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ROSA-III SYSTEM DESCRIPTION FOR FUEL
ASSEMBLY NO.4

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ROSA-III System Description
for Fuel Assembly No. 4

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The ROSA (Rig of Safety Assesment)-III System with fuel assembly No.4 and its instrumentations are described. The informations are necessary to understand and analyze the experimental data obtained from loss-of-coolant experiments (LOCEs) conducted in the ROSA-III facility.

Keywords : LOCA, LOCE, ROSA-III Facility, BWR, System Description
Instrumentation, Fuel Assembly No. 4

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ROSA-Ⅲ試験装置および第4次模擬燃料集合体の概要

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本資料は、沸騰水型原子炉の冷却材喪失事故の模擬実験であるROSA-Ⅲ計画の実験解析を行うさいに必要な基本的な情報、即ちROSA-Ⅲ装置の概要と計測についてまとめたものである。本編は第4次模擬燃料集合体を対象とした改訂版である。

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ABBREVIATIONS

ADS	Automatic Depressurization System
AT	Air Tank
AV	Air Actuation Valve
(2)B	(2) inches Pipe of Schedule 80
BN	Boron Nitride
BWR	Boiling Water Reactor
CA	Chromel-Alumel
CHV	Check Valve
CV	Control Valve
CWT	Cooling Water Tank
D	Differential Pressure
DF	Density of Fluid
DL(+100)	Elevation (+100 mm) from the bottom of PV
ECCS	Emergency Core Cooling System
ESF	Engineered Safety Features
F	Flow Rate
Fig.	Figure
FS	Full Scale
FWP	Feed Water Pump
FWT	Feed Water Tank
HPCS	High Pressure Core Spray
HPCSP	High Pressure Core Spray Pump
HPCST	High Pressure Core Spray Tank
HPWP	High Pressure Water Pump
ID	Inner diameter
INC 600	Inconel 600
JP	Jet Pump
K	Kelvin

kg	Kilogram
kPa	Kilopascal
kW	Kilowatt
L	Liquid Level
l	Liter
LB	Liquid Level in Channel Box
LBWR	Large Boiling Water Reactor
LL	Liquid Level in the Lower Plenum
LOCA	Loss-of-Coolant Accident
LOCE	Loss-of-Coolant Experiment
LP	Lower Plenum
LPCI	Low Pressure Coolant Injection
LPCIP	Low Pressure Coolant Injection Pump
LPCIT	Low Pressure Coolant Injection Tank
LPCS	Low Pressure Core Spray
LPCSP	Low Pressure Core Spray Pump
LPCST	Low Pressure Core Spray Tank
M	Momentum Flux
m	Meter
mm	Milimeter
MLHR	Maximum Linear Heat Rate
MPa	Megapascal
MRP	Main Recirculation Pump
MW	Megawatt
N	Rotation Speed
OR	Orifice
P	Pressure
PV	Pressure Vessel
PWT	Pure Water Tank

QOBV	Quick Opening Blowdown Valve
QSV	Quick Shut-off Valve
RCN	Rapid Condenser
ROSA	Rig of Safety Assessment
rpm	Revolution per Minute
S	Signal
s	Second
Sch	Schedule
SUS	Stainless Steel
T	Temperature
T/C	Thermocouple
TC	Temperature of Fluid
TF	Temperature of Fuel
TS	Temperature of Structure Material
V	Valve
VF	Void Fraction
W	Power
W	Watt
WL	Water Level
WSP	Water Supply Pump

1. INTRODUCTION

The ROSA (Rig of Safety Assessment)-III Program is one of several water reactor research test programs conducted by JAERI (Japan Atomic Energy Research Institute).

