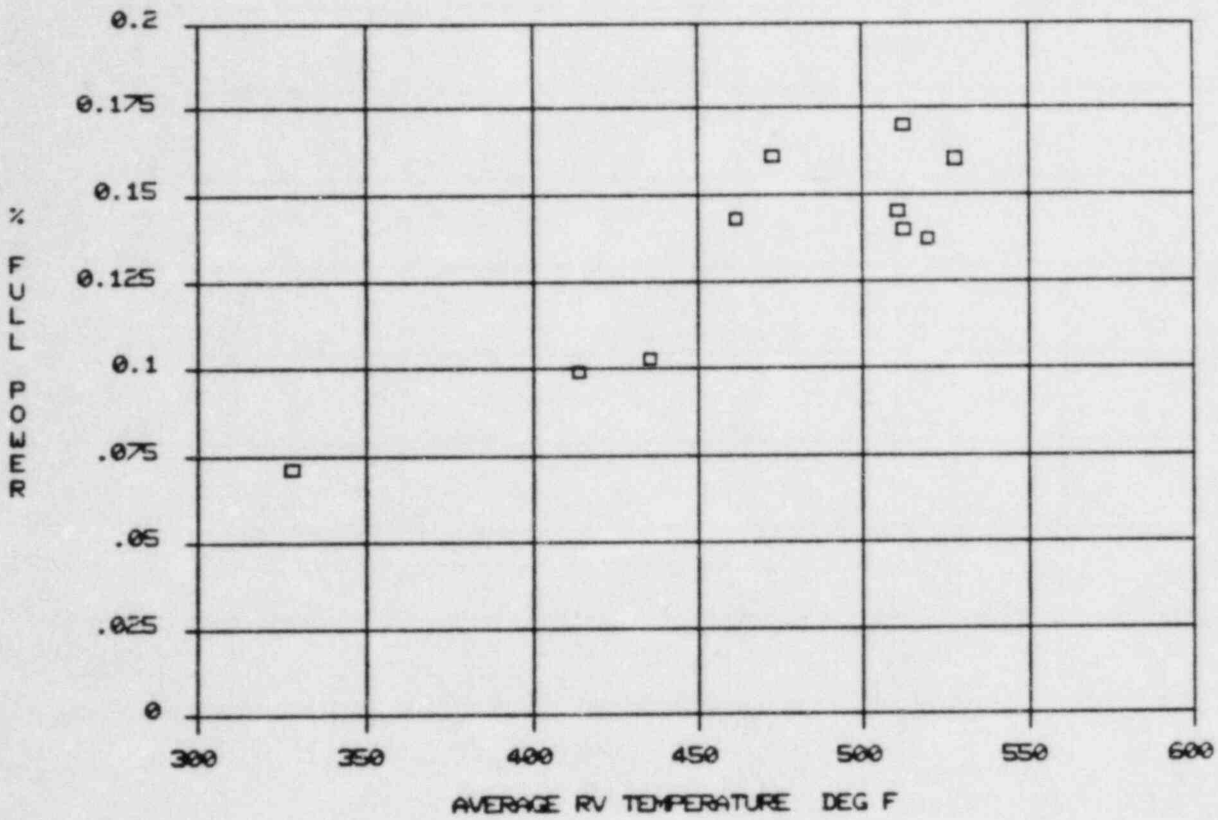


Figure 4-5 GERDA Reactor Vessel Heat Loss
(No Guard Heaters)

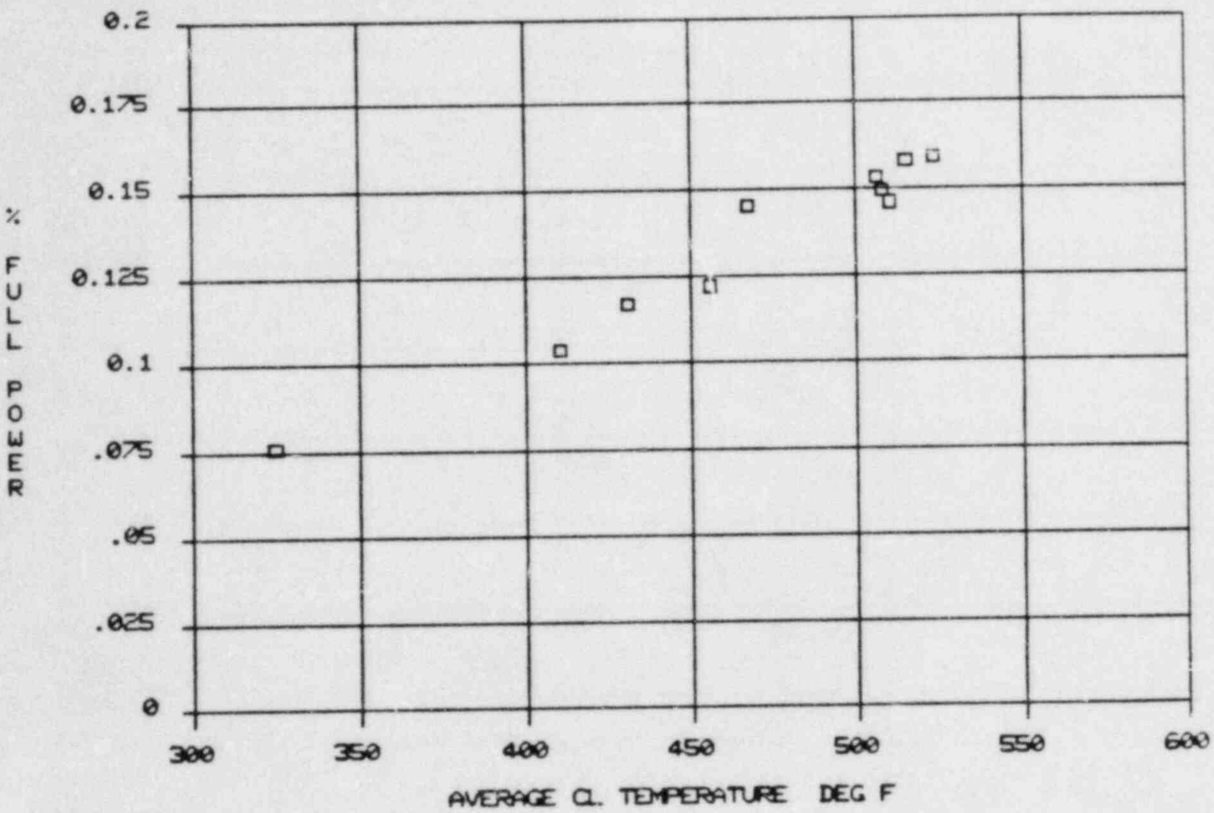


Figure 4-6 GERDA Cold Leg Heat Loss

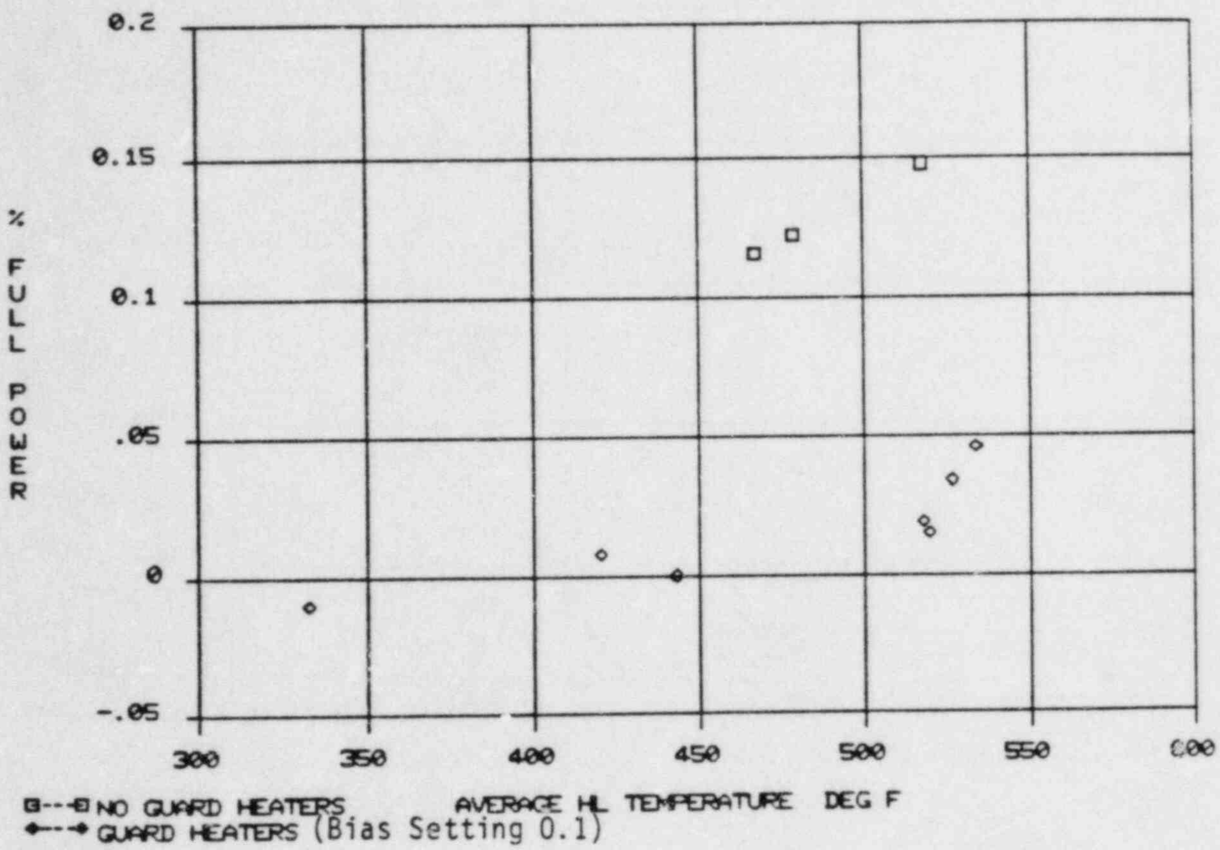


Figure 4-7 GERDA Hot Leg Heat Loss

main heaters controlling to a set pressure (~2000 psia) and the guard heaters making up for heat loss. The main and guard heaters were tripped and the vessel was allowed to depressurize (due to heat loss). Based on the temperature, pressure, and collapsed water level data, the heat loss was calculated as the vessel depressurized from 2000 to 1650 psia, and again from 1250 to 500 psia. The heat loss during these tests was 0.047 and 0.042% of full power at 622° and 530°F, respectively.

For OTIS testing, guard heaters were added at the pressurizer surge line and at the reactor vessel upper and top plenums. Guard heater control bias settings were determined to minimize heat loss from these regions. Characterization test results for these OTIS components will be added to this text when test results are available.

4.6 GUARD HEATER CHARACTERI~~STICS~~ ZATIONS

A Pressurized Water Reactor (PWR) at operating temperature typically loses less than 0.1% of full power to ambient[15]. OTIS, with its larger surface area to volume ratio, will lose a larger percentage of the heat being generated to the surroundings. To minimize the undesirable effects of heat loss in the hot leg, pressurizer surge line, and reactor vessel upper and top plenums, a guard heating system was used on these components. The guard heating system (discussed in Section 2.0) was designed to provide heat to the components in an amount equal to that components heat loss to ambient.

During the GERDA Phase 0 Loop Characterization Tests, the performance of the hot leg guard heaters was characterized. The hot leg guard heaters are divided into eight (8) control zones, each zone covering about eleven feet of pipe. Heat input to the zone was controlled based on a ΔT measurement between the pipe OD and

[15] "Scaling Criteria and an Assessment of Semiscale Mod-3 Scaling for Small Break Loss of Coolant Transients", T. K. Larson, J. L. Anderson, and D. J. Shimeck, EGG-SEMI-ST21, March, 1980.

a point approximately mid-way into the 1/2" layer of control insulation. The guard heater concept is illustrated on Figure 2-4. The proposed method to minimize the heat loss was to control the guard heater so that the ΔT between the pipe OD and the control insulation was zero. With the ΔT being zero, an adiabatic condition would exist at the pipe wall, thus the heat loss would be zero. During the heat loss tests it was found that with the guard heaters maintaining a zero ΔT, there was a net heat loss along the hot leg. The temperature at the steam generator inlet was about 2°F less than the reactor vessel outlet temperature. This represented a heat loss along the hot leg of about 0.045% (at 500°F). This net heat loss was due to a higher heat loss through instrument penetrations (thermocouples, conductivity probes, viewports, etc.) than through the insulated sections of the pipe where the control signal was located. To minimize the overall heat loss from the hot leg, that is making the steam generator inlet temperature equal to the reactor vessel outlet temperature, the heater control setpoint was increased (biased to +0.1). With the higher control setpoint there was a net heat addition over the insulated section of the control zone to compensate for the higher heat loss through the instrument penetrations in that zone. The result is illustrated in Figure 4-8. Between the reactor vessel outlet and steam generator inlet, the net heat loss was approximately zero with the guard heaters on (and biased to +0.10). The fluid temperatures along the hot leg varied by ±1°F. This guard heater control setpoint (bias +0.10) was used for all GERDA Phase 1 tests. The fluid temperature profile with the guard heaters off is also illustrated on Figure 4-8. There was about a 5°F temperature difference from the outlet of the reactor vessel to the steam generator inlet with the hot leg guard heaters off.

As part of the OTIS characterization testing, a run was performed to determine the control settings for the eight hot leg guard heaters for a steam environment at 500°F. The effects of slightly overpowered guard heaters are most apparent in a steam environment due to the relatively small volumetric heat capacity of the fluid. This guard heater characterization test showed that the control settings for the eight hot leg zones, established during the GERDA program, were too high. An estimate of the excess heat addition to the hot leg

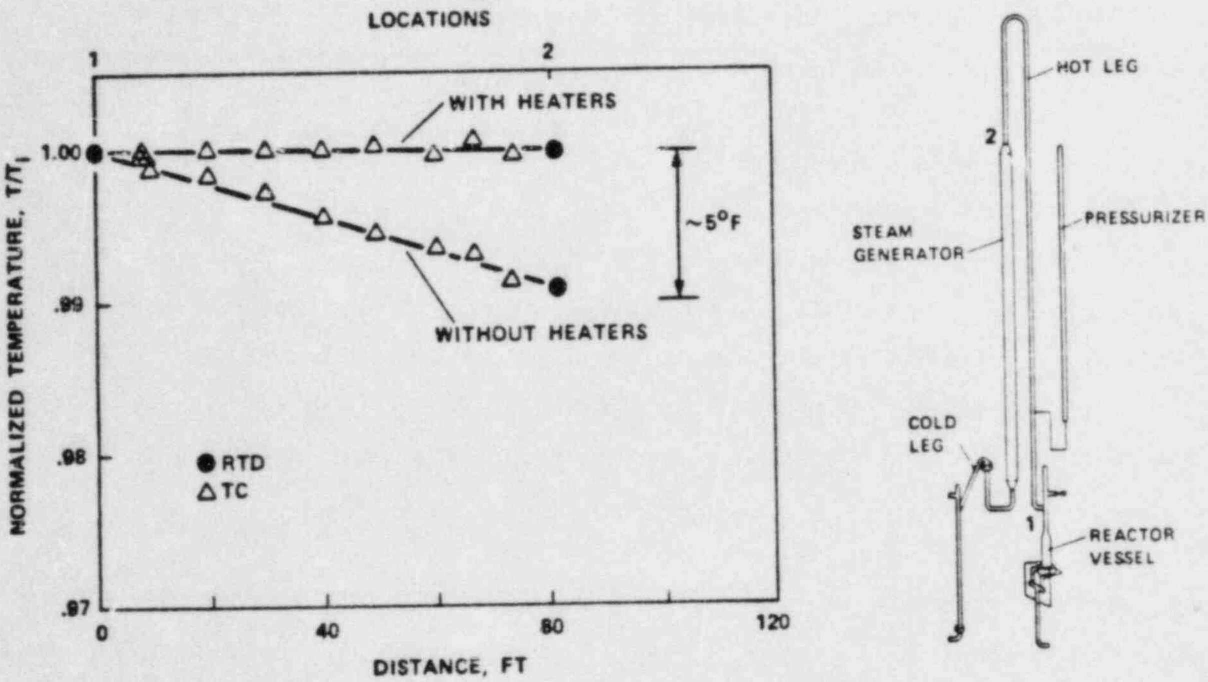


Figure 4-8 GERDA Hot Leg Fluid Temperatures With and Without Guard Heaters

was made and totalled 324 watts[16]. The control settings were reduced to +0.09 for zone 4 (see Table 3-6 for zone elevations), +0.08 for zones 1 and 5, +0.07 for zones 2, 6, 7 and 8, and +0.06 for zone 3. Finally, the loop was refilled and the adequacy of the reduced hot leg guard heater control settings was verified under natural circulation conditions. The natural circulation hot leg fluid temperatures were within 1.5°F of those in a steam environment.

The control settings for the reactor vessel upper and top plenum guard heaters were also determined in a steam environment at 500°F. A control setting of +0.230 for the upper plenum and +0.135 for the top plenum (see Section 3.1 for zone elevations) were required so that the top plenum fluid temperature (RVTC08) was within 1°F of the core outlet fluid temperature (RVTC07). The heat loss from the reactor vessel was reduced from 3.36 KW to 2.26 KW at 500°F using these guard heaters. The total loop heat loss was decreased from 12.1 KW (or 0.57% of full power where 1% of full power equals 21.4 KW for OTIS) to 11.0 KW (0.51% of full power). These same reactor vessel guard heater control settings resulted in a 14°F temperature gradient between the core outlet and the top plenum for a water filled reactor vessel and natural circulation conditions in the loop. The heat loss from the reactor vessel upper and top plenums under these conditions was only 29W.

The pressurizer surge line guard heater control setting was set at +0.0 for OTIS testing. A larger bias setting was not required due to the absence of local heat sinks (instrument stand-offs, pipe supports, viewports, etc.) in the surge line piping.

As mentioned in Section 3.5, the pressurizer guard heater control was based on the arithmetic average of three sets of control thermocouples for all tests performed before April 3, 1984. On that date, one of the three sets of control thermocouples failed and control was switched to a single set of control

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[16] Letter from D.P. Birmingham to H.R. Carter, "OTIS Guard Heater Characterization Test Results, OTIS-158", April 17, 1984.

thermocouples. New characterization of the guard heaters was required. The characterizations were performed at pressures of 500 psia and 1600 psia with a half-full pressurizer. The new controller bias was determined to be 0.07 to 0.08 and was used for the remainder of the OTIS testing.

4.7 STORED METAL ENERGY EFFECTS

During a depressurization transient, the water gives up its energy by flashing to steam. The metal, which was initially at the fluid temperature, dissipates its stored energy by convecting heat to the fluid. During this depressurization the guard heater will shut off, only when the temperature of the pipe OD begins decreasing (to follow the temperature of the depressurizing fluid). During the GERDA refill and composite tests (Tests 14 and 16), the hot leg fluid temperature in the steam region of the hot leg remained hot (became superheated) as the loop depressurized. An analyses was conducted to determine if this superheating was a result of an overpowering guard heater or from stored energy.

The effects of stored energy was determined using a computer code (TRUMP) model of the hot leg. The fluid, pipe wall, control insulation, heater, and passive insulation were modeled. One axial layer of the model represented the water region, and the other layer represented the steam region. Each region was of unit (1 foot) length. Axial conduction in the pipe was not included. The model is illustrated in Figure 4-9.

The temperature of the water region was prescribed to follow the primary saturation temperature during the first 50 minutes of GERDA Run 140301. During this depressurization, the fluid temperature decreased from 518°F (initially) to 392°F (at 50 minutes into the transient test). The rate at which the fluid temperature changed was varied according to the saturation temperature for this run. The initial steady-state temperature distribution for the hot leg model was determined based on a fluid temperature of 518°F. All thermal properties in the model were temperature dependent. The water was assumed to make perfect contact with the pipe (infinite heat transfer coefficient), while the steam heat transfer

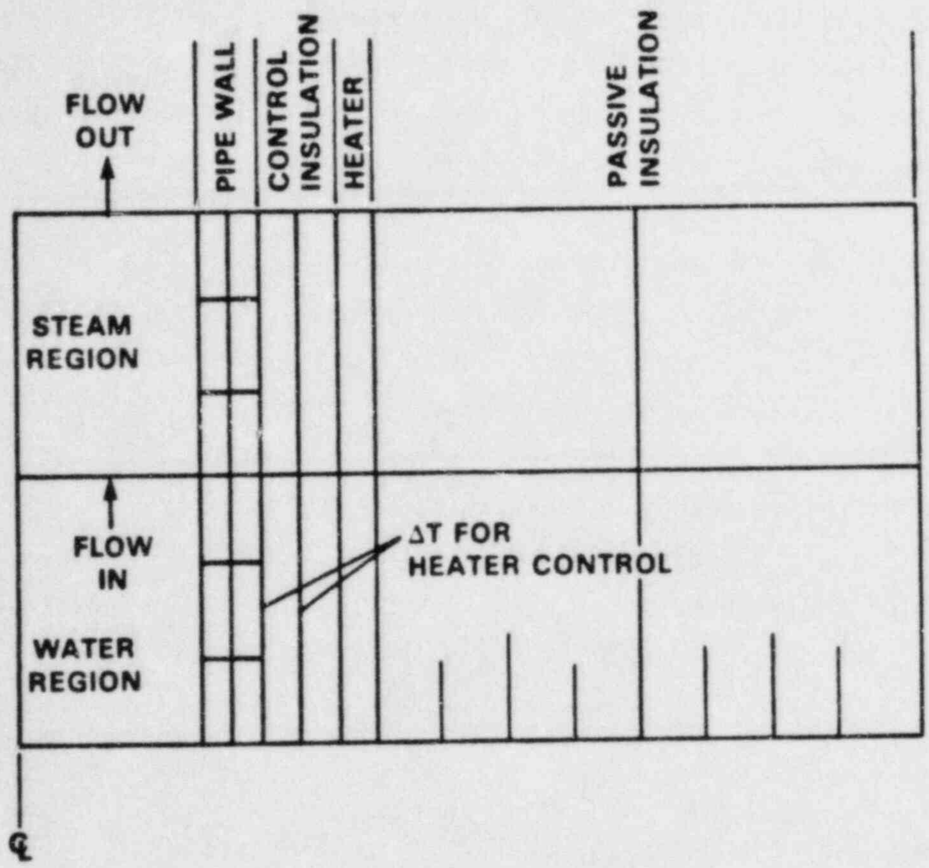

Figure 4-9 Hot Leg Guard Heater Model

to the pipe was based on the Dittus and Boelter equation[17]. Heat transfer from the passive insulation to the ambient was based on a natural convection heat transfer coefficient. The guard heater was off during this depressurization.

Saturated steam, at the temperature of the water control volume, enters the steam control volume. The temperature of the steam control volume was calculated based on the heat convected to the steam region from the pipe wall. The steaming rate up the hot leg was varied. The minimum steaming rate considered was the high point vent (HPV) capacity of 10 lb/hr. This is approximately the HPV capacity at 900 psia. The steaming rate could be greater than the HPV capacity since steam may be condensing in the steam generator. To investigate this, steaming rates of 10, 20, 100, and 500 lb/hr were considered.

Using the initial temperature distribution calculated for GERDA Test 140301, the transient calculation was initiated to follow the depressurization rate from this run. The steam temperature, metal temperature (at inside diameter of pipe), and fluid temperature (saturation) are presented for hot leg steaming rates of 10, 20, and 100 lb/hr in Figures 4-10 to 4-12, respectively. The stored energy release rate, heat flow from the pipe to the steam control volume, for hot leg steaming rates of 20, 100, and 500 lb/hr are shown in Figure 4-13.

The analysis shows that even at 50 minutes into the test, stored energy was still being released from the pipe. At a steaming rate of 20 lb/hr, the heat release rate was about 25 watt/foot (of hot leg) at 50 minutes. Based on a stored energy capacity of 220 BTU/foot for a 3" Schedule 160 pipe, which cools from 518°F to 392°F, the pipe only released about 26% of its stored energy during the first

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[17] Dittus-Boelter equation is: $Nu = 0.023\ Re^{0.8}\ Pr^{0.3}$

where: Nu = Nusselt Number
Re = Reynolds Number
Pr = Prandtl Number

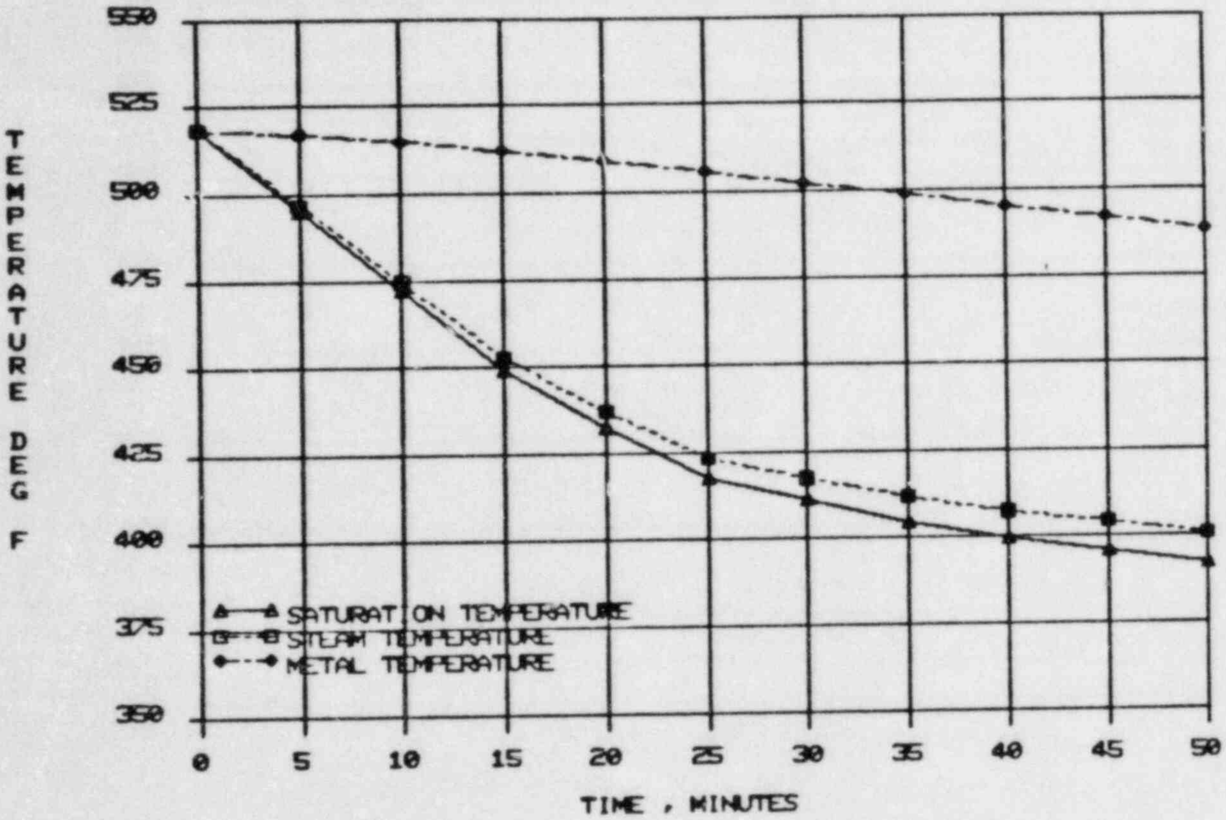

Figure 4-10 Predicted Fluid and Metal Temperatures In Vapor Region of Hot Leg Pipe During Depressurization - 10 LB/HR

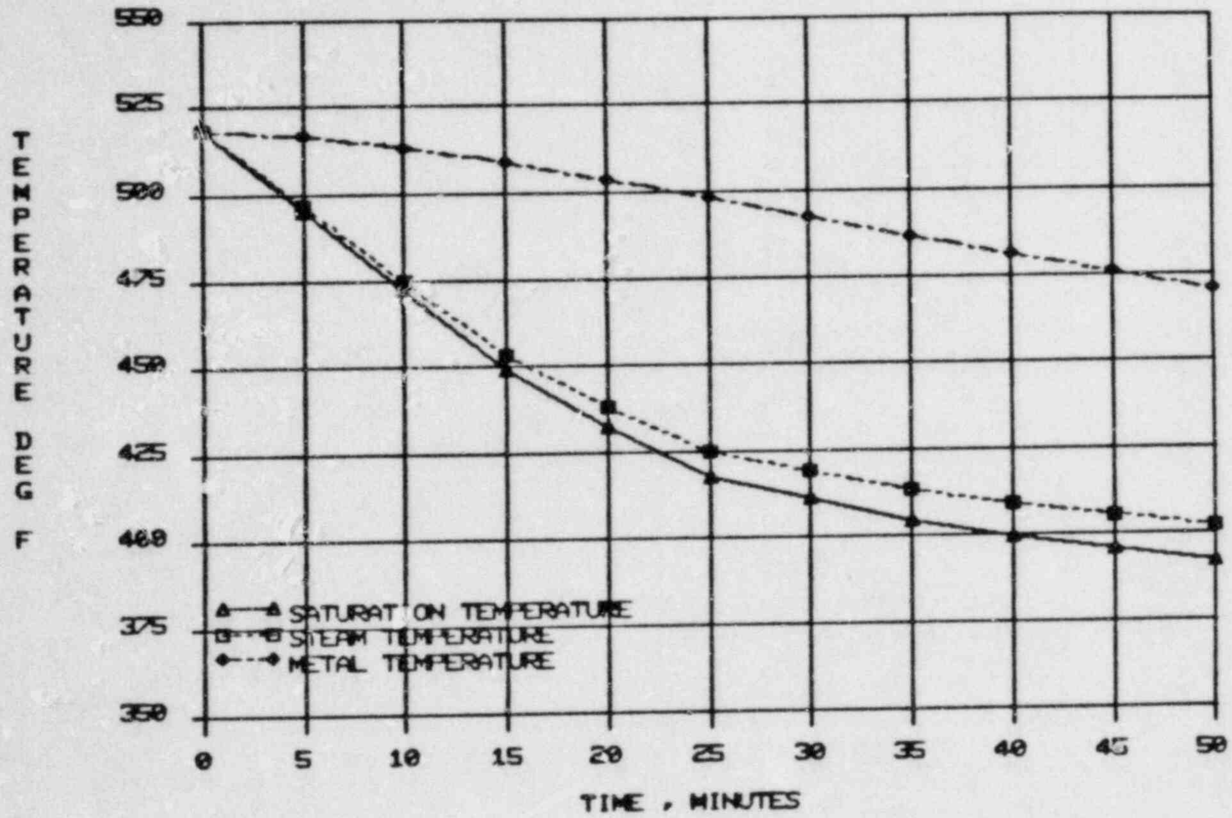

Figure 4-11 Predicted Fluid and Metal Temperatures In Vapor Region of Hot Leg Pipe During Depressurization - 20 LB/HR

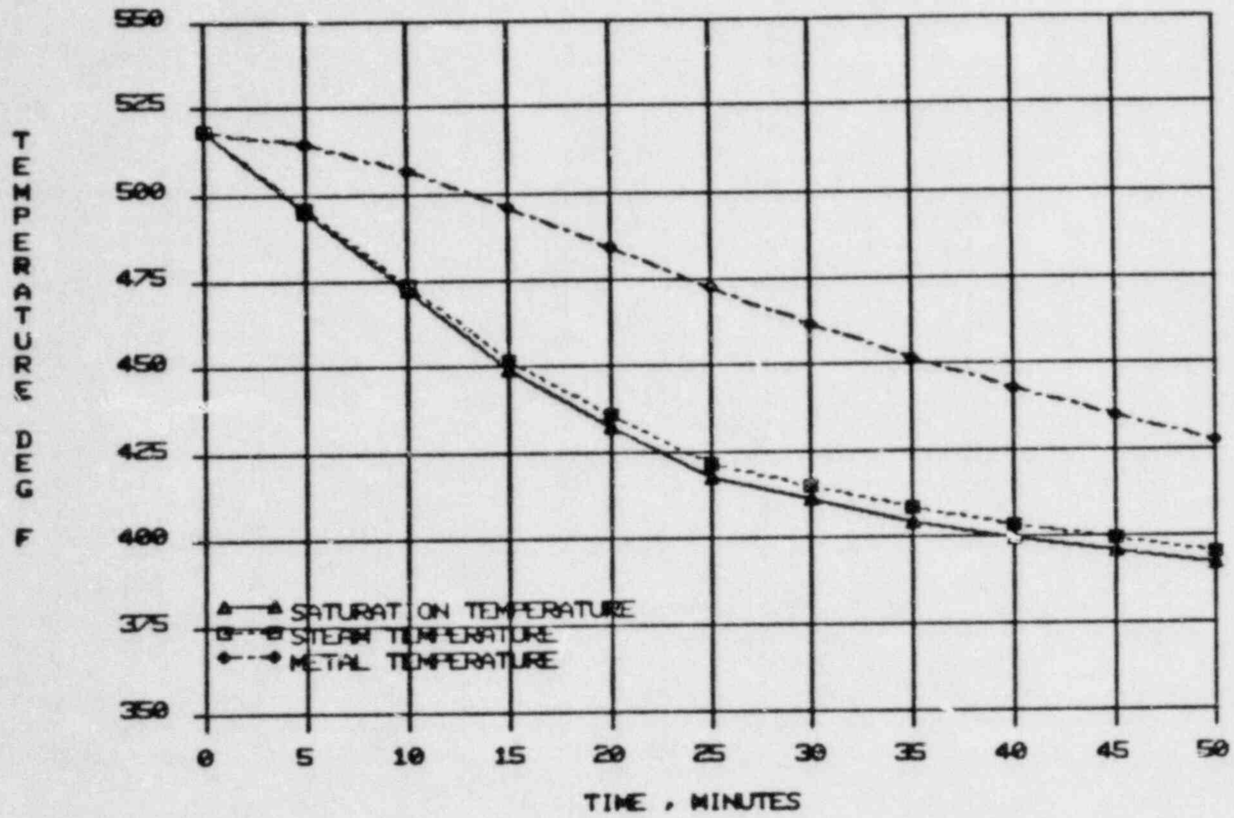

Figure 4-12 Predicted Fluid and Metal Temperatures In Vapor Region of Hot Leg During Depressurization - 100 LB/HR

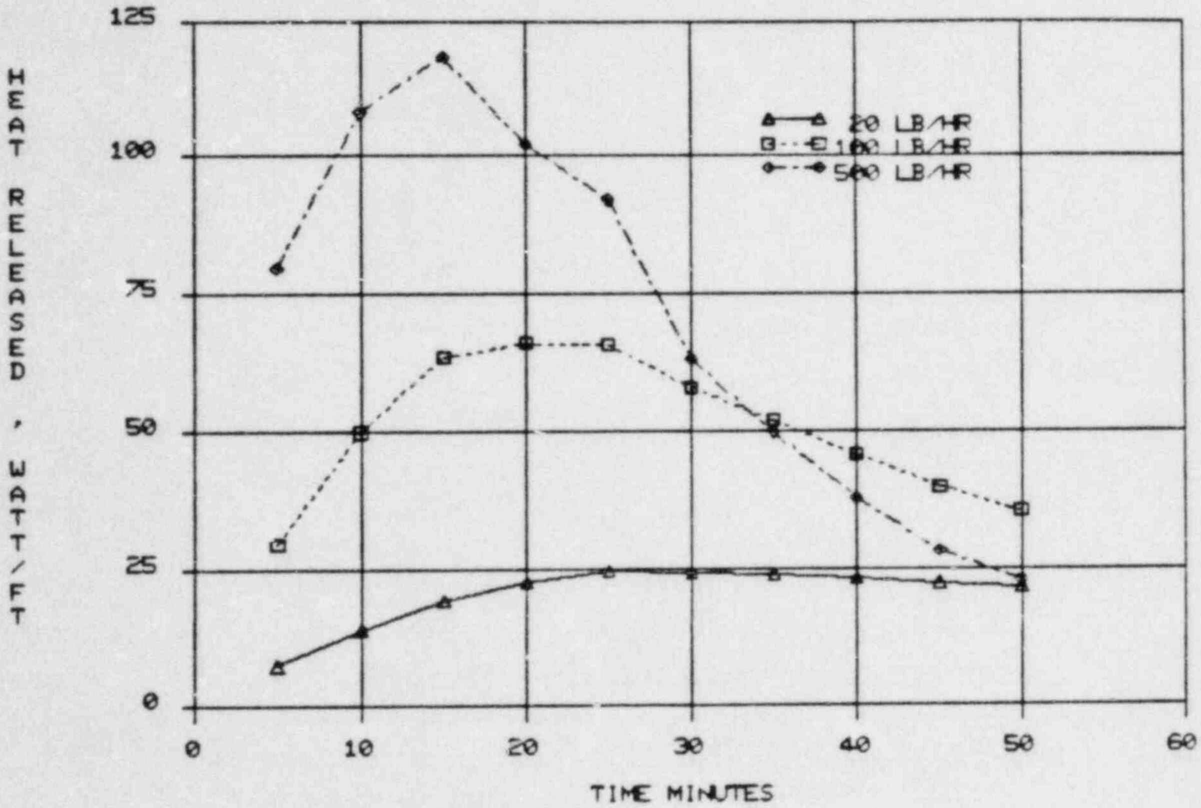

Figure 4-13 Stored Heat Release Rate Versus Time In Vapor Region of Hot Leg

50 minutes of the transient (with 20 lb/hr steaming rate). The percent of stored energy released at 50 minutes, and the average heat release rate for 20, 100, and 500 lb/hr steaming rate is shown in Table 4-5.

Table 4-5

EFFECT OF STEAMING RATE ON STORED ENERGY RELEASE

Steam Flowrate lb/hr	Stored Heat Removed @ 50 min. (%)	Average Release Rate watt/foot
20	26.3	20.4
100	65.5	50.6
500	90.9	70.3

Based on these average release rates, the amount of superheat produced in a 10 foot section of pipe is shown in Table 4-6. These temperatures are based on the inlet fluid being saturated vapor at 900 psia.

Table 4-6

SUPERHEAT PRODUCED BY STORED ENERGY RELEASE

Flowrate lb/hr	Average Release Rate watt/foot	Amount of Superheat Produced °F
20	20.4	35
100	50.6	16
500	70.3	2

As a result, it is concluded that stored energy release from the pipe to the fluid, can add heat at a rate to produce the superheated steam temperatures observed during the first hour of some of the refill tests.

A GERDA test was performed to determine if significant condensation occurred in the voided hot leg with and without guard heaters on. To void the hot leg, the reactor vessel leak was opened allowing the primary to saturate at approximately 1000 psia. The leak remained opened until the hot leg level was below the hot leg viewport at the 35' elevation. A video camera at this viewport recorded the events following the opening of the leak. The recordings revealed that vapor bubbles passed up the hot leg to replace energy removed by the steam generator and by heat loss after the hot leg voided and natural circulation stopped. Also, there was no detectable condensation film on the pipe ID with or without the hot leg guard heaters in service.

4.8 CALIBRATION OF PRIMARY FLOW ELEMENTS

There were two flow elements in the GERDA primary loop - an orifice located just upstream of the cold leg spillover, and a Herschel venturi meter located in the downcomer. The venturi was calibrated in the 1000 GPM flow loop test facility using a certified weigh scale measurement as the standard. The cold leg orifice was calibrated in the GERDA loop using the venturi as the standard. For OTIS testing, the cold leg orifice (orifice diameter of 1.110 inches) was relocated to the vertical pipe just downstream of the SG outlet. The cold leg orifice was recalibrated in the OTIS loop, again using the venturi as the calibration standard.

A schematic diagram illustrating the arrangement for the venturi calibration is shown in Figure 4-14. Flow to the meter was provided either by a gravity feed from a constant head reservoir, or by pumping from the reservoir. A low range (0-5" H_2O) and/or a high range (0-150" H_2O) differential pressure transmitter was used to measure the ΔP across the throat of the venturi, and to measure the irrecoverable pressure loss. An integrating digital voltmeter (DVM) was used to average the signals from the ΔP transmitters. Downstream of the meter, the water was collected on a weigh scale. Weigh scales with capacities of 100, 1000, and 20,000 pounds were available and were selected based on the flow rate being tested.

The calibration range was established by matching the calibration Reynolds number range to the operating Reynolds number range. An operating Reynolds number range (based on throat diameter) of 5000 to 370,000 was selected based on expected GERDA flow rates.