The ROSA-III facility is a volumetrically scaled (1/424) boiling water reactor (BWR) system with electrically heated core designed to study the response of the engineered safety features (ESF) in commercial BWR systems during the postulated loss-of-coolant accident (LOCA). With recognition of the differences in commercial BWR designs and inherent distortions in reduced scale systems, the design objective for the ROSA-III facility was to produce the significant thermal-hydraulic phenomena that would occur in commercial BWR systems in the same sequence and with approximately the same time frames and magnitudes. The objectives of the ROSA-III experimental program are:

- (1) To provide data required to evaluate the adequacy and improve the analytical methods currently used to predict the LOCA response of large BWRs. The performance of the ESFs, with particular emphasis on emergency core cooling systems (ECCSs), and the quantitative margins of safety inherent in performance of the ESF are of primary interest.
- (2) To identify and investigate any unexpected event(s) or threshold(s) in the response of either the plant or the ESF and develop analytical techniques that adequately describe and account for such unexpected behavior.

The information acquired from loss-of-coolant experiments (LOCEs) is thus used for evaluation and development of LOCA analytical methods and

assessment for the quantitative margins of safety of ESFs in response to a LOCA.

In order to meet the program objectives, test plans have been made and several tests were already performed since the initiation of the ROSA-III program in 1978. The objectives of this document is to provide system informations to interpret the ROSA-III test data. This document describes the ROSA-III test facility with fuel assembly No.4 and instrumentations in detail.

2. ROSA-III TEST FACILITY

The test assembly consists of four major subsystems which have been instrumented such that desirable system parameters can be measured and recorded during a LOCE. The subsystems include: (a) the pressure vessel, (b) the steam line and the feedwater line, (c) the coolant recirculation system, and (d) the ECCS. System instrumentation is discussed in Section 3. The ROSA-III major components and the pressure vessel internal structures are shown schematically in Fig. 2.1 and 2.2, respectively. Coolant flow directions in the vessel during steady state operation is shown schematically in Fig. 2.3 along with ECCS and feed water flow directions. The ROSA-III piping system is shown in Fig. 2.4 and the major characteristics of the ROSA-III test facility are compared with those of a LBWR in Table 2.1.

2.1 Pressure Vessel

The pressure vessel (see Fig. 2.5) simulates the pressure vessel of a BWR. It has a simulated core, a lower plenum, an upper plenum, an annular downcomer, a steam separator, a simulated steam dryer plate, and a steam dome. It should be noted in this figure that the jet pumps are not placed in the vessel. The downcomer gap is extremely narrow to maintain the volumetric scaling ratio and relative elevation of downcomer top and bottom. It is difficult to install extremely small jet pumps in such narrow downcomer space, therefore, it was decided to install the jet pumps outside the pressure vessel.

The detail of the pressure vessel is shown in Fig. 2.6. Overall height of the vessel is approximately 6m. Elevation of the jet pump suction nozzle was chosen so that the core can be reflooded as an actual BWR after ECCS activation.

The core is consisted of four half-length simulated fuel assemblies and a control rod simulator. Each fuel assembly contains 62 fuel rods and two water rods which are spaced and supported in a square (8 x 8) array by upper tie plate (Fig. 2.7) and lower tie plate (Fig. 2.8). The simulated fuel rod (Fig. 2.9) is heated electrically with chopped-cosine axial power distribution (Fig. 2.10(a)). The effective heated length is 1880 mm, one half of the active length of a BWR fuel rod. Core Power distribution is shown in Fig. 2.10(b). The simulated water rod is used to measure fluid temperature (Fig. 2.11(a)) and void fraction (Fig. 2.11(b)) in the core. These rods are spaced by the spacers (Fig. 2.12) and connected by the connectors (Fig. 2.13) at the top of the core. The orifice at the core inlet (Fig. 2.14) simulates the flow resistance of the nuclear core.

The details the lower plenum are shown in Fig. 2.15. It should be noticed that lead rods to the fuel rods penetrate through the lower plenum and a grid (Fig. 2.16) is used to prevent vibration of the lead rods. The holes for core bypass flow are dimensioned so that approximately 10 percent of total flow will bypass the core region. The rest of the flow will enter the core region through the core inlet orifices.