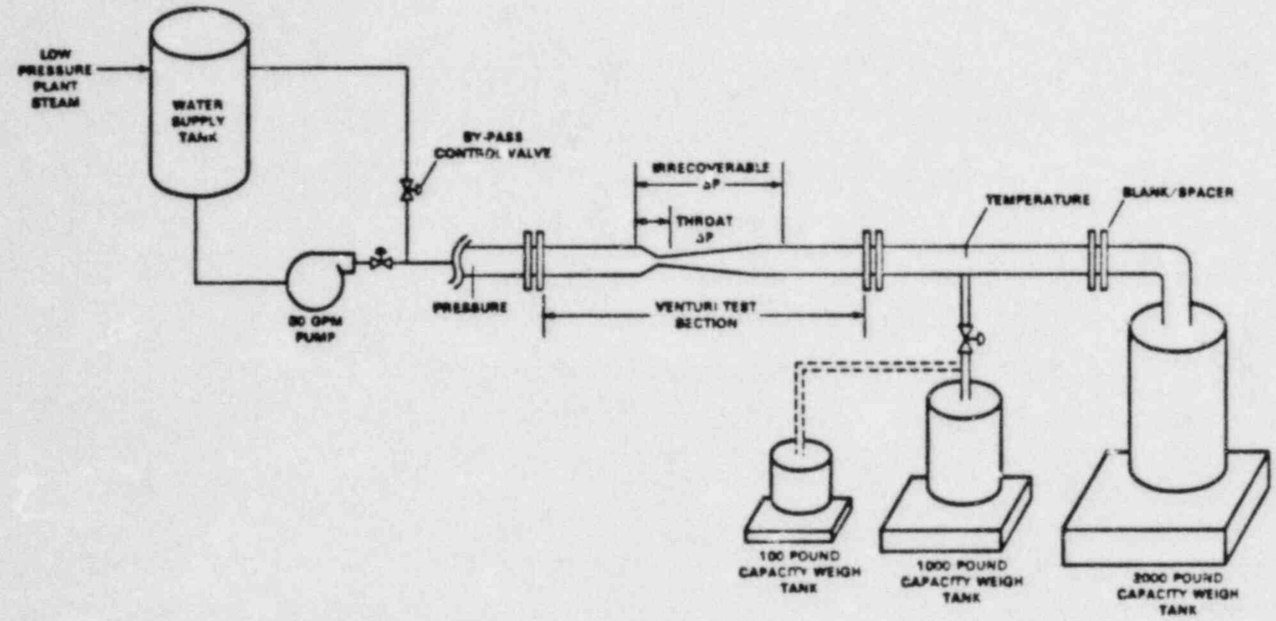

Figure 4-14 Flow Loop Arrangement for Venturi Calibration

The expression for mass flow rate through a venturi is:

$$\dot{m} = C\,a\sqrt{\frac{2\,g_c\,\rho\,\Delta P_m}{1 - \beta^4}}$$

Defining a flow coefficient, K, as:

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

and solving for K in terms of the measurable parameters yields:

$$K = \frac{\dot{m}}{\sqrt{2\,g_c\,\rho\,\Delta P_m}\;a}$$

where

$\dot{m}$ = mass flow rate, lb_m/sec

ρ = fluid density, lb_m/ft^3

a = throat area, ft^2

ΔP_m = differential pressure across throat, lb_f/ft^2

g_c = gravitational constant, 32.174 $lb_m\text{-}ft/sec^2\text{-}lb_f$

C = coefficient of discharge

β = throat to pipe diameter ratio, $\frac{d}{D}$

The flow coefficient, K, was computed using the above expression, and correlated with the parameter $1000/\sqrt{Re_D}$ where Reynolds number is based on the 2-1/2" Schedule 160 pipe diameter. A plot showing this correlation is shown in Figure 4-15.

The data were curve fitted (using a linear fit) for use in the GERDA and OTIS data bases.

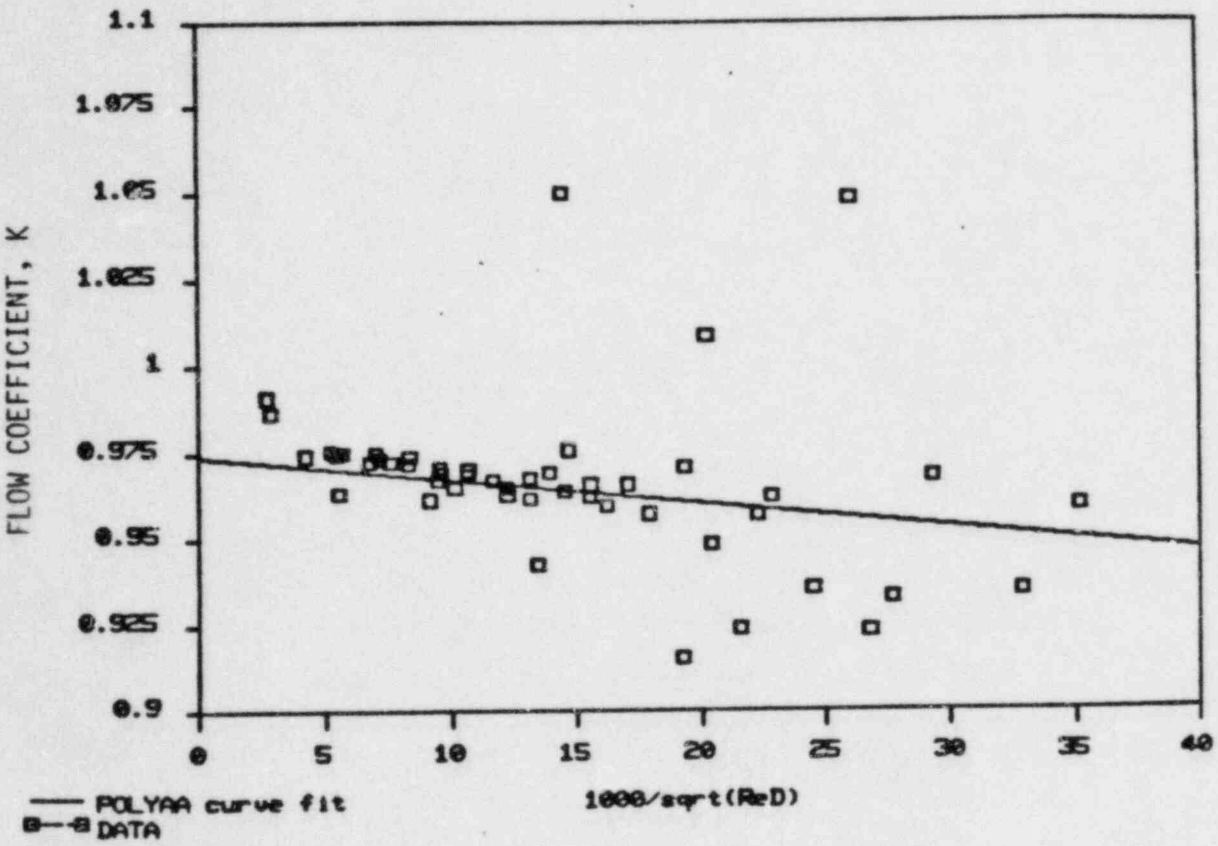

Figure 4-15 Venturi Flow Coefficient

During the venturi (throat diameter of 0.775 inches) calibration, data were also taken to determine the Euler number for the assembly to be installed in the loop. An Euler number, based on a 3" Schedule 160 pipe, of 14.2 was experimentally determined for the assembly to be installed in the downcomer. This value agreed well with the predicted Euler number of 16.7.[18] ~~The venturi calibration data and the supporting equations development is included in~~[18].

The cold leg orifice (1.110 inch bore diameter) just downstream of the SG outlet was calibrated in the OTIS loop because of the non-standard installation required by the loop piping. The downcomer venturi was used as the standard for this calibration. Calibration data were recorded using the OTIS data acquisition system. The ΔP across the orifice was recorded using a low range (0-7" H_2O) and a high range (0-25" H_2O) differential pressure transmitter. Calibration data were taken under natural circulation conditions. The flow coefficient, K, was calculated from the measured parameters using:

$$K = \frac{\dot{m}}{0.525\, d^2 \sqrt{\rho\, \Delta P}}$$

where

$\dot{m}$ = mass flow rate indicated by downcomer venturi, lb_m/sec

d = orifice bore diameter, inches

ρ = fluid density, lb_m/ft^3

ΔP = orifice differential pressure, psid

This flow coefficient was correlated with the parameter $1000/\sqrt{Re_D}$, where Reynolds number is based on the 3" Schedule 160 pipe diameter. These calibration

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[18] Letter from J.E. Blake to H.R. Carter, "GERDA Downcomer Venturi Calibration", SBLOCA-932, January 11, 1983.

data are plotted in Figure 4-16. The data were curve fitted (using a linear fit) for use in the OTIS database. ~~The calibration data and supporting calculations are included in[19].~~

4.9 CALIBRATION OF FEEDWATER AND STEAM FLOWMETERS

The feedwater and steam orifices were calibrated in the GERDA loop. The feedwater orifices and the high range steam orifice were calibrated using the turbine meters upstream of the feedwater heaters as the standard. The low range steam orifice was calibrated using the low range feedwater orifice as the standard.

The flow coefficient, K, for each feedwater and steam orifice was calculated from:

$$K = \frac{\dot{m}}{0.525\, d^2 \sqrt{\rho\, \Delta P}}$$

where

$\dot{m}$ = mass flow rate from the flow standard, lb_m/sec

d = orifice bore diameter, inches

ρ = fluid density, lb_m/ft^3

ΔP = differential pressure, psid

For each flowmeter the flow coefficient was correlated with the parameter $1000/\sqrt{Re_D}$, where the Reynolds number was based on the pipe diameter (1" Schedule 80 for steam and 3/4" Schedule 80 for feedwater). A curve fit of flow coefficient versus the Reynolds number parameter was developed for each meter for use in the GERDA and OTIS data bases.

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[19] Letter from J.E. Paxson to D.P. Birmingham, "Cold Leg Spillover Orifice Calibration", OTIS-103, February 21, 1984.

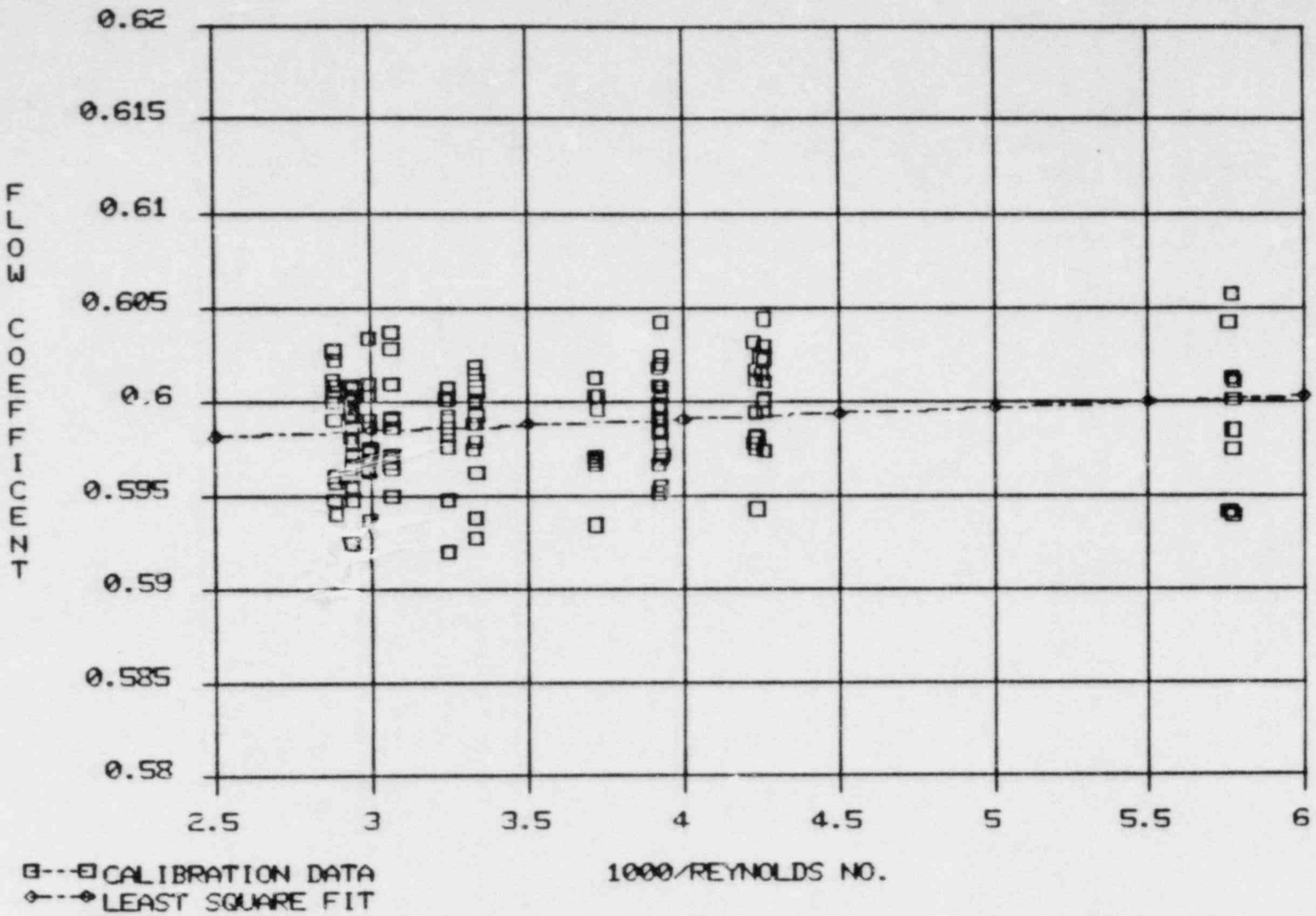

Figure 4-16 Cold Leg Flowmeter Calibration Data and Curve Fit

The flow coefficient versus the Reynolds numbers parameter is shown in Figure 4-17 for the low range feedwater orifice. For the low range steam flow orifice one flow coefficient was computed for each of the temperatures from PSRT01, PSTC01, and SSTC25 used to compute the density term. The flow coefficient calculated with SSTC25 was about 2% higher than that using SPRT01 and PSTC01. Since the earlier steam flow data from GERDA Tests 1 through 4 showed the low range steam flow rate to be approximately 3-5% less than the low range feedwater flow rate, the flow coefficient based on SSTC25 was used. This flow coefficient versus the Reynolds number parameter is shown in Figure 4-18.[20] ~~The data for the low range steam orifice calibration is included in~~[20].

4.10 FILLED NONCONDENSIBLE GAS TEST

A GERDA Phase 0 test was identified to determine the noncondensible gas (NCG) concentration in the primary loop using the normal fill procedure. The objective of this test was to determine if degassing was required prior to selected GERDA Phase 1 tests.

The initial total gas content for each test with a voided primary was specified to be less than 60 cc/Kg H_2O prior to voiding. To verify the total gas content was less than 60 cc/Kg H_2O, a total gas sample was taken from the primary loop prior to each voided primary test. The sample was taken just prior to each test after the inventory had been circulated for at least 1 hour. The sample was drawn from the cold leg suction leak location, through a heat exchanger, and into a high pressure sample bomb. The sample bomb was flushed with at least 10 sample bomb volumes prior to collecting the sample. After the sample was collected, it was analyzed at the Chemistry Lab for total gas content. If the gas content was greater than 60 cc/Kg H_2O, the gases were further reduced by feeding and bleeding,

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[20] Letter from D.P. Birmingham to H.R. Carter, "Low Range Steam Orifice Calibration", December 28, 1982.

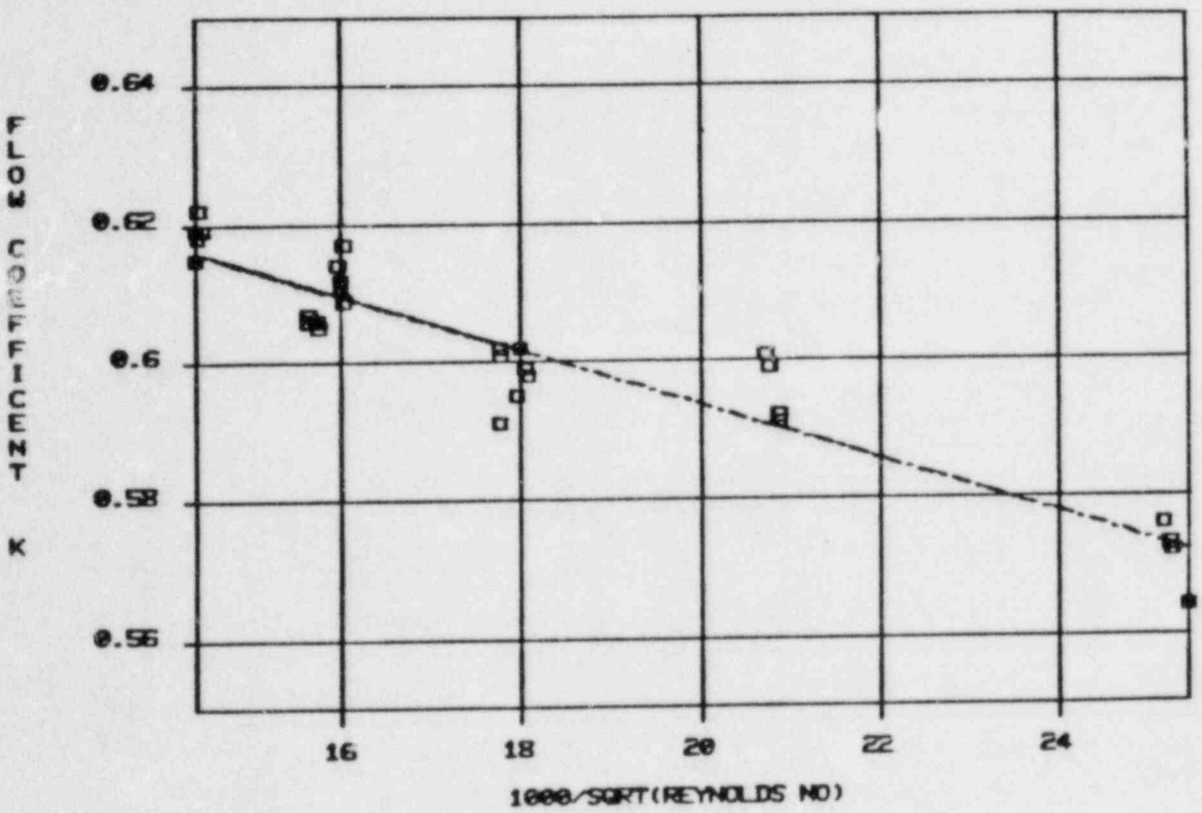

Figure 4-17 Low Range Feedwater Orifice Calibration Data and Curve Fit

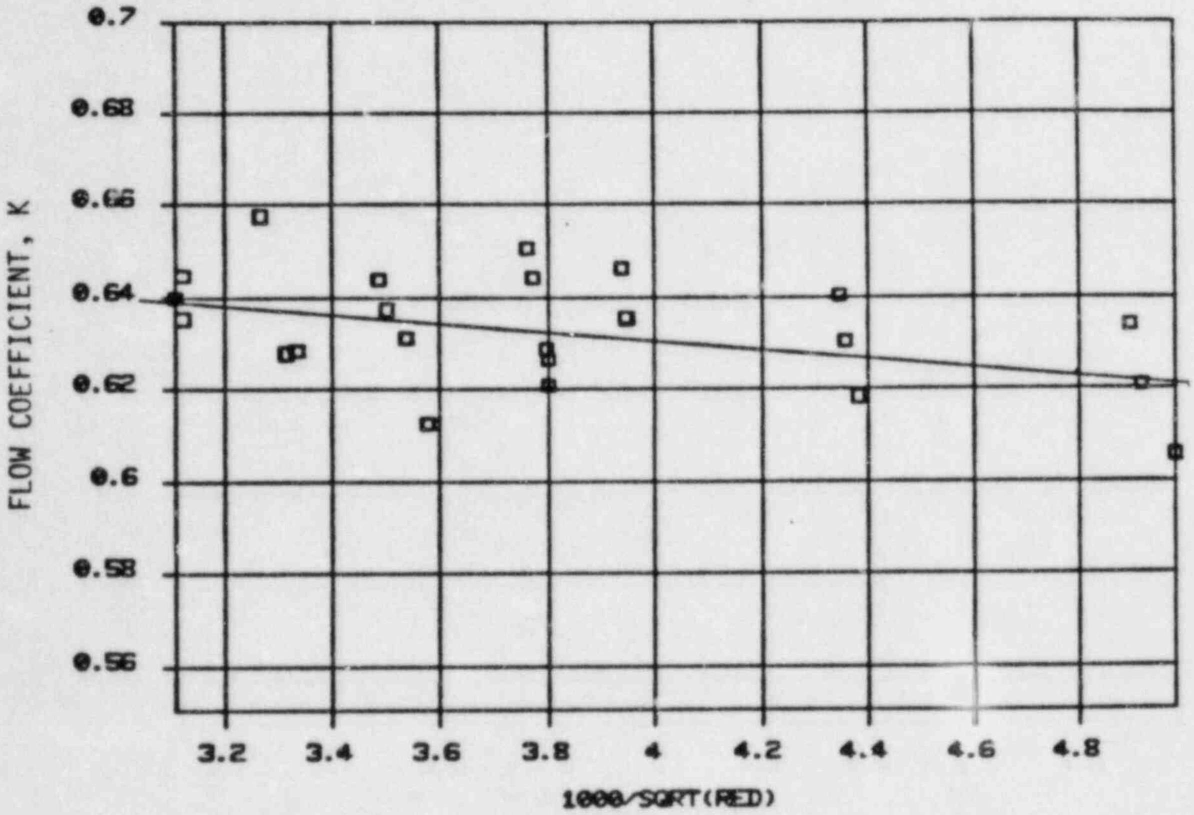

Figure 4-18 Low Range Steam Flow Orifice Calibration Data and Curve Fit

passing through the vacuum deaerator, until the content was less than 60cc/Kg H_2O. A compilation of the initial gas contents prior to each OTIS test is included in Table 4-7.

4.11 TEMPERATURE CALIBRATIONS

The objective of these GERDA tests was to calibrate the thermocouples (TCs) in the primary natural circulation loop, the pressurizer, and the secondary side of the steam generator. The pressurizer TCs were calibrated by isolating the pressurizer from the loop, and then establishing a saturated condition in the pressurizer. Nine (9) pressure plateaus, ranging from 200 to 1900 psia were established for the temperature calibration points. The TCs were calibrated to the saturation temperature corresponding to the measured pressure. The measured saturation pressure was corrected to correspond to the saturation pressure at the elevation of the TC.

Table 4-7

TOTAL GAS CONTENT PRIOR TO VOIDED PRIMARY OTIS TESTS

Test	Total Gas Content cc/Kg H_2O
210100	2.7
220100	11.0
220201	17.9
2202AA	15.5
2202BB	15.5
220304	18.3
220402	17.9
220503	3.5
220604	11.0
220756	11.7
220899	7.4
220999	16.4
221099	15.7
230199	13.4
230299	14.0

The primary-side TCs in the hot leg, steam generator, cold leg, and downcomer, and the secondary-side TCs in the steam generator were calibrated with forced circulation conditions in the primary loop, with the steam generator isolated. Heater power was adjusted to establish the desired steam generator inlet temperature. Using four (4) Resistance Temperature Detectors (RTDs) around the primary loop as standards, most of the primary-side TCs were calibrated to a temperature based on a linear interpolation between the RTDs. A total of thirteen (13) temperature plateaus, ranging from 350° to 575°F were established.

The calibration data (voltage and temperature standard) for each TC was recorded on a file. The data was then curve fit to a second-order polynomial equation using the POLYAA Comupter program. The coefficients for the polynomial equations were then entered into the database for each TC.

The reactor vessel thermocouples (except RVTC01) were not calibrated due to their close proximity to the heat source and/or due to their being located in a non-flow region. The thermocouple voltage versus temperature data used for the non-calibrated thermocouples were traceable to the National Bureau of Standards (NBS) Monograph 125. This is discussed further in the uncertainty analysis report[20].

4.12 LOOP VOLUME MEASUREMENTS VERSUS ELEVATION

The volume versus elevation for the four (4) primary regions - pressurizer, reactor vessel, active region, and in-active region, and for the secondary side of the steam generator was determined during GERDA Phase 0 testing. These volumes were obtained by filling the loop, isolating the component to be measured, then draining the cold water from the component into a weigh tank, periodically stopping the drain to record the weight drained and the differential pressure. A

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[20]Uncertainties for OTIS Instrumentation and Derived Calculations, RDD:85:4091-30:01:01, R.P. Ferron, August, 1984.

water level was calculated from the differential pressure and fluid temperature measurements. The detailed procedure and valve alignments for these volume checks are contained in the technical procedures ARC-TP-500 and ARC-TP-502.

The volume versus elevation for the pressurizer and reactor vessel are shown in Figures 4-19 and 4-20, respectively. Volume versus elevation for the active regions of the hot leg and the cold leg and downcomer are shown in Figures 4-21 and 4-22, respectively. The in-active regions of the hot leg, cold leg and the steam generator (primary) are shown in Figure 4-23. The OTSG secondary-side volume versus elevation is shown in Figure 4-24.

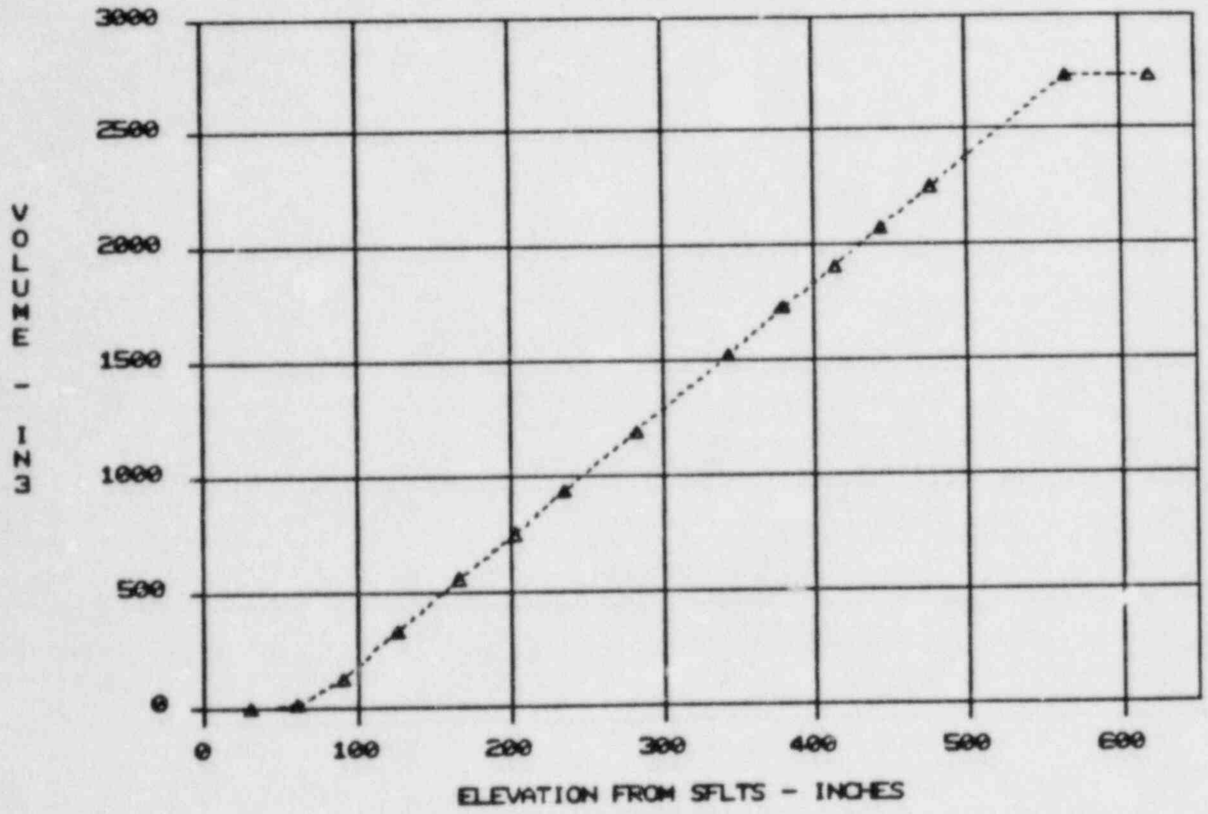

Figure 4-19 Pressurizer Volume Versus Elevation

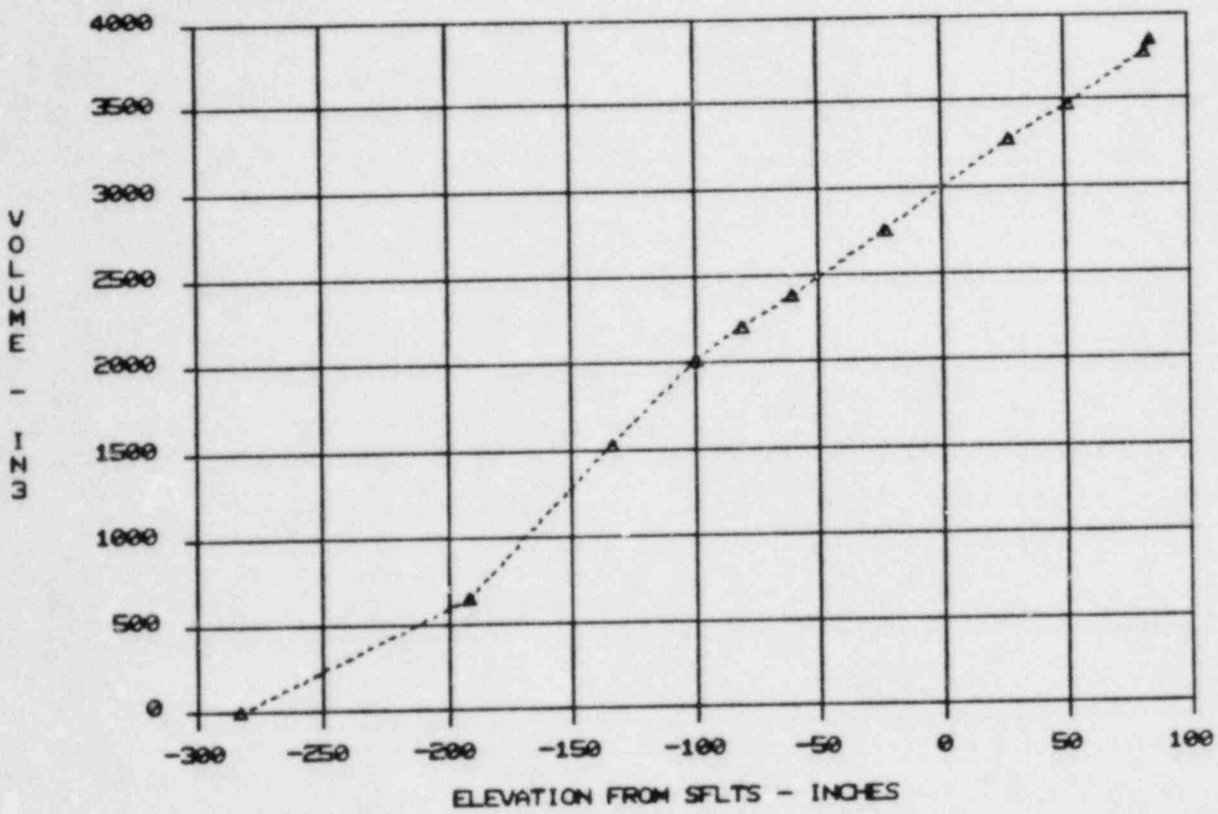

Figure 4-20 Reactor Vessel Volume Versus Elevation

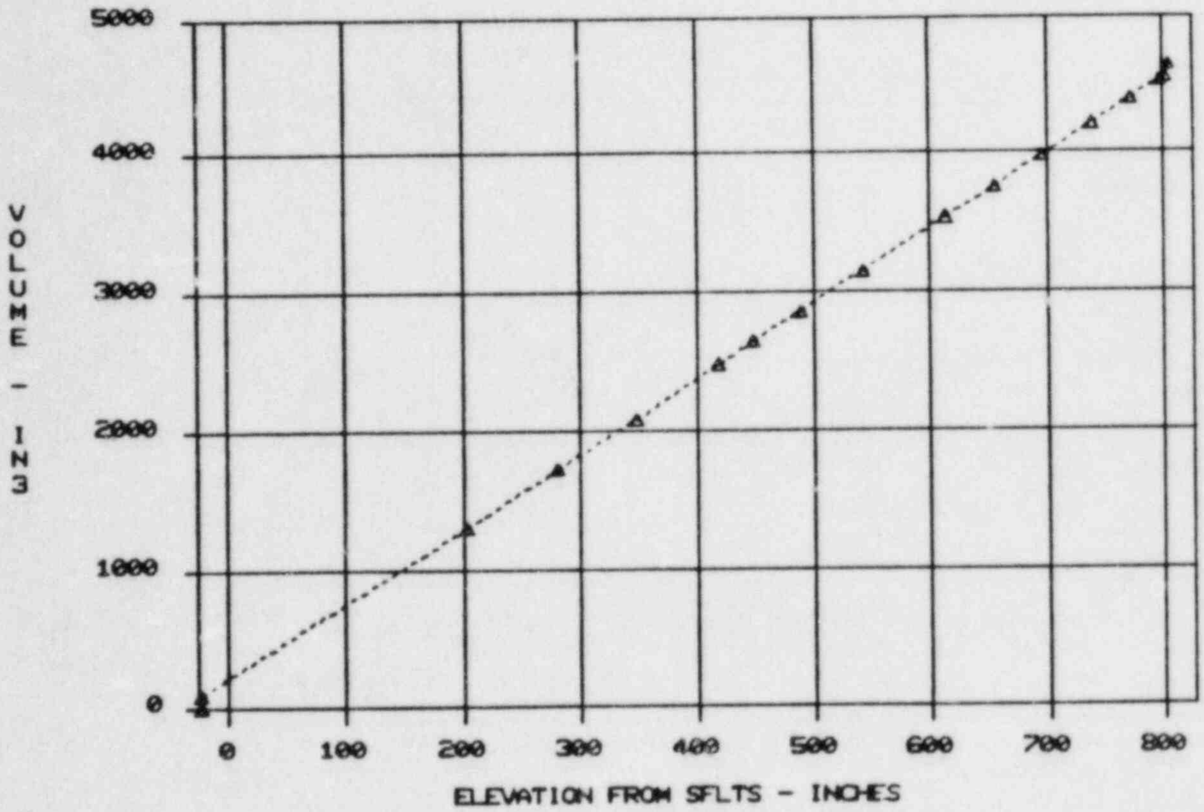

Figure 4-21 Hot Leg Active Region Volume Versus Elevation

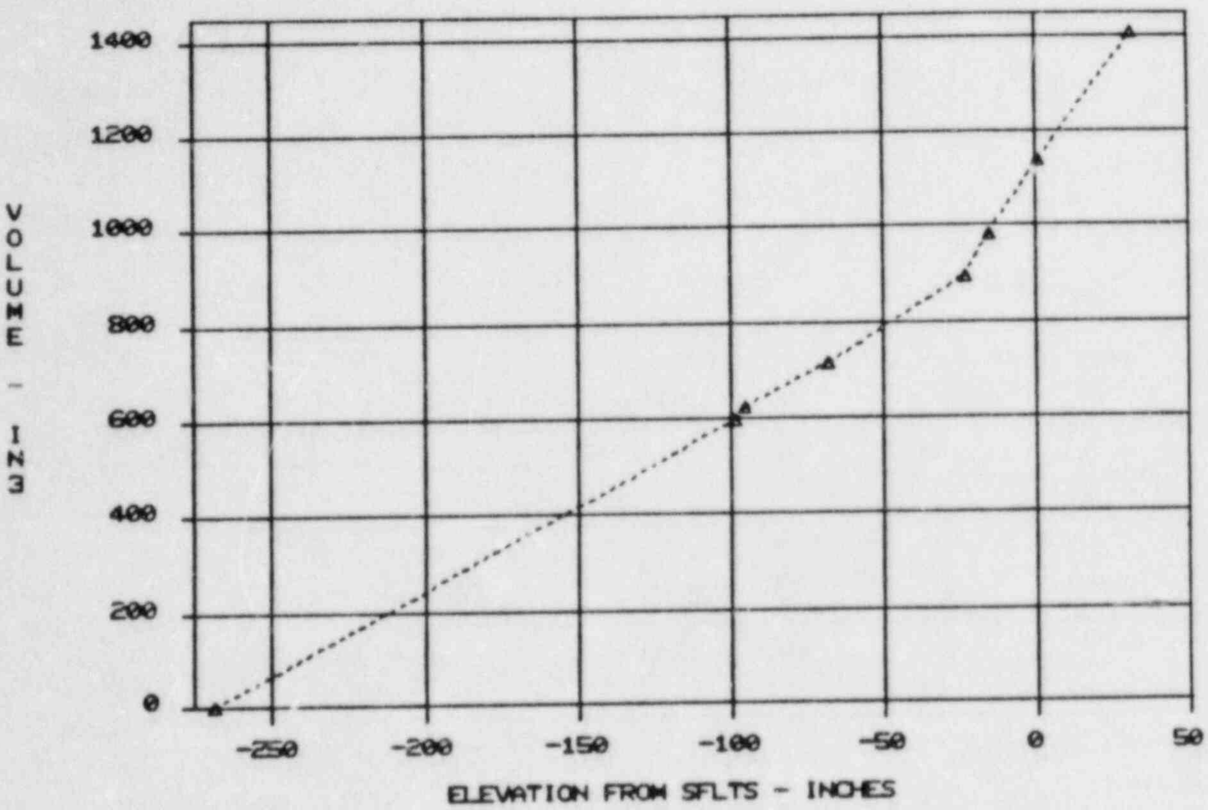

Figure 4-22 Cold Leg and Downcomer Active Region Volume Versus Elevation

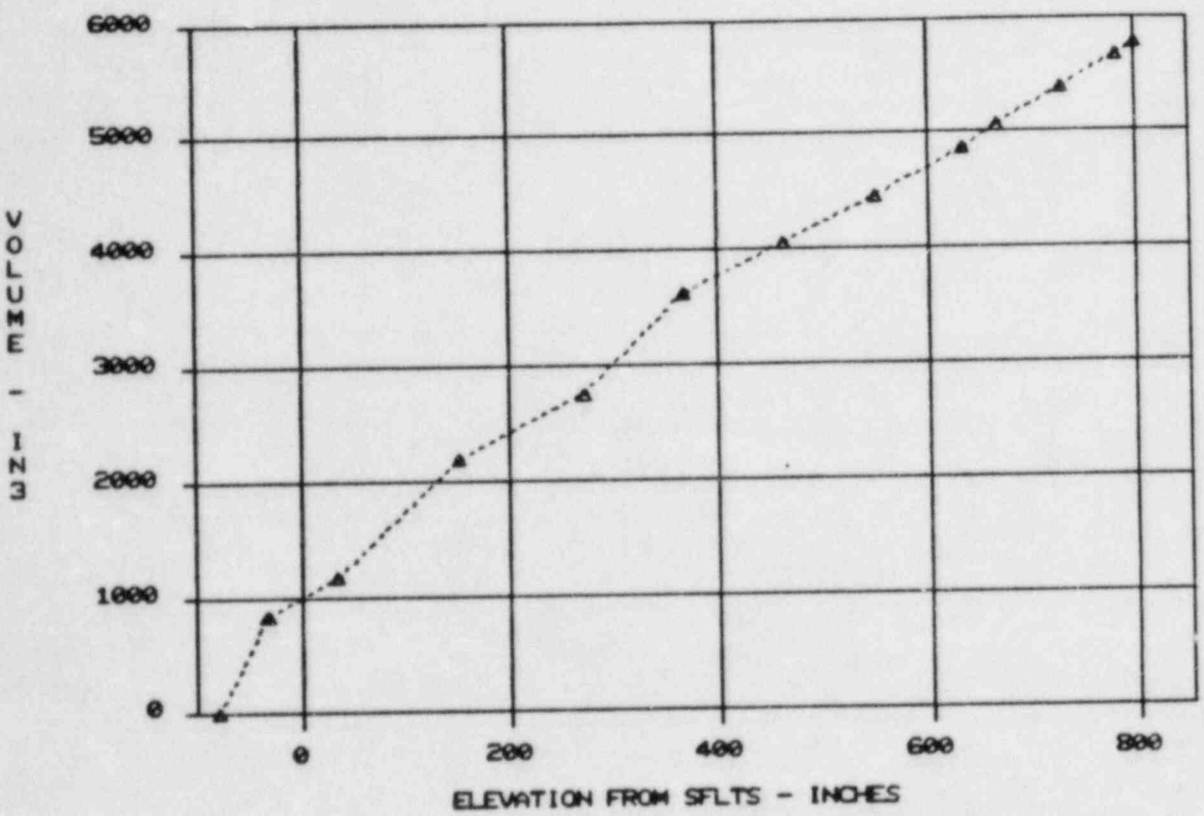

Figure 4-23 Steam Generator Primary, Hot Leg and Cold Leg In-Active Region Volume Versus Elevation