The upper plenum configuration is shown in Fig. 2.17. The HPCS and the LPCS spargers and LPCI nozzle are arranged as shown in this figure.

The downcomer is annular (Fig. 2.18) and filler blocks are used to fill the gap between the square core-shroud and the circular vessel wall simulating the volume and geometry of an annular downcomer.

The steam separator (Fig. 2.19) is designed to simulate function of an actual steam separator of a BWR while the steam dryer plate (Fig. 2.20) simulates the flow resistance only.

2.2 Steam Line and Feed Water Line

The steam line and the feedwater line simulate those of a BWR. However the steam line and feed water line are independent open loops for the ROSA-III test. Steam is discharged into the atmosphere through the steam line connected to the steam dome. The steam line has three branches as shown in Figure 2.21. The first branch has a control valve (CV 130) to control the steady state steam dome pressure before blowdown. The second brach simulates the automatic depressurization system (ADS). The third branch has an orifice to simulate the flow resistance of a steam turbine-generator. Immediately after the blowdown initiation, the steam line is changed from the steady branch to the transient one. The closure of valves in the steam line takes a few seconds. Table 2.2 shows these valve characteristics along with orifice diameters in the steam line. The piping layout of the steam line is shown in Fig. 2.22.

The feed water line (Fig. 2.23) is connected to the feed water sparger (Fig. 2.24) located above the downcomer region. The feed water conditions are controlled by the feed water tank (FWT) and the heat exchangers (EX1 and EX2).

2.3 Coolant Recirculation System

The coolant recirculation system (Fig. 2.25) simulates the BWR recirculation loop. The system consists of two loops provided with a recirculation pump and two jet pumps in each loop. Characteristics of these pumps are discussed in section 2.6. One of recirculation loops is the intact loop which simulates the unbroken loop of a BWR and the other is the broken loop which simulates the broken loop of a BWR.

The broken loop has two break simulators and a quick shutoff valve (QSV) to simulate a double-ended shear break or a split break. Each break simulator is composed of an orifice (Fig. 2.26) or a nozzle (Fig. 2.27) which determines the break area and a quick opening blowdown valve (QOBV) (Fig. 2.28). The break type, position, and area are experimental variables. The standard break condition is a 200 % double-ended shear break at the recirculation pump inlet side with the orifice diameter of 26.2 mm.

Details of piping dimensions in recirculation loops are shown in Fig. 2.29 through Fig. 2.39.

2.4 Emergency Core Cooling System

The ECCS of ROSA-III simulate those of a BWR. The ECC systems include HPCS, LPCS, LPCI and ADS. The pipings of the ECC systems are shown schematically in Fig. 2.40. The spray systems, the HPCS (Fig. 2.41) and the LPCS (Fig. 2.42), spray the emergency core cooling water on the top of the core. The LPCI system (Fig. 2.43) supplies the emergency core cooling water into the core-bypass region directly (See Fig. 2.17). Each ECCS is provided with a tank, a pump, a valve, and a control system to control the valve trip delay, valve opening speed, and the flow rate. The flow rates of HPCS, LPCS and LPCI are shown as a function of pressure vessel pressure in Fig. 2.44, 2.45, and 2.46, respectively, comparing with the data for a BWR/6⁽¹⁾.

2.5 Power Curve for Simulated Fuel Rods

The power curve⁽³⁾ for simulated fuel rods in the ROSA-III test is shown in Fig. 2.47 and Table 2.3 comparing with the calculated results for the BWR/6⁽²⁾ plant. The ROSA-III facility has heater rods in the core for fuel rod simulation, therefore, it is quite important for ROSA-III tests to give appropriate power transient to heater rods, because there are large differences in thermal characteristics between nuclear fuel rod and heater rod. Especially there is large difference in the heat capacity or the stored heat.

The power curve of ROSA-III simulates the average heat transfer rate in a BWR/6 core neglecting the stored heat of ROSA-III heater rods.

The power transferred to the coolant in a BWR core is consisted of delayed-neutron fission power, decay power of fission products and actinides