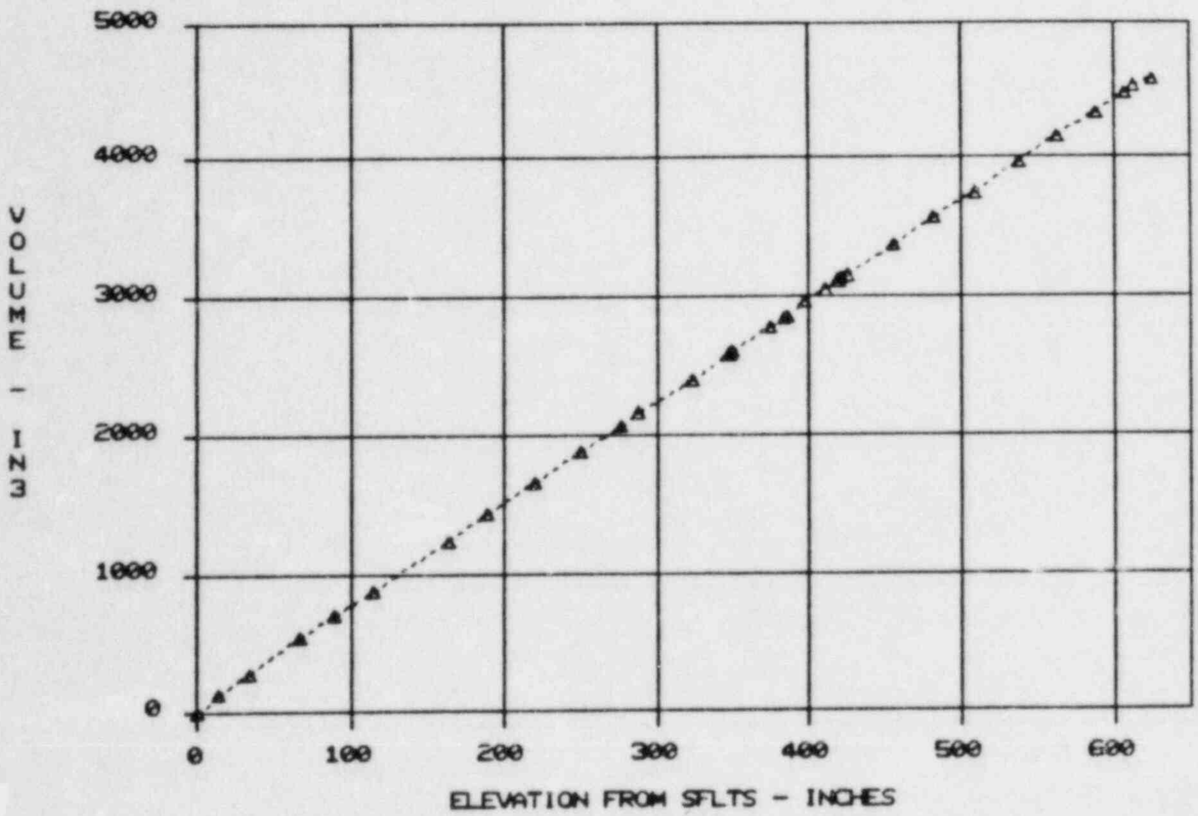

Figure 4-24 Steam Generator Secondary Volume Versus Elevation

Appendix A

OTIS Facility Drawings List

OTIS DRAWING LIST

MECHANICAL DRAWINGS

NOTE: The complete list of GERDA drawings is being used as a reference for the OTIS project!
##-Indicates Revision to Listing

DRAWING NUMBER		TITLE
		*** AUXILIARY FEEDWATER INJECTION BENCHSCALE TESTS ***
9303 D-1		Auxiliary Feedwater Injection (AFWI) Benchscale Test for Small Break Loss of Coolant Accident Tests - Model Side Panel
9409 B-0		Auxiliary Feedwater Injection (AFWI) Benchscale Test for Small Break Loss of Coolant Accident Tests - Test Loop
9410 B-0		Auxiliary Feedwater Injection (AFWI) Benchscale Test for Small Break Loss of Coolant Accident Tests - Model General Assembly
		*** SBLOCA FACILITY ***
9500 E-2		Details of MK-12 Hot Well, SBLOCA Facility
9501 E-3		Details and Assembly of MK-13, Feedwater Heater, SBLOCA Facility
9502 E-3		Sundyne Pump Piping Modifications for SBLOCA Test
9503 E-3		Feedwater Heater Piping Arrangements
9504 E-0		Secondary Low Pressure Clean-Up System Piping and Instrumentation Arrangement - SBLOCA Test
9505 E-6	##	OTIS Test - Reactor Vessel Bottom Section
9506 E-6	##	OTIS Test - Reactor Vessel Top Section
9507 D-1		SBLOCA Test - Reactor Vessel Bottom Flange

9508 D-1		SBLOCA Test - Reactor Vessel Bottom Head
9509 D-1		Steam Condensing Reservoir
9510 E-2		SBLOCA Test - Lower Plenum
9511 C-0		Special Nuts for Bottom Head
9512 E-1		SBLOCA Test - Reactor Vessel Heater Support
9513 E-0		Steam Condenser - SBLOCA
9514 E-0		Installation Assembly of Secondary Steam Condenser and LPCUS Heat Exchanger in Bay #19, Building "A"
9515 E-0		Arrangement of Condenser and Steam Piping System - SBLOCA
9516 E-4	##	Arrangement of Condenser and Steam Piping System - OTIS Facility
9517 E-1		Tower Water Hook-Up Steam Condenser - SBLOCA
9518 E-2		SBLOCA Test - Pressurizer Vessel
9523 E-0		SBLOCA Reactor Vessel Connection Box
9524 C-1		SBLOCA Test - Reactor Vessel Heater MK-2-A-13
9526 D-0		MK-47 Steam Mixer Detail - SBLOCA - Steam Piping
9527 E-4	##	"A" Generator Modifications - OTIS
9528 E-1		Installation Assembly of 19-Tube "A" Generator - SBLOCA
9529 D-2		Generator Vessel Support Stand - SBLOCA
9530 D-1		"A" Generator Modification Details - SBLOCA
9531 E-0		Arrangement and Details of Wireways SBLOCA Control Room - Bay 19 Extension Building "A" High Bay
9533 E-0		Arrangement & Details of Console Writing & Work Top - SBLOCA Control Room - Bay 19 Extension, Building "A", High Bay
9534 E-1		Arrangement and Details of Control Panel Equipment Support - SBLOCA Control Room - Bay 19 Extension - Building "A" - High Bay
9535 E-0		SBLOCA Test - Reactor Vessel Support
9536 E-0		SBLOCA Test - Reactor Vessel Support
9539 D-0		Primary Venting (Single-Phase) Heat Exchanger - SBLOCA

9541 D-1 90 Degree Pipe Bends for Hot Leg Piping - SBLOCA

9542 E-5 ## OTIS Test - Primary Forced Circulation Loop and Primary Cold Leg Piping

9543 D-2 ## OTIS Test - Primary Cold Leg Piping Penetration Details

9544 D-2 SBLOCA Test - Primary Cold Leg Piping Penetration Details

9545 D-0 Hot Leg View Port Section W/High Point Vent

9546 E-1 Building 'A' Bay 19 Extension Wireway Installation - SBLOCA Test

9547 E-1 Pressurizer Vessel Installation Arrangement - SBLOCA

9548 E-4 'A' Generator Penetrations for Conductivity Probes

9549 D-4 ## OTIS Test - Surge Line

9550 E-0 Feedwater Piping System - General Arrangement

9552 D-1 SBLOCA Test - RVVV Piping

9553 E-4 Primary Hot Leg Piping - SBLOCA

9554 D-0 Primary Hot Leg Piping - Details - SBLOCA

9555 D-0 Support Stand for Hot Leg and Cold Leg Piping - SBLOCA

9556 E-0 SBLOCA Test - Primary Forced Circulation Loop and Cold Leg Piping Supports

9557 D-0 SBLOCA Test - Primary Forced Circulation Loop and Cold Leg Piping Supports

9558 D-0 SBLOCA Test - Downcomer Support Detail

9559 D-0 2 Phase Primary Venting and Sampling System Schematic - SBLOCA

9560 E-0 SBLOCA Test - Lower Plenum Bypass Lines

9561 D-0 High Point Vent - Separator - SBLOCA

9562 D-0 P.O.R.V. - Separator 2 Phase Primary Venting and Sampling System - SBLOCA

9563 D-0 Overflow Stack Detail - SBLOCA - 2 Phase Primary Venting and Sampling System

9564 D-0 HPV - Separartor Installation and Piping - SBLOCA

9565 D-3 Displacement Tanks and P.O.R.V. Installation Assembly - SBLOCA - Primary Venting and Sampling System

9566 E-2 SBLOCA Test - Ultrsonic Flowmeter

9567 D-0		SBLOCA Test - Strainer Plate Detail
9569 C-1		SBLOCA Test - Downcomer Orifice Plate
9570 D-0		SBLOCA Test - Pressurizer Relief Valve Installation
9571 D-1		SBLOCA Test - Reactor Vessel Relief Valve Installation
9572 E-0		SBLOCA Test - High Pressure Injection and Spray Line Tubing Layout
9573 D-0		8" Overflow Pipe Installation and Tank Discharge Piping - SBLOCA - 2 Phase Primary Venting and Sampling System
9574 E-2	##	OTIS Test - Single-Phase Leak Location
9575 D-4	##	OTIS Test - Single-Phase Leak Flow Control Orifice
9576 C-0		SBLOCA Test - Vent Valve Installation
9578 B-0		SBLOCA Facility H.P.I. System Schematic
9579 D-0		Hot Leg Piping Supports - SBLOCA
9582 D-0		SBLOCA Test - Gas Sampling - Typ. for 2 Locations on Hot Leg Piping
9583 D-0		SBLOCA Test - Gas Addition Inlet Manifold
9584 D-0		SBLOCA Test - Gas Sampling - To Be Located in Top View Port Block on Hot Leg
9585 D-0		SBLOCA Test - Gas Sampling - Top of Reactor Vessel
9586 E-0		SBLOCA Test - Gas Addition NCG Supply Manifold
9587 C-0		Multi-Junction Thermocouple Support Locations - SBLOCA
9588 E-2		SBLOCA Test - Ground Floor DP and Pressure Transmitter Panel Board Arrangement
9589 E-0		SBLOCA Test - Ground Floor DP and Pressure Transmitter Panel Board Detail
9590 C-0		Flow Distribution Plate Detail, "A" Generator - SBLOCA
9591 B-0		Stud and Spacer for View Port - SBLOCA
9592 D-3	##	Conductivity Probe Details - OTIS
9593 D-0		SBLOCA Test - Second Deck DP and Pressure Transmitter Panel Board Detail
9594 E-1		SBLOCA Test - Second Deck DP and Pressure Transmitter Panel Board Arrangement

9595 D-1		Steam Orifice Plate - SBLOCA
9596 B-0		1" - 6000# Threadolet for SBLOCA Steam Generator
9597 B-0		1-1/4" - 6000# Sockolet and Plug for SBLOCA Steam Generator
9599 D-0		SBLOCA Test - Bulkhead Fitting Support Panel Detail
10009 D-1		SBLOCA Test - Pit DP and Pressure Transmitter Panel Board Arrangement
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10298 D-0		Downcomer Venturi Flowmeter Details - SBLOCA
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10706 D-0	##	OTIS Project - Cold Leg Orifice Location
10710 E-7	##	Assembly & Details of 19 Tube "A" Gen.
10857 D-0	##	OTIS Test - Branch Leak Connection
10868 C-0	##	OTIS Test - Reactor Vessel Vent Valve
SK 1996		Heater, Pressurizer for Babcock & Wilcox Co. - Watlow Electric Mfg. Co.
501-070-04		High Temperature Ultrasonic Flowmeter

4-5236-1 D-A	Proposed Hot Leg Probe Assembly
4-5236-5 C-0	Conductivity Probe Holders
C-SK-2200-611	Special Multipak Assembly
706125, Rev. 6 Sheet 1 of 3	Ass'y: Level Sensor, Miniature B & W Simulated Reactor Test System - Single Switch Point
706125, Rev. 6 Sheet 2 of 3	Level Sensor Miniature B & W Simulated Reactor Test System - Dual and Single Switch Point
706125, Rev. 6 Sheet 3 of 3	Ass'y: Level Sensor, Miniature B & W Simulated Reactor Test System - Single Switch Point
D-489190	Rockwell Edwards Forged Steel Univalve Globe Stop Valve - Class 1690

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9520 B-0 Sheet J SBLOCA Test - Reactor Vessel Controls - Electrical

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9520 B-4 Sheet M ** OTIS Test - Reactor Vessel Controls - Electrical

9520 B-3 Sheet N SBLOCA Test - Reactor Vessel Controls - Electrical

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9520 B-2 Sheet P		SBLOCA Test - Pressurizer Controls - Electrical
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9520 B-4 Sheet R	##	OTIS Test - Pressurizer Controls - Electrical
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9520 B-3 Sheet T	##	OTIS Test - Hot Leg Controls and Primary Circulation Pump Controls - Electrical
9520 B-0 Sheet U		SBLOCA Test - Facility Low Pressure Clean-Up System Controls - Electrical
9520 B-1 Sheet V		SBLOCA Test - Facility Low Pressure Clean-Up System and Deaerator Controls - Electrical
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9520 B-2 Sheet X		SBLOCA Test - HPI Controls - Electrical
9520 B-1 Sheet Y		SBLOCA Test - HPI Make-Up Pump Controls - Electrical
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9520 B-2 Sheet AA	##	OTIS Test - Hot Leg Controls 5-8 - Electrical
9520 B-2 Sheet AB	##	OTIS Test - Steam Generator Level Controls - Electrical
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9520 B-3 ## Sheet AF	OTIS Test - Secondary Steam Pressure Controls - Electrical
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9520 B-2 Sheet AI	SBLOCA Test - Secondary Circulation Pump Controls and Hot Well Controls - Electrical
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9520 B-0 Sheet AK	SBLOCA Test - Feedwater Temperature Controls - Electrical
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9520 B-3 Sheet AO	SBLOCA Test - General Instrumentation Power Connections - Electrical
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9520 B-2 Sheet AQ	SBLOCA Test - Flowmeters - Electrical
9520 B-5 Sheet AR	SBLOCA Test - General Instrumentation - Electrical
9520 B-3 Sheet AS	SBLOCA Test - Heated RTD Connections - Electrical
9520 B-1 Sheet AT	SBLOCA Test - 120 V AC Outlets - Electrical
9520 B-1 Sheet AU	SBLOCA Test - Annunciator - Electrical
9520 B-2 Sheet AV	SBLOCA Test - Annunciator - Electrical

9520 B-1 Sheet AH		SBLOCA Test - Annunciator - Electrical
9520 B-5 Sheet AX	**	OTIS Test - Transmitter Connections - B&W Model 7601 Power Supply - Electrical
9520 B-2 Sheet AY		SBLOCA Test - Transmitter Connections - B&W Model 7601 Power Supply - Electrical
9520 B-3 Sheet AZ		SBLOCA Test - Transmitter Connections - B&W Model 7601 Power Supply - Electrical
9520 B-2 Sheet BA		SBLOCA Test - Electrical
9520 B-2 Sheet BB		SBLOCA Test - Multi-Point Recorder Signal Connections - Electrical
9520 B-2 Sheet BC		SBLOCA Test - RTD Connection Box - Electrical
9520 B-5 Sheet BD	**	OTIS Test - Reference Junction Thermocouple Signal Channels - Electrical
9520 B-1 Sheet BE		SBLOCA Test - Computer Interface Cable Layout - Electrical
9520 B-0 Sheet BF		SBLOCA Test - Analogic Master Chassis - 0 Configuration - Electrical
9520 B-0 Sheet BG		SBLOCA Test - Analogic Chassis - 1 Configuration - Electrical
9520 B-1 Sheet BH		SBLOCA Test - Analogic Chassis - 2 Configuration - Electrical
9520 B-2 Sheet BI		SBLOCA Test - Analogic Chassis - 3 Configuration - Electrical
9520 B-1 Sheet BJ		SBLOCA Test - Analogic Chassis - 4 Configuration - Electrical
9520 B-0 Sheet BK		SBLOCA Test - Analogic DAS - Local and Program Channel Addresses - Electrical
9520 B-0 Sheet BL		SBLOCA Test - Analogic DAS - Local and Program Channel Addresses - Electrical
9520 B-0 Sheet BM		SBLOCA Test - Analogic DAS - Local and Program Channel Addresses - Electrical

9520 B-0 Sheet BN	SBLOCA Test - Analogic DAS - Local and Program Channel Addresses - Electrical
9520 B-0 Sheet BO	SBLOCA Test - Analogic DAS - Local and Program Channel Addresses - Electrical
9520 B-0 Sheet BP	SBLOCA Test - Analogic DAS - Local and Program Channel Addresses (Future) - Electrical
9520 B-0 Sheet BQ	SBLOCA Test - Analogic DAS - Local and Program Channel Addresses (Future) - Electrical
9520 B-0 Sheet BR	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-0 Sheet BS	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BT	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BU	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BV	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BW	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BX	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet BY	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-2 Sheet BZ	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-4 Sheet CA	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CB	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-2 Sheet CC	SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CD	SBLOCA Test - Patch Panel Connections - Electrical

9520 B-3 Sheet CE		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CF		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-2 Sheet CG		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CH		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-2 Sheet CI		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CJ		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-0 Sheet CK		SBLOCA Test - Patch Panel Connections - Electrical
9520 B-1 Sheet CL		SBLOCA Test - Gas Sample: Hot Leg (U-Bend) Controls - Electrical
9520 B-2 Sheet CM	##	OTIS Test - Gas Sample: Hot Leg (Main) Controls - Electrical
9520 B-1 Sheet CN		SBLOCA Test - Gas Sample: Steam Gen. Prim. Outlet Controls - Electrical
9520 B-2 Sheet CO	##	OTIS Test - Gas Sample: Reactor Vessel Controls - Electrical
9520 B-3 Sheet CP	##	OTIS Test - 2-Phase Vent System Controls - Electrical
9520 B-4 Sheet CQ		SBLOCA Test - 2-Phase Vent System Controls - Electrical
9520 B-4 Sheet CR		SBLOCA Test - 2-Phase Vent System Controls - Electrical
9520 B-3 Sheet CS		SBLOCA Test - 2-Phase Vent System
9520 B-2 Sheet CT		SBLOCA Test - Gas Addition System - Electrical
9520 B-2 Sheet CU		SBLOCA Test - Gas Addition System Valve Switch Connections - Electrical

9520 B-4 Sheet CV	**	OTIS Test - 1-Phase Vent System - Electrical
9520 B-4 Sheet CW	**	OTIS Test - 1-Phase Vent System Valve Switch Connections - Electrical
9520 B-3 Sheet CX	**	OTIS Test - Vent and Spray Valves - Electrical
9520 B-2 Sheet CY	**	OTIS Test - Digital Input Chart - Electrical
9520 B-6 Sheet CZ	**	OTIS Test - Digital Input Chart - Electrical
9520 B-3 Sheet DA	**	OTIS Test - Wire Number Listing - Electrical
9520 B-7 Sheet DB	**	OTIS Test - Wire Number Listing - Electrical
9520 B-0 Sheet DC		Number Listing - SBLOCA - Electrical
9520 B-1 Sheet DD		Cable Number Listing - SBLOCA - Electrical
9520 B-4 Sheet DE (1 of 2)	**	Cable Number Listing - OTIS - Electrical
9520 B-1 Sheet DE (2 of 2)	**	OTIS Test - Cable Number Listing - Electrical
9520 B-0 Sheet DF		SBLOCA Test - Conductivity Probe Connections
9520 B-0 Sheet DG		SBLOCA Test - Conductivity Probe Connections
9520 B-0 Sheet DH		SBLOCA Test - Conductivity Level Probe Connections - Electrical
9520 B-0 Sheet DI	**	OTIS Test - Reactor Vessel Guard Heater Controllers - Electrical
9520 B-2 Sheet DJ	**	OTIS Test - Heater Power Control Reactor Vessel & Surge Line - Electrical
9520 B-0 Sheet DK	**	OTIS Test - Reactor Vessel & Surge Line Guard Heater Controls - Electrical
9520 B-1 Sheet DL	**	OTIS Test - 1 Phase Vent System Valve Switch Connections - Electrical

Appendix B

Instrumentation and Valve Designation

The instrumentation and valves in OTIS are identified by a six or seven character string. The first two letters identify the system of which the instrument or valve is a part, the second two letters identify the instrument or valve type, and the last two or three numbers are a unique number for the particular instrument or valve. Numbers between 01 and 99 are used to identify "test data instruments". Three digit numbers, 100 or greater, are used to identify "loop operation instruments". For example, SSDP02 stands for Steam Generator Secondary (SS), Differential Pressure (DP), instrument 02. RVCV03 stands for Reactor Vessel (RV) Control Valve (CV), number 03. A complete listing of the abbreviations used are contained in Tables B-1 and B-2.

Table B-1

ABBREVIATIONS FOR LOOP COMPONENTS

Loop Component	Abbreviation
Steam Generator - Primary	SP
Steam Generator - Secondary	SS
Steam Generator - Metal	SM
Reactor Vessel	RV
Downcomer	DC
Pressurizer	PR
Facility Water Supply and Clean-Up System	HP
Secondary Low Pressure Clean-Up System	SC
Primary Venting 1-Ø	V1
Primary Venting 2-Ø	V2
Primary Forced Circulation	PC
Cold Leg	CL
Hot Leg	HL
High Pressure Injection	HP
Secondary Forced Circulation	SF
Feedwater Heater	SF
Steam Piping	PS
Feedwater Piping	FP
Gas Addition	GA
Gas Sampling	GS

Table B-2

ABBREVIATION FOR INSTRUMENTS AND VALVES

Instrument or Hardware	Abbreviation
Thermocouple	TC
Resistance Temperature Detector	RT
Differential Temperature	DT
Thermometer	TH
Pressure	PR
Differential Pressure	DP
Flow Rator	FR
Turbine Meter	TM
Orifice	OR
Conductivity Probe	CP
Watt Meter	WM
Control Valve	CV
Hand Valve	HV
Safety Valve	SV
Limit Switch	LS
Accumulating Flow Meter	AC
Oxygen Monitor	OX

Appendix C

OTIS Instrument List

*** INSTRUMENT LIST ***

TODAYS DATE: 16-JULY-84

COMPONENT: STEAM GENERATOR

REFERENCE DRAWINGS: 9527E4,9548E4,9553E4,9587C0

INSTRUMENT IDENT (RVSD)	INSTRUMENT IDENT (NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED(1)	DESIGNED	INSTALLED	COMMENT
	SPPR01		53'-1-1/2"	53'-1 3/4"	9553E4
	SPRT01	53'-1"	53'-2 1/2"	53'-1 3/4"	9553E4
	SPRT02	53'-1"	53'-1 1/2"	53'-3/4"	9553E4
	SSTC25	49'-10"	49'-9"	49'-9 1/2"	
03/23/83	SPTC01			47'-1/4"	THE INSTALLED ELEVATION
	SSTC23	47'-0"	47'-0"	47'-1/4"	FOR ALL SMTC & SPTC'S
	SSTC24	47'-0"	47'-0"	47'-1/4"	WAS DETERMINED FROM
	SSTC21	44'-2"	44'-2"	44'-2 1/4"	PENETRATION MEASUREMENTS
03/23/83	SSTC22	44'-2"	44'-2"	44'-2 "	MINUS 3" BASED ON DRAWING
	SMTC06	44'-2"	44'-2"	44'-2 1/2"	KL-136649-6
	SSTC19	41'-2"	41'-3"	41'-3"	
	SSTC20	41'-2"	41'-3"	41'-3"	
	SPTC02			38'-2"	
	SSTC17	38'-2"	38'-2"	38'-2"	
	SSTC18	38'-2"	38'-2"	38'-2"	
	SMTC05	38'-2"	38'-2"	38'-2"	
	SPTC03			35'-3 3/4"	
	SSTC15	35'-5"	35'-4"	35'-4"	
	SSTC16	35'-5"	35'-4"	35'-4"	
	SSTC11	29'-2"	29'-3"	29'-2 3/4"	
	SSTC12	29'-2"	29'-3"	29'-2 3/4"	
	SMTC03	29'-2"	29'-3"	29'-3"	
	SSTC09	25'-4"	26'-4"	26'-3 1/2"	
	SSTC10	25'-4"	26'-4"	26'-3 1/2"	
	SMTC02	25'-4"	26'-4"	26'-3 1/2"	
	SSTC08	23'-2"	23'-2"	23'-1 1/2"	
	SSTC07	20'-2"	20'-2"	20'-1 1/2"	
	SMTC01	20'-2"	20'-2"	20'-1 1/2"	
	SPTC04		17'-4"	17'-3 1/2"	
	SSTC06	17'-4"	17'-4"	17'-3 1/2"	
	SSTC05	14'-2"	14'-2"	14'-1 1/2"	
	SSTC04	11'-1"	11'-1"	11'-3/4"	
	SPTC05		8'-1"	8'-7/8"	
	SSTC03	8'-1"	8'-1"	8'-7/8"	
	SSTC02	4'-11"	4'-11"	4'-10 7/8"	
	SSTC01	1'-6"	1'-6"	1'-6"	
	SPRT03	-2'-1"	-2'-9 1/4"	-2'-9 3/4"	9542E5

	SPRT04	-2'-2"	-2'-11 1/4"	-2'-11 1/4"	9542E5
	SPPT01		-24"		9527E4 PT#3 (ON NOZ)
01/30/84	SPTC16		-0.5"		9527E4 (ON NOZ TC)
	SPPT02		-24"		9527E4 PT#1 (OFF NOZ)
01/30/84	SPTC18		-0.5"		9527E4 (OFF NOZ TC)
	SPPT03		-24"		9527E4 PT#2 (OPP NOZ)
01/30/84	SPTC17		-0.5"		9527E4 (OPP NOZ TC)
	SPTC06		23'-1-3/8"		9567C0,9527E4
	SPTC07		30'-1-3/8"		SPTC06 TO SPTC15
	SPTC08		35'-1-3/8"		IN "NW" TUBE(PLANT "SW")
	SPTC09		39'-1-3/8"		MJ TC "ON NOZZLE"
	SPTC10		43'-1-3/8"		CS GORDON TC#3
	SPTC11		47'-1-3/8"		
	SPTC12		49'-1-3/8"		
	SPTC13		50'-1-3/8"		
	SPTC14		50'-7-3/8"		
	SPTC15		51'-1-3/8"		
	SSCP14		21'-1"	21'-1/2"	9548E4 REF PROBE
	SSCP01	35'-5"	35'-7"	35'-6 1/2"	9548E4
	SSCP02	34'-6"	34'-6"	34'-5 1/2"	
	SSCP03	34'-0"	34'-0"	33'-11 1/2"	
	SSCP04	33'-6"	33'-6"	33'-5 1/2"	
	SSCP05	33'-0"	33'-0"	32'-11 1/2"	
	SSCP06	32'-8"	32'-7"	32'-6 1/2"	
	SSCP07	32'-0"	32'-0"	31'-11 1/2"	
	SSCP08	31'-6"	31'-6"	31'-5 1/2"	
	SSCP09	31'-0"	31'-0"	30'-11 3/4"	
	SSCP10	30'-6"	30'-6"	30'-5 1/2"	
	SSCP11	30'-0"	30'-0"	29'-11 1/2"	
	SSCP12	29'-6"	29'-6"	29'-5 3/4"	
	SSCP13	29'-0"	29'-0"	28'-11 1/2"	
	SSDP01		32'-0"	32'-3 3/4"	REMOVED SSTC14
	SSDP01		00'-0"	0'-0"	SFLTS
	SSDP02		51'-7-1/4"	51'-4"	STEAM LINE
	SSDP02		00'-0"	0'-0"	SFLTS
	SSDP03		35'-4"	35'-3 3/4"	
	SSDP03		23'-2"	23'-1 1/2"	9548E4
	SSDP04		35'-4"	35'-3 3/4"	
	SSDP04		32'-0"	32'-3 3/4"	
	SSDP05		32'-0"	32'-3 3/4"	
	SSDP05		29'-3"	29'-2 1/2"	9548E4
	SPDP01		53'-1-1/2"	52'-11 3/4"	9553E4 SG INLET
03/23/83	SPDP01		-2'-9-1/4"	-2'-9 1/4"	9542E3 SG OUTLET
	SSDP100				SG LEVEL IN-CONTROL ROOM
03/31/83	SSDP02			51'-3"	HOT DIMENSION BTWN TAPS @ SSTC01=501.4F SSTC25=508.9F
03/31/83	SPDP01			55'-10 1/2"	HOT DIMENSION BTWN TAPS @ SPRT01=510.5F SPRT03=500.2F

COMPONENT: REACTOR VESSEL

REFERENCE DRAWINGS: 9505E6,9506E6,9510E2

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	RVTC01	-23'-8"	-23'-8 3/4"	-23'-8 3/4"	FLUID,BOTTOM PIPE
	RVTC02	-19'-2"	-19'-1"	-19'-1 1/2"	FLUID
	RVWM01				
	RVTC03	-15'-6"	-16'- 3/8"	-16'-1/2"	SKIN
04/05/83	RVTC100		-14'-6"		HEATER TC
	RVTC103	-14'-4"	-13'-11 5/8"	-13'-11 3/4"	HI SKIN TEMP(WAS RVTC04)
04/05/83	RVTC101		-12'-2"		HEATER TC
	RVTC05	-12'-10"	-11'-10 7/8"	-11'-11"	SKIN
	RVTC06	-11'-2"	-9'-10 1/8"	-9'-10 1/4"	SKIN
	RVTC102		-8'-7 1/2"	-8'-8"	HI FLUID TEMP
	RVTC07	-8'-10"	-8'-3 1/2"	-8'-3 7/8"	FLUID
	RVTC10	0'-8"		0'-7 1/2"	9552D1 RVVV LINE,DC SIDE
	RVTC09	0'-10"		0'-7 1/2"	9552D1 RVVV LINE,RV SIDE
	RVTC104				HEATER TC
	RVTC105				HEATER TC
	RVTC106				HEATER TC
	RVTC107				HEATER TC
	RVTC108			-23'-5-1/4"	FLUID,TOP CROSSOVER PIPE
	RVPP01	7'-2"	7'-1 3/8"	7'-5/8"	
	RVTC08	7'-2"	6'-10 3/8"	6'-9 3/4"	FLUID
	RVCP02	-2'-4"	-2'-5"	-2'-5"	RV-HL
	RVCP01	-1'-6"	-1'-4 5/8"	-1'-5"	RV-HL
	RVCP04		0'-6 19/32"	0'-6 5/8"	RVVV
	RVCP03		0'-7 29/32"	0'-8"	RVVV
	RVCP05		-9'-1 1/2"	-8'-11"	9506E6 REF PROBE
	RVDP01		7'- 5/8"	7'-5/8"	RV TOP
	RVDP01		-1'-11"	-1'-11"	RV-HL
	RVDP02		-1'-11"	-1'-11"	RV-HL
	RVDP02		-8'-1/2"	-8'-3/4"	CORE TOP
	RVDP03		0'-7 1/4"	0'-7 1/2"	RVVV
	RVDP03		0'-7 1/4"	0'-7 1/2"	RVVV
	RVDP04		-8'-1/2"	-8'-3/4"	CORE TOP
	RVDP04		-16'-1/2"	-16'-3/4"	CORE BOTTOM
	RVDP05		7'-5/8"	7' 5/8"	RV TOP
	RVDP05		-16'-1/2"	-16'-3/4"	CORE BOTTOM
	RVLS01				RVVV LIMIT SWITCH
	RVRF01		3'-11 3/4"	3'-11 1/2"	SWID HTR VOLTAGE
	RVRT01		3'-11 3/4"	3'-11 1/2"	SWID REF RTD
	RVLS02		3'-11 3/4"	3'-11 1/2"	SWID S/W IND
	RVLS03		3'-11 3/4"	3'-11 1/2"	SWID FAILURE IND
	RVHR01		3'-11 3/4"	3'-11 1/2"	HRTD DT
	RVHR02			-17'-5 1/2"	STD HRTD DT
	RVRF02			-17'-5 1/2"	STD HTR VOLTAGE
	RVRT02			-17'-5 1/2"	STD REF RTD
	RVLS04			-17'-5 1/2"	STD S/W IND
	RVLS05			-17'-5 1/2"	STD FAILURE IND

	RVRT03			-17'-5 1/2"	STD SAT TEMP
	RVPR100				RV PRESSURE-CONTROL ROOM
03/23/83	RVLS06				RVVV CLOSED INDICATION
03/31/83	RVDP05			23'-2 7/16"	HOT DIMENSION BTWN TAPS
					@ DCRT01=497.6F
					RVTC07=515.2F
					RVTC08=479.1F
04/13/84	RVDT01			-4.0"	DATA
04/13/84	RVDT101			-4.0"	LOOP
04/13/84	RVDT02			4'-10"	DATA
04/13/84	RVDT102			4'-10"	LOOP
04/13/84	RVTC11			-4.0"	METAL (9506E6)
04/13/84	RVTC12			4'-10"	METAL (9506E6)

COMPONENT: PRESSURIZER AND SURGE LINE

REFERENCE DRAWINGS: 9518E2,9549D4

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	PRTC101		7'-11 1/2"	7'-11 1/2"	SKIN
	PRTC100		9'-7 1/4"	9'-7 1/4"	HI FLUID TEMP
	PRDT01			12'-2 3/4"	DATA
	PRDT101			12'-3 3/4"	LOOP
	PRTC01	11'-0"	21'-10 3/4"	21'-10 1/2"	FLUID
	PRTC04	11'-0"	17'-5 1/2"	17'-11 1/2"	SKIN
	PRDT02			27'-1 3/4"	DATA
	PRDT102			27'-1 3/4"	LOOP
	PRTC02	23'-6"	34'-2 1/4"	34'-2"	FLUID
	PRTC05	23'-6"	36'-5 1/2"	36'-9 1/2"	SKIN
	PRTC102		26'-11 1/2"	27'-1 3/4"	SKIN (RECORDER)
	PRDT03			42'-9"	DATA (BEFORE 4/3/84 ONLY)
	PRDT103			42'-9"	LOOP
	PRTC03	42'-10"	46'-5 3/4"	46'-5 3/4"	FLUID
	PRTC06	42'-10"	45'-11 1/2"	46'-5 3/4"	SKIN
	PRPR01	46'-10"	40'-5 3/4"	40'-5 3/4"	
	PRDP01	46'-10"	40'-5 3/4"	40'-5 3/4"	TOP OF PP
	PRDP01		2'-5 1/2"	2'-5 3/4"	9549D4 SURGE LINE
	PRHP01		21'-4 3/4"	21'-5 1/2"	SWID DT
	PRRF01			21'-5 1/2"	SWID HTR VOLTAGE
	PRRT01			21'-5 1/2"	SWID REF RTD
	PRLS01			21'-5 1/2"	SWID S/W IND
	PRLS02			21'-5 1/2"	SWID FAILURE IND
	PRPR100				PRESSURIZER PRES. CONTROL
01/30/84	PRDT04			3'-1 1/4"	SURGE LINE DT (DATA)
01/30/84	PRDT104			3'-1 1/4"	SURGE LINE DT (LOOP)
04/05/83	PRTC07			2'-6 3/8"	SKIN,DATA
03/31/83	PRDP01			38'-1 1/8"	HOT DIMENSION BTWN TAPS
					@ PRTC01=585.7F
					PRTC03=586.0F
04/13/84	PRTC08			12'-2 3/4"	METAL
04/13/84	PRTC09			27'-1 3/4"	METAL
04/13/84	PRTC10			42'-9"	METAL
04/13/84	PRTC11			3'-1"	METAL (SURGE LINE)

COMPONENT: HPI AND FLPCUS

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	HPPR101				
	HPPR100				
	HPTH100				
	HPCP100				
	HPCP101				
	HPPS100				
	HPPR105				
	HPPR106				
	HPPR107				
	HPPR108				
	HPTM01				
	HPTC01				FLUID TEMP
	HPTC101				ELLIOT TANK
	HPTC102				DEAERATOR
	HPTM02				
	HPTM03				
	HPTH101				
	HPPR102				
	HPPR103				
	HPTC100				
	HPAC100				
	HPPR104				
	HPAC01				TOTALING FLOW

COMPONENT: PRIMARY CIRCULATION LOOP

REFERENCE DRAWING: 9542E5

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	PCTC100		-78"		UPSTRM PUMP
	PCTC101		-58 3/4"		DWNSTRM PUMP
	PCTC102				COOLING WATER OUTLET
	PCDP100				
	PCOP100				
	PCPR102				
	PCDP101				
	PCPS100				
	PCPR100		-78"		UPSTRM PUMP
	PCPR100				
	PCPR101		-58 3/4"		DWNSTRM PUMP

COMPONENT: COLD LEG PIPING

REFERENCE DRAWING: 9542E5,9543D2,9544D2,10697C0,10706DC

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
6/8/84	CLTC01	-4'-10"	-4'-9"	-4'-8 5/8"	FLUID
	CLTC02	-4'-10"	-4'-6"	-4'-6"	FLUID
	CLUS01	-1'-10"	-4'-3/4"		
	CLTC03	-0'-10"	-0'-3 1/2"	-0'-1 3/4"	FLUID
	CLTC04	1'-10'	1'-9"	1'-9"	FLUID
	CLTC05	-0'-6"	-0'-6"	-0'-5 3/4"	FLUID
	CLDP01		2'-7 5/16"	2'-7 3/4"	CL-SD
	CLDP01		-8'-3"	-8'-3"	DC
6/ 8/84	CLDP02		-5'-4 1/2"	-5'-4 1/2"	CLC LO RANGE (UPPER TAP)
6/ 8/84	CLDP02		-5'-7 1/16"	-5'-7 1/16"	CLC LO RANGE (LOWER TAP)
	CLDP03		2'-7 5/16"	2'-7 3/4"	CL-SD
6/ 8/84	CLDP03		-4'-5 3/8"	-4'-5 3/8"	CL US LOWER DRAIN
04/05/83	CLDP04		-5'-4 1/2"	-5'-4 1/2"	CLC HI RANGE (UPPER TAP)
04/05/83	CLDP04		-5'-7 1/16"	-5'-7 1/16"	CLC HI RANGE (LOWER TAP)
	CLLS101				CLCV01 OPEN
	CLLS102				CLCV01 MAX
	DCTC01	-3'-2"	-3'-3"	-3'-3"	FLUID
	DCTC02	-10'-0"	-9'-9"	-10'-0"	FLUID
	DCRT01		-20'- 1/4"	-20'-0"	
05/09/83	DCDP01		-20'-91/2"	-12'-8"	RV DC VENTURI LO RANGE
05/09/83	DCDP01		-20'-11 1/2"	-13'-2"	RV DC VENTURI LO RANGE
	DCDP02		-8'-3"	-8'-3"	DC
	DCDP02		-16'-5"	-16'-3/4"	9505E6 CORE BOTTOM
05/09/83	DCDP03			-12'-8"	RV DC VENTURI HI RANGE
05/09/83	DCDP03			-13'-2"	RV DC VENTURI HI RANGE

COMPONENT: SECONDARY LOW PRESSURE CLEAN-UP SYSTEM

REFERENCE DRAWING: 9504E0

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	SCPP104				
	SCPR105				
	SCFR102				
	SCTS100				
	SCTC100				
	SCTH102				
	SCPS100				
	SCPR102				
	SCPR103				
	SCFR101				
	SCTH100				
	SCTH101				
	SCFR100				
	SCPR100				
	SCPR101				

COMPONENT: SINGLE-PHASE VENTING SYSTEM

REFERENCE DRAWING: 9574E2,10857D0,10668C0

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	V1TC01				FLUID TEMP DWNSTRM COOLER
01/30/84	V1TC02				CLS LEAK TEMPERATURE
01/30/84	V1TC03				CLD LEAK TEMPERATURE
	V1LS01				RV LOWER PLENUM LEAK
03/23/83	V1LS03				CLD LEAK
01/30/84	V1LS04				10 CM2 CLS LEAK SITE
01/30/84	V1LS05				10 CM2 CLS LEAK SITE
01/30/84	V1LS06				15 CM2 CLS LEAK SITE
01/30/84	V1LS07				15 CM2 CLS LEAK SITE
01/30/84	V1LS08				RV TOP PLENUM LEAK SITE
	V1AC01				

COMPONENT: TWO-PHASE VENTING SYSTEM

REFERENCE DRAWING: 9559D0,9565D3

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	V2TC01				HPV SEPARATOR
	V2TC02				PORV SEPARATOR
	V2TC03				NCG TEMP(250 GAL TANK)
	V2TC04				SURGE WATER TEMP
	V2DP01				HPV SEPARATOR 1
	V2DP02				PORV SEPARATOR 2
03/23/83	V2DP03			19'-11 11/16"	OVERFLOW TANK 1(SOUTH)
03/23/83	V2DP04			19'-10 7/16"	OVERFLOW TANK 2(NORTH)
03/23/83	V2DP05			19'-11 11/16"	OVERFLOW TANK 3(SURGE)
	V2LS01				HPV
	V2LS02				HPV
	V2LS03				PORV
	V2LS04				PORV
	V2PR01				TWO PHASE VENT SYSTEM PRE
	V2AC01				HPV ACCUM FLOW
	V2AC02				PORV ACCUM FLOW

COMPONENT: HOT LEG PIPING

REFERENCE DRAWING: 9553E4

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	HLRT01	0'-0"	0'-0"	0'-0"	
	HLCP01	1'-0"	1'-0"	1'-0"	
	HLDT01	4'-0"		2'-9"	DATA
	HLDT101			2'-9"	CONTROL
	HLTC01	8'-0"	8'-0"	8'-1"	BELOW SURGE
	HLTC02	9'-0"	9'-0"	9'-1 3/4"	ABOVE SURGE
	HLDT02	15'-0"		12'-9"	DATA
	HLDT102			12'-9"	CONTROL
	HLCP02	15'-0"	15'-0"	15'-0"	
	HLTC03	20'-0"	20'-0"	19'-11 3/4"	FLUID
	HLDT03	25'-0"		23'-9"	DATA
	HLDT103			23'-9"	CONTROL
	HLTC04	30'-0"	30'-0"	29'-11 3/4"	FLUID
	HLCP03	35'-0"	35'-0"	34'-11 1/2"	
	HLDT04	35'-0"		34'-6"	DATA
	HLDT104			34'-6"	CONTROL
	HLCP04	37'-0"	37'-0"	36'-11 3/4"	
	HLCP05	41'-0"	41'-0"	41'-0"	
	HLTC05	40'-0"	40'-0"	39'-11 3/4"	FLUID
	HLCP06	45'-0"	45'-0"	44'-11 1/2"	
	HLDT05	45'-0"		46'-3"	DATA
	HLDT105			46'-3"	CONTROL
	HLCP07	49'-0"	49'-0"	48'-11 1/2"	
	HLCP08	53'-0"	53'-0"	52'-11 1/2"	
	HLDT06	55'-0"		57'-3"	DATA
	HLDT106			57'-3"	CONTROL
	HLCP09	57'-0"	57'-0"	56'-11 1/2"	
	HLCP10	61'-0"	61'-0"	60'-11 1/2"	
	HLTC07	60'-0"	60'-0"	59'-11 1/2"	FLUID
	HLDT07	65'-0"	65'-0"	65'-11"	DATA
	HLDT107			65'-11"	CONTROL
	HLCP11	65'-0"	65'-0"	64'-11 1/2"	
03/23/83	HLCP12	67'-5"		67'-6 1/8"	9545D0
03/23/83	HLTC08			67'-3 1/2"	9545D0,FLUID
	HLCP13	65'-0"	65'-0"	64'-11 1/4"	
	HLCP14	61'-0"	61'-0"	60'-11 3/8"	
	HLTC09	60'-0"	60'-0"	59'-11 1/4"	FLUID
	HLDT08	60'-0"		57'-2"	DATA
	HLDT108			57'-2"	CONTROL
	HLCP15	57'-0"	57'-0"	56'-11 1/4"	
03/23/83	HLCP16	53'-1"	53'-2 1/2"	53'-0 3/4"	
	HLCP17		-0'-6"	0'-6 1/4"	REF PROBE
	HLVP01	35'-0"	35'-0"		9545D0
	HLVP02	67'-6"			9545D0
	HLDP01		-1'-11"	-1'-11"	9506E6,PV-HL
03/31/83	HLDP01		67'-4-3/4"	67'-5 5/16"	9545D0,HLUP (DSTNC BTW TAPS ADDED TO LWR ELV)

	HLDP02	-1'-11"	-1'-11"	9506E6,RV-HL
[illegible]23/83	HLDP02	53'-1-1/2"	53'-1 3/4"	SG INLET
[illegible]31/83	HLDP03	67'-4-3/4"	67'-5 5/16"	9545D0,HLUB (SAME AS HLDP01-HLUB)
	HLDP03	53'-1-1/2"	52'-11 3/4"	SG INLET
03/23/83	HLHR01		66'-11 3/4"	SWID DT
	HLRF01		"	SWID HTR VOLTAGE
	HLRT02		"	SWID REF RTD
	HLLS01		"	SWID S/W IND
	HLLS02		"	SWID FAILURE IND
	HLPR100			HL PRESSURE(HLDP01-HIGH) -CONTROL ROOM
03/31/83	HLDP01		69'-9 3/4"	HOT DIMENSION BTWN TAPS @ HLTC08=513.0F HLRT01=512.3F
03/31/83	HLDP03		14'-5 15/16"	HOT DIMENSION BTWN TAPS @ SGRT01=510.5F
04/13/84	HLTC10		34'-6"	METAL (DATA)
04/13/84	HLTC11		65'-11"	METAL (DATA)
04/13/84	HLTC12		2'-8 1/2"	METAL (DATA)
04/13/84	HLTC13		12'-8 1/2"	METAL (DATA)
04/13/84	HLTC14		23'-8 1/2"	METAL (DATA)
04/13/84	HLTC15		46'-2 3/8"	METAL (DATA)
04/13/84	HLTC16		57'-2 3/8"	METAL (DATA)
04/13/84	HLTC17		57'-2 3/8"	METAL (DATA)

COMPONENT: SECONDARY FORCED CIRCULATION AND FEEDWATER HEATERS

REFERENCE DRAWINGS: 9500F2,9502E3,9503E3

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	SFOR01				LO FLOW
	SFDP01				LO,LO FLOW
	SFDP02				HI,LO FLOW
	SFOR02				HI FLOW
	SFDP03				LO,HI FLOW
	SFDP04				HI,HI FLOW
	SFTM01				LO FLOW
	SFTM02				HI FLOW
01/30/84	SFLS01				FEED LO FLOW CV
01/30/84	SFLS02				FEED HI FLOW CV
	SFAM100				SUNDYNE STARTER
	SFAM101				FW HTR 1
	SFAM102				FW HTR 2
	SFAM103				FW HTR 3
	SFAM104				FW HTR 4
	SFAM105				FW HTR 5
	SFAM106				FW HTR 6
	SFTC100				SUNDYNE
	SFTC101				FW HTR(LIMIT)
	SFTC102				FW HEATER(RECORDER
	SFTC103				FW HTR(CONTROL)
	SFTC104				FLUID,HOT WELL
	SFPR101				DWNSTRM FISHER BY-PASS, CONTROL ROOM
	SFPR102				FEEDWATER HTR-CONTROL ROOM
	SFPR103				HOT WELL-CONTROL ROOM
	SFDP101				LEVEL GAGE &CONTROL,HOT WELL-CONTROL ROOM
	SFFS100				SUNDYNE COOLING WATER
	SFHM100				
	SFPR100				DWNSTRM SUNDYNE-CONTROL ROOM
	SFOR100				DWNSTRM SUNDYNE
	SFDP100				DWNSTRM SUNDYNE-CONTROL ROOM
	SFPS100				FW HTR PERMISSIVE

COMPONENT: STEAM PIPING

REFERENCE DRAWINGS: 9515F0,9516E4,9517E1

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	PSPR100				STM OUTLET-CONTROL ROOM
	PSPR01				STM OUTLET(DATA)
	PSTC01				FLUID,UPSTRM OF MIXER
	PSRT01				FLUID,DWNSTRM OF PSTC01
	PSDR01				LO FLOW
	PSDP01				LO,LO FLOW
	PSDP02				HI,LO FLOW
	PSDP02				HI FLOW
	PSDP03				LO,HI FLOW
	PSDP04				HI,HI FLOW
	PSTC04				FLUID,LO FLOW SIDE
	PSPR101				DWNSTRM STM CV CONT. ROOM
	PSTC101				FLUID,UPSTRM CONDENSER
	PSTC102				FLUID,DWNSTRM CONDENSER
	PSTC05				FLUID,HI FLOW SIDE
	PSTC100				STEAM OUTLET(TO RECORDER)
01/30/84	PSLS01				STEAM LO FLOW CV
01/30/84	PSLS02				STEAM HI FLOW CV

COMPONENT: FEEDWATER PIPING

REFERENCE DRAWING: 9550E0

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
	FPRT03		50'-10 3/8"		177FA AFWI
	FPRT02		5'-11"		205FA AFWI
	FPRT01		0'-3/8"		AFWI AT SFLTS
	FPTC01				DWNSTRM FW HEATERS
	FPPR100				

COMPONENT: GAS ADDITION SYSTEM

INSTRUMENT IDENT (RVSD)	(NEW)	ELEVATION RELATIVE TO SF LTS PROPOSED	DESIGNED	INSTALLED	COMMENT
REFERENCE DRAWING: 9583D0					
	GATC01				
	GAPR01				
	GALS01				HLUB
	GATC02				HLUB
	GALS02				UPSTRM OTSG
	GATC03				UPSTRM OTSG
	GALS03				COLD LEG
	GATC04				COLD LEG
	GALS04				RV-LP
	GATC05				RV-LP

COMPONENT: MISCELLANEOUS

	MSRF01	RTD REFERENCE VOLTAGE
	MSRF02	STD CELL VOLTAGE-DAS MON.
	MSTC01	REFENENCE OVEN TEMP
	MSTC02	REFERENCE OVEN TEMP
	MSTC03	ANALOGIC DAS TEMP

(1) ELEVATIONS TO THE NEAREST INCH

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The following instruments were used for dimensional inspections during facility construction and testing, and are included in this list to complete the scope of instrumentation used during the project.

REVISED	B&W ID	DESCRIPTION
20-JUN-83	780363	Micrometer, Outside
20-JUN-83	780364	Micrometer, Outside
20-JUN-83	610062	Comparator, Optical
20-JUN-83	750160	Caliper, Verrier
20-JUN-83	780355	Caliper, Vernier

A

Appendix D

VTAB Data Cards - Parameters and Format

VTABLE Structure

The data base for the SBLOCA data acquisition system is designed so the user can define all parameters needed to couple each of the user defined table entries (VTAB's) to the available options in the data acquisition software. This information is stored on disk in account [201,10] with the file name, VTABLE.DAT.

The VTAB generally corresponds to an instrument such as a thermocouple, pressure transmitter, conductivity probe, etc. However, the VTAB may refer to a 'non-instrument entry' desired by the user to more appropriately define the output of the instrument. For example, an orifice used for flow measurement is monitored by a differential pressure transmitter that measures the pressure differential across the orifice. It is necessary for the data acquisition system to measure and record this differential pressure but it is also convenient for the operator to have an on-line indication of the flow rate based on this measured differential pressure. The SBLOCA data acquisition software allows the user to define a second VTAB which contains the necessary conversion constants and reference VTAB's (or instruments) to compute the flow rate through the orifice. This flow rate remains in memory until the next data acquisition cycle. Hence, any on-line calculation for the current data acquisition cycle would have this flow rate available without the need to recompute the flow. This flow rate is also present in the off-line data base for distribution to users outside of ARC.

With this intoduction, the following options require user input for each VTAB and are summarized below.

Global definition to the data acquisition software regarding the status of a VTAB, ie., in or out of service, use for loop alarm indications to the operator, or use for control of the time interval between data acquisition scans.

Identification of a VTAB for alarm monitoring and the parameters required to define the low and high alarm values, and alarm deadband.

Identification of a VTAB for rate control of the data acquisition hardware, ie., based on the rate of change of a VTAB raw data signal or engineering value, the time interval between data acquisition scans is either increased or decreased.

Definition of the ANALOGIC ANDS5400 'card' (analog, counter-timer, or digital input) and ANALOGIC channel associated with the VTAB.

Conversion of the raw data signal (voltage, frequency, digital input, count, etc.) to the appropriate value in engineering format or units. This operation requires the following user defined information:

> Calibration constants and material or test loop geometry constants needed to perform the raw data signal to engineering format conversion.
>
> Reference VTAB's (or instrument readings in this case) needed to perform the raw data signal to engineering format conversion.

Definition of the 'units descriptor' (ex., DEG F, PSIA, LBM/HR) associated with the converted engineering value for each VTAB.

Definition of the number of significant decimal places that will be associated with the converted raw data signal to engineering value.

Descriptor associated with each VTAB for user ease in identification of the VTAB.

The following discussion defines the parameter order and format for each of the VTAB data cards. All VTAB's require the same parameter entries on cards #1 and #2. Cards #3 and #4 are optional depending on the data reduction type needed to convert from the raw input signal to the engineering formatted value.

****

Card #1 defines the parameter list for global alarming and rate specifications, set up of the data acquisition system prior to a data scan, definition of the data reduction routine, and VTAB units and descriptor.

****

```
*** CARD #1 ***   FORMAT(2X,3A2,1X,9I3,4X,40A1)

            *********** CARD COLUMN AND ENTRIES **********

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
  A1A2A3 BBBCCCDDDEEEFFFGGGHHHIIIJJJ    KKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKKK
```

CARD ENTRY	SOFTWARE PARAMETER	DESCRIPTOR	VALUE(S)	FORMAT
*******	*********	************************	***************	*******
A1A2A3	VTAB	Name of VTABLE.DAT entry (Instrument or "dummy" name)	A1 - Subsystem A2 - Instrument A3 - Number	A2 A2 A2
BBB	KEYS	Read, Rate, Alarm, and Ref Channel Code Word	VALUE PARAM 0/1 1 VREAD Read/No Read 2 AWORD Alarm Out/In 4 RWORD Rate Out/In 8 VREF None/Ref VTAB(s) BBB = Summation of [VALUE*(0 or 1)]	I3
CCC	ALARMW	Alarm Code Word	VALUE PARAM 0/1 1 AVTAB No Alarm/Yes 2 ADEAD Delta/%Deadband 4 ALSTAT No/Yes Alarm State (User Should Set This to 0 Initially -- System Will Then Modify) 8 ALVTAB Lo/Hi Alarm State CCC = Summation of [VALUE*(0 or 1)]	I3
DDD	RATEW	Rate Option Code Word	VALUE PARAM 0/1 1 RVTAB No/Yes Rate Change 2 RDUM **Not Used** 4 RVOLTS Not Used/Eng Units 8 RLIMIT Limit/Rate of Change DDD = Summation of [VALUE*(0 or 1)]	I3
EEE	REDUC	Reduction Equation	TYPE DESCRIPTION 1 Engineering Value = Raw Value	I3

2	RTD
3	C1+C2*(V-VV)+C3*(V-VV)**2
4	C1+C2*V+...+C5*V**4
5	Type J TC
6-8	Not Used
9	Uncalibrated 100 ohm Platinum RTD
10-20	Not Used
21	Turbine Flow Meter
22	DP Transmitter (W/O H2O Correction)
23	Orifice Flow Meter With Flange or Corner Taps
24	DP From TYPE 22 to Actual (H2O & Thermal Expansion Corrected) And Vertical Orifice DP in Upflow and Downflow
25	Correct Pressure Transmitter Reading to Upper Tap
26	Not Used
27	Volume of Gas Discharged into the Two-Phase Venting System
28	Composite Steam Flow Rate in GERDA Steam Circuit
29	Composite Feed Flow Rate in GERDA Feed Circuit
30	Pressurizer Collapsed Water Level
31	OTSG Primary Collapsed Water Level
32	OTSG Secondary Collapsed Water Level
33	Hot Leg Collapsed Water Level
34	Hot Leg Stub Collapsed Water Level
35	Reactor Vessel Collapsed Water Level
36	OTSG Secondary Wetted CP
37	Hot Leg Stub Wetted CP
38	Hot Leg Wetted CP
39	Reactor Vessel Wetted CP
40	Feedwater Temperature
41	RVVV Mass Flow Rate
42	HPV & PORV Composite Mass Flow Rate
43	Single Phase Leak Mass Flow Rate
44	Pitot Tube Mass Flow Rate
45	RV Downcomer Composite Venturi Mass Flow Rate
46	Cold Leg Orifice Composite Mass Flow Rate
47	Not Used
48	Integrate Turbine Meter Flow Rate with Time to Get Accumulated Total
49	RVVV Limit Switch (Open,

			Neither, Closed) 50 Cold Leg Collapsed Water Level 51 RV Downcomer Collapsed Water Level 52 Cold Leg Orifice Mass Flow Rate w/ Level & Sat Checks ** Called from Type 23 ** 53 RV Downcomer Venturi Mass Flow Rate ** Called from Type 23 ** 54 Saturation temperature from pressure 55 Auctioneered cold leg suction leak for OTIS	
FFF	DEC	# of Significant Digits After the Decimal Places in the Converted ENG Value		I3
GGG	UNIT	CODE FOR UNITS	CODE / UNITS 1 Volts 2 Deg F 3 PSIA 4 PSIG 5 GPM 6 LBM/HR 7 PSI 8 KWATT 9 BTU/HR 10 DRY/WET 11 OPN/CL 12 LBM 13 FT 14 SCF 15 GAL	I3
HHH	CHAN	Analogic Channel		I3
III	GAIN	Gain Code Word For ANALOGIC Cards	GAIN / DESCRIPTION 0 "DUMMY" Channel--Not Instrument VTAB Or Accumulating Flow Meter 1 Gain of 1 for ADTYPE's 1-3 2 Gain of 2 " " " 4 Gain of 4 " " " 8 Gain of 8 " " " # # = Bit for Digital Input Card (1-16, 16 bit) ## ## = Gate Time for Frequency Input ## / GATE TIME (SEC) 4 / 600 5 / 3600 6 / 60 7 / 100 8 / 10 9 / 1 10 / 0.1	I3

11	0.01
12	0.001
13	0.0001
14	0.00001
15	0.000001

JJJ ADTYPE ANALOGIC Card Type I3

CODE	CARD
0	"DUMMY" Channel
1	Analog +/- 40 mv
2	Analog +/- 1.25 v
3	Analog +/- 10.0 v
4	Digital Input
5	Counter
6	Frequency

KKK..KKK DESCR VTAB Descriptor 40A1

*** END CARD #1 ***

****

****

Data input to card #2 is specific to the data reduction type code, REDUC, defined above. The input parameters for each reduction type are defined below.

```
*****************************************************************************
*****************************************************************************
*** CARD #2 ***    FORMAT(10X,5(E13.7,1X))
                   FORMAT(10X,4(E13.7,1X),2(I3,2X),4X)      <--- TYPE 23 ONLY

              *********** CARD COLUMN AND ENTRIES **********

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          AAAAAAAAAAAAA BBBBBBBBBBBBB CCCCCCCCCCCCC DDDDDDDDDDDDD EEEEEEEEEEEEE
          AAAAAAAAAAAAA BBBBBBBBBBBBB CCCCCCCCCCCCC DDDDDDDDDDDDD EEE  eee !!!

                                                              !!! Type 23 only
```

CARD ENTRY	FORMAT	REDUCTION TYPE	DESCRIPTOR	VALUE (IF CONSTANT)
*******	********	*********	*****************************	*************
AAAAAAA	E13.7	1	Engineering = Raw Input	0.00
		2	RTD Resistance (OHM) @ 0.0 (C)	
		3	C1 of C1+C2*(V-VV)+C3*(V-VV)**3	
		4	C1 of C1+C2*V+C3*V**2+....+C5*V**4	
		5	TYPE J TC (Coefficients Hardwired)	0.00
		6-8	Not Used	0.00
		9	RTD Resistance (OHM) at 0 (C)	
		10-20	Not Used	0.00
		21	C1 of C1 + C2*K + C3*K*K + C4*K**3	
		22	C1 of (C1+C2*DE+C3*DE**2)(1-C4*PRES)	
		23	Pipe Inside Dia. (inches)	
		24	Distance (FT) Between DP Taps	
		25	Elevation (FT) of Pressure Tap Above Transmitter	
		26	Reduction Type Not Used	
		27	Not Used	0.00
		28	Not Used	0.00
		29	Not Used	0.00
		30-43	Not Used	0.00
		44	Flow Cross Sectional Area (FT**2)	
		45	Minimum Transmitter Voltage	
		46	Minimum Transmitter Voltage	
		47	Reduction Type Not Used	
		48-55	Not Used	0.00
BBBBBBB	E13.7	1	Engineering = Raw Input	1.00
		2	RTD Temp Coeff @ 0.0 (C) -- Alpha	
		3	C2 OF C1+C2*(V-VV)+C3*(V-VV)**3	
		4	C2 OF C1+C2*V+C3*V**2+....+C5*V**4	
		5	TYPE J TC (Coefficients Hardwired)	0.00
		6-8	Not Used	0.00
		9	Temperature Coefficient at 0 (C)	
		10-20	Not Used	0.00
		21	C2 of C1 + C2*K + C3*K*K + C4*K**3	
		22	C2 of (C1+C2*DE+C3*DE**2)(1-C4*PRES)	
		23	Orifice Dia (FT)	
		24	Coefficient of Thermal Expansion (1/F)	
		25	Not Used	0.00

		26	Reduction Type Not Used	
		27	Not Used	0.00
		28	Max Voltage for Over-Range	
		29	Max Voltage for Over-Range	
		30-44	Not Used	0.00
		45	Max Voltage for Over-Range	
		46	Max Voltage for Over-Range	
		47	Reduction Type Not Used	
		48-55	Not Used	0.00
CCCCCCC	E13.7	1	Engineering = Raw Input	0.00
		2	RTD Constant -- DELTA	
		3	C3 OF C1+C2*(V-VV)+C3*(V-VV)**3	
		4	C3 OF C1+C2*V+C3*V**2+....+C5*V**4	
		5	TYPE J TC (Coefficients Hardwired)	0.00
		6-8	Not Used	0.00
		9	RTD Constant -- Typically About 1.49	
		10-20	Not Used	0.00
		21	C3 of C1 + C2*K + C3*K*K + C4*K**3	
		22	C3 of (C1+C2*DE+C3*DE**2)(1-C4*PRES)	
		23	C3 +C3 ==> K=C3(1+C4/REd) Flange	
			-C3 ==> K=-C3+C4*1000/SQRT(RE) Corner	
		24	C1=0.0 ==> Invert DP with Ref Leg	
			C1=1.0 ==> Orifice DP for Downflow	
			C1=2.0 ==> Orifice DP for Upflow	
		25	Not Used	
		26	Reduction Type Not Used	
		27-46	Not Used	0.00
		47	Reduction Type Not Used	
		48-55	Not Used	0.00
DDDDDDD	E13.7	1	Engineering = Raw Input	0.00
		2	Resistance (OHM) of Precision Resistor	
		3	C4 of C1+C2*(V-VV)+C3*(V-VV)**3	
		4	C4 of C1+C2*V+C3*V**2+....+C5*V**4	
		5	TYPE J TC (Coefficients Hardwired)	0.00
		6-8	Not Used	0.00
		9	Current (AMPS) Through RTD	
		10-20	Not Used	0.00
		21	C4 of C1 + C2*K + C3*K*K + C4*K**3	
		22	C4 of (C1+C2*DE+C3*DE**2)(1-C4*PRES)	
			Static Pressure Span Error (Typically	
			1% per 1000 PSI or +1.E-05)	
		23	C4 of K=C3(1+C4/REd) Flange	
			or K=-C3+C4*1000/SQRT(RE) Corner	
		24	Not Used	0.00
		25	Not Used	
		26	Reduction Type Not Used	
		27-46	Not Used	0.00
		47	Reduction Type Not Used	
		48-55	Not Used	0.00
EEEEEEE	E13.7	1	Engineering = Raw Input	0.00
	E13.7	2	Not Used	0.00
	E13.7	3	VV of C1+C2*(V-VV)+C3*(V-VV)**3	
	E13.7	4	C5 of C1+C2*V+C3*V**2+....+C5*V**4	
	E13.7	5	TYPE J TC (Coefficients Hardwired)	0.00
		6-20	Not Used	0.00
	E13.7	21	Not Used	0.00

	E13.7	22	'Zero' Voltage	
EEE	I3	23	Pipe Mat'l O=Stainless, 1=Carbon	
eee	I3		Orifice Mat'l O=Stainless, 1=Carbon	
	E13.7	24	Not Used	0.00
	E13.7	25	Not Used	0.00
		26	Reduction Type Not Used	
	E13.7	27-46	Not Used	0.0C
		47	Reduction Type Not Used	
	E13.7	48-55	Not Used	0.00

*** END CARD #2 ***

****

****

Card #3 contains the reference VTAB's (when used) for converting the input of the VTAB to engineering format. For example, an RTD requires the voltage drop across a precision resistor to determine the current flow in the circuit. Hence, the reference voltage drop across this resistor appears as a reference VTAB for the RTD in location A1A2A3.

Note that unused reference VTAB entries must be set to blanks by the user since the read is for 4 entries.

```
********************************************************************************
********************************************************************************
*** CARD #3 ***    FORMAT(8X,4(2X,3A2),40X)

               *********** CARD COLUMN AND ENTRIES **********

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          A1A2A3  B1B2B3  C1C2C3  D1D2D3
```

Where,
A1A2A3, B1B2B3, C1C2C3, D1D2D3 are the reference VTAB's

REDUCTION TYPE	A1A2A3	B1B2B3	C1C2C3	D1D2D3
1	Card Not Required			
2	Voltage Drop Across Precision Resistor	'6 Blanks'	'6 Blanks'	'6 Blanks'
3	Card Not Required			
4	Card Not Required			
5	Card Not Required			
6-8	Not Used			
9	Card Not Required			
10-20	Not Used			
21	Fluid Pressure	Fluid Temperature	'6 Blanks'	'6 Blanks'
22	Fluid Pressure	'6 Blanks'	'6 Blanks'	'6 Blanks'
23	Fluid Pressure	Fluid Temperature	Orifice Diff Pressure	'6 Blanks'
24	Fluid Pressure	Ref Leg Temp	Diff Pressure	Fluid Temp
25	Fluid Pressure	Ref Leg Temp	'6 Blanks'	'6 Blanks'
26	Not Used			
27	Vent Sys Press	Vent Sys Temp	'6 Blanks'	'6 Blanks'

28-30	Card Not Required			
31	'6 Blanks'	'6 Blanks'	'6 Blanks'	Flow Rate
32	Card Not Required			
33-35	'6 Blanks'	'6 Blanks'	'6 Blanks'	Flow Rate
36-40	Card Not Required			
41	Cold Leg Flow Rate	RV DC Flow Rate	'6 Blanks'	'6 Blanks'
42	Two-Phase Vent System Pressure	Two-Phase Vent System Temp	HPV Acc Flow Meter	PORV Acc Flow Meter
43	Primary Pressure	Temp at Single-Phase Acc Meter	Single-Phase Acc Flow Meter	'6 Blanks'
44	Fluid Pressure	Fluid Temp	Pitot DP	'6 Blanks'
45-46	Card Not Required			
47	Not Used			
48	Flow Rate	'6 Blanks'	'6 Blanks'	'6 Blanks'
49	Card Not Required			
50-51	'6 Blanks'	'6 Blanks'	'6 Blanks'	Flow Rate
52-53	Called From Type 23			
54	Fluid Pressure	'6 Blanks'	'6 Blanks'	'6 Blanks'
55	Card Not Required			

*** END CARD #3 ***
****
****

Card #4 defines the parameters associated with alarm messages and rate control (time between data acquisition scans) of the data acquisition system. This card is therefore used only when the VTAB is selected for alarming or rate control. In all other instances this card should not be part of the VTAB identity. The 'KEYS' parameter on card #1 should be switched to include the presence of rate and/or alarm control for the subject VTAB.

```
*******************************************************************************
*******************************************************************************
*** CARD #4 ***    FORMAT(10X,4(E13.7,1X))

                ********** CARD COLUMN AND ENTRIES **********

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          AAAAAAAAAAAAA BBBBBBBBBBBBB CCCCCCCCCCCCC DDDDDDDDDDDDD EEEEEEEEEEEEE
```

CARD ENTRY	SOFTWARE PARAMETER	D E S C R I P T I O N	FORMAT
*******	*********	***	*******
AAAAAAA	ALARMH	Hi Alarm Value	E13.7
BBBBBBB	ALARML	Low Alarm Value	E13.7
CCCCCCC	ALARMD	Alarm Deadband	E13.7
DDDDDDD	RVALUE	Maximum Change of VTAB Engineering Value Between Successive Data Acquisitions or Maximum Engineering Value Allowed Before 'Pegging' DAS Speed	E13.7
EEEEEEE	RATOLD	Previously Calculated Value for Rate	E13.7

```
*** END CARD #4 ***
*******************************************************************************
*******************************************************************************
```

This concludes the definition of the VTABLE.DAT file. The information in VTABLE.DAT is used to define system common data for each of the VTAB's. This information is then available to all other SBLOCA DAS routines. The next section lists and describes all of these SBLOCA DAS routines.

Appendix E

List of GERDA and OTIS Phase 0 Characterization Tests

GERDA PHASE 0 TESTS

Run Number	Description
000100	TC Calibration - Pressurizer at 382°F
000200	TC Calibration - Pressurizer at 432°F
000300	TC Calibration - Pressurizer at 486°F
000400	TC Calibration - Pressurizer at 532°F
000500	TC Calibration - Steam Generator at 350°F
000600	TC Calibration - Steam Generator at 375°F
000700	TC Calibration - Steam Generator at 400°F
000800	TC Calibration - Steam Generator at 425°F
000900	TC Calibration - Steam Generator at 450°F
001000	TC Calibration - Steam Generator at 450°F
001100	TC Calibration - Steam Generator at 475°F
001200	TC Calibration - Steam Generator at 475°F
001300	TC Calibration - Steam Generator at 500°F
001400	TC Calibration - Steam Generator at 500°F
001500	TC Calibration - Pressurizer at 587°F
001600	TC Calibration - Steam Generator at 525°F
001700	TC Calibration - Steam Generator at 525°F
001800	TC Calibration - Steam Generator at 550°F
001900	TC Calibration - Steam Generator at 550°F
002000	TC Calibration - Steam Generator at 575°F
002100	TC Calibration - Steam Generator at 575°F
002200	TC Calibration - Pressurizer at 629°F
002300	TC Calibration - Steam Generator at 500°F
002400	TC Calibration - Steam Generator at 500°F
002500	TC Calibration - Pressurizer at 587°F
002600	TC Calibration - Steam Generator at 425°F
002700	TC Calibration - Steam Generator at 425°F
002800	Steam Ramp Cooldown
002900	Steam Ramp Cooldown
003000	Steam Ramp Cooldown
003100	VOID
003200	TC Calibration - Steam Generator at 350°F
003300	TC Calibration - Steam Generator at 350°F
003400	TC Calibration - Pressurizer at 486°F
003500	TC Calibration - Pressurizer at 382°F
003600	TC Calibration - Reactor Vessel at 382°F
003700	TC Calibration - Reactor Vessel at 432°F
003800	TC Calibration - Reactor Vessel at 488°F
003900	TC Calibration - Reactor Vessel at 531°F
004000	TC Calibration - Reactor Vessel at 587°F
004100	VOID
004200	TC Calibration - Reactor Vessel at 629°F
004300	TC Calibration - Reactor Vessel at 587°F
004400	TC Calibration - Reactor Vessel at 527°F
004500	TC Calibration - Reactor Vessel at 486°F
004600	TC Calibration - Reactor Vessel at 382°F
004700	VOID
004800	VOID

PHASE 0 TESTS (cont'd.)

Run Number	Description
004900	Steam/Feedwater Orifice Calibration - 200 lb/hr
005000	Steam/Feedwater Orifice Calibration - 250 lb/hr
005100	Steam/Feedwater Orifice Calibration - 300 lb/hr
005200	Steam/Feedwater Orifice Calibration - 350 lb/hr
005300	Steam/Feedwater Orifice Calibration - 200 lb/hr
005400	Steam/Feedwater Orifice Calibration - 300 lb/hr
005500	Steam/Feedwater Orifice Calibration - 400 lb/hr
005600	VOID
005700	Steam/Feedwater Orifice Calibration - 250 lb/hr
005800	Steam/Feedwater Orifice Calibration - 300 lb/hr
005900	Steam/Feedwater Orifice Calibration - 350 lb/hr
006000	Steam/Feedwater Orifice Calibration - 200 lb/hr
006100	Steam/Feedwater Orifice Calibration - 120 lb/hr
006200	Steam/Feedwater Orifice Calibration - 200 lb/hr
006300	Steam/Feedwater Orifice Calibration - 250 lb/hr
006400	Steam/Feedwater Orifice Calibration - 300 lb/hr
006500	Steam/Feedwater Orifice Calibration - 200 lb/hr
006600	Steam/Feedwater Orifice Calibration - 250 lb/hr
006700	Steam/Feedwater Orifice Calibration - 285 lb/hr
006800	Steam/Feedwater Orifice Calibration - 100 lb/hr
006900	4 HPI Pump Head-Flow Control
007000	4 HPI Pump Head-Flow Control
007100	2 HPI Pump Head-Flow Control
007200	2 HPI Pump Head-Flow Control
007300	Primary Flow Calibration at 9450 lb/hr
007400	Primary Flow Calibration at 12000 lb/hr
007500	Primary Flow Calibration at 2300 lb/hr
007600	Primary Flow Calibration at 2300 lb/hr
007700	Primary Flow Calibration at 1600 lb/hr
007800	Primary Flow Calibration at 2000 lb/hr
007900	Primary Flow Calibration at 2400 lb/hr
008000	Primary Flow Calibration at 2900 lb/hr
008100	Primary Flow Calibration at 3350 lb/hr
008200	Primary Flow Calibration at 3600 lb/hr
008300	Primary Flow Calibration at 1100 lb/hr
008400	Heat Loss - No Guard Heaters - 505°F
008500	Heat Loss - Zone 1 On - 505°F
008600	Heat Loss - Zone 1 and 2 On - 512°F
008700	Heat Loss - Zones 1-6 On - 553°F
008800	Heat Loss - Guard Heaters On - 561°F
008900	Surge Line Special Test
009000	Heat Loss - No Guard Heaters - 566°F
009100	Heat Loss - Zones 2-6 On - 536°F
009200	Heat Loss - Guard Heaters On - 502°F
009300	Heat Loss - Bias + 0.1
009400	Heat Loss - Bias 0.0
009500	Heat Loss - Zones 2-6 On - 492°F
009600	Condensation and Guard Heating Vapor Region
009700	Heat Loss - No Guard Heaters - 490°F

PHASE 0 TESTS (cont'd.)

Run Number	Description
009800	Heat Loss - No Guard Heaters - 490°F
009900	Heat Loss - No Guard Heaters - 490°F
009901	63-Bar Interception
009902	Conductivity Probe Checkout
009903	HPV w/o NCG
009904	HPV w/o NCG
009905	HPV w/o NCG
009906	HPV w/o NCG
009907	Gas Sample HLUB
009908	Gas Sample with NCG
009909	Gas Sample HLUB with NCG
009910	PORV w/o NCG
009911	PORV with NCG
009912	PORV with NCG
009913	Heat Loss - No Guard Heaters - 497°F
009914	Heat Loss - No Guard Heaters - 451°F
009915	Heat Loss - Guard Heaters On - 494°F
009916	Ultrasonics - No Flow
009917	Ultrasonics - Intermodulations
009918	Ultrasonics - Pulse Echo w/o NCG
009919	Ultrasonics - Pressure = 1266 psia
009920	Ultrasonics - Pressure = 1541 psia
009921	Ultrasonics - Pressure = 1908 psia
009922	Ultrasonics - Pressure = 2100 psia
009923	Ultrasonics - Pressure = 928 psia
009924	Ultrasonics - Pressure = 790 psia
009925	Ultrasonics - Water Injected at CLS
009926	Ultrasonics - Pressure = 840 psia with NCG
009927	Ultrasonics - Pressure = 1425 psia
009928	Heat Loss - SG Level 32%, 554°F
009929	Ultrasonics - Spectrum Analysis
009930	Heat Loss - SG Dry, 550°F
009931	Ultrasonics - Pressure = 1200 psia
009932	Ultrasonics - Density Layering
009933	Ultrasonics - Pressure = 1200 psia
009934	Conductivity Probes
009935	Steam/Feedwater Orifice Calibration - 120 lb/hr
009936	Steam/Feedwater Orifice Calibration - 200 lb/hr
009937	Steam/Feedwater Orifice Calibration - 250 lb/hr
009938	Steam/Feedwater Orifice Calibration - 300 lb/hr
009939	Steam/Feedwater Orifice Calibration - 250 lb/hr
009940	Steam/Feedwater Orifice Calibration - 200 lb/hr
009941	Steam/Feedwater Orifice Calibration - 150 lb/hr
009942	Steam/Feedwater Orifice Calibration - 110 lb/hr
009943	DCUS, Pressure = 1200 psi (no disk file)
009944	DCUS, with Guard Heaters, 460°F
009945	DCUS, with Guard Heaters, 513°F
009946	VOID
009947	Energy Balance at 520°F

PHASE O TESTS (cont'd.)

Run Number	Description
009948	Pitot Tubes (Renamed 010302)
009949	Heat Loss at 515°F
009950	Cold Leg Orifice Calibration @ 1% Power
009951	Cold Leg Orifice Calibration @ 1.5% Power
009952	Cold Leg Orifice Calibration @ 2% Power
009953	Cold Leg Orifice Calibration @ 2.5% Power
009954	Cold Leg Orifice Calibration @ 3.0% Power
009955	Cold Leg Orifice Calibration @ 3.5% Power
009956	Cold Leg Orifice Calibration @ 4.0% Power
009957	Cold Leg Orifice Calibration @ 4.5% Power
009958	Cold Leg Orifice Calibration @ 5.0% Power
009959	Cold Leg Orifice Calibration @ 5.5% Power
009960	Cold Leg Orifice Calibration @ 0.3% Power
009961	Cold Leg Orifice Calibration @ 0.54% Power
009962	Euler Number Test - Stalled Flow
009963	Euler Number Test - Minimum Forced Flow
009964	Euler Number Test - Repeat of 9963
009965	Cold Leg Calibration @ 8.6 KW
009966	Euler Number Test - 15000 lb/hr
009967	Euler Number Test - Stalled Flow
009968	Euler Number Test - 20,000 lb/hr
009969	Euler Number Test - Stalled Flow
009970	Data Storage Check
009971	Heat Loss at 465°F
009972	Heat Loss, Guard Heaters On, 519°F
009973	Heat Loss, Guard Heaters On, 526°F
009974	Heat Loss, Guard Heaters On, 420°F
009975	Heat Loss, Guard Heaters On, 330°F
009976	Conductivity Probe Check at 30 μmho/cm
009977	Conductivity Probe Check at 24.5 μmho/cm
009978	Conductivity Probe Check at 44.5 μmho/cm
009979	Leak - HPI Equilibrium for 070602
009980	Heat Loss at 537°F, SG Dry
009981	Two-Phase Vent Exercise
009982	Heat Loss, SG Level 30%, G.H. On
009983	Heat Loss, SG Level 67%, No G.H.
009984	Equilibrium Pressure for 10 cm^2 CLS and 3 cm^2 HPV - 2 HPI Pumps
009985	Equilibrium Pressure for 10 cm^2 CLS and 3 cm^2 HPV - 4 HPI Pumps
009986	Equilibrium Pressure for 10 cm^2 CLS - 2 and 4 HPI Pumps
009987	Heat Loss, SG Level 35%, No G.H.
009988	Equilibrium Pressure for 070301
009989	Equilibrium Pressure for 071112
009990	Equilibrium Pressure for 070801
009991	MK(2) AFW Head-Flow, Part 2
009992	MK(2) AFW Head-Flow, Part 1
009993	Equilibrium Pressure for 070401
009994	Heat Loss, 433°F
009995	Equilibrium Pressure for 070201
009996	Equilibrium Pressure for 071224

OTIS PHASE 0 TESTS

Run Number	Description
200001	RVUP and SL Guard Heater Characterization, w/HL heaters only, 2/2/84
200002	Same as 200001, 2/2/84
200003	Same as 200001, 2/3/84
200004	RVUP and SL Guard Heater Characterization, BIAS = 0 2/3/84
200005	GH Test, HL BIAS = 0.1, RV = 0.05, SL = 0.00, 2/4/84
200006	CL Orifice Calibration @ 2.5% Power, 2/6/84
200007	CL Orifice Calibration @ 2.0% Power, 2/9/84
200008	CL Orifice Calibration @ 1.5% Power, 2/10/84
200009	CL Orifice Calibration @ 1.0% Power, 2/10/84
200010	CL Orifice Calibration @ 3.0% Power, 2/10/84
200011	CL Orifice Calibration @ 3.5% Power, 2/10/84
200012	CL Orifice Calibration @ 4.0% Power, 2/10/84
200013	Deleted
200014	Heat Loss, HL BIAS = 0.1, PR = 0.35, RV Upper = 0.2, RV top = 0.15, PR SL = 0.10, 2/13/84
200015	CL Orifice Calibration @ 3.0% Power, 2/13/84
200016	CL Orifice Calibration @ 4.5% Power, 2/13/84
200017	CL Orifice Calibration @ 5.0% Power, 2/13/84
200018	CL Orifice Calibration @ 5.5% Power, 2/13/84
200019	CL Orifice Calibration @ 5.0% Power (Report), 2/13/84
200020	CL Orifice Calibration @ 1.0% Power (Report), 2/13/84
200021	CL Orifice Calibration w/dry SG, 2/14/84
200022	Heat Loss, all GH on, 2/17/84
200023	Heat Loss, all GH on, 2/17/84
200024	Heat Loss, all GH on except SL, 2/17/84
200025	Heat Loss, continuation of 200024, 2/17/84
200026	Heat Loss, all GH on except SL, 2/20/84
200027	RV, HL Guard Heater Test for Steam, Drain Phase, 2/22/84
200028	RV, HL Guard Heater Test for Steam, 2/23/84
200029	Continuation of 200028, 2/23/84
200030	Continuation of 200028, 2/24/84
200031	Continuation of 200028, 2/24/84
200032	Continuation of 200028, 2/28/84
200033	GH Settings for Steam, Final Run, 3/1/84
200034	Steam GH Settings with Water-Solid Loop, 3/2/84
200035	Continuation of 200034, 3/3/84
200036	Continuation of 200034, 3/4/84
200037	Continuation of 200034, 3/5/84
200038	Continuation of 200034, 3/6/84

OTIS PHASE 0 TESTS (Continued)

Run Number	Description
200039	Pressurizer GH Re Characterization, BIAS = 0.07, 4/3/84
200040	Continuation of 200039, 4/4/84
200041	Continuation of 200039, 4/4/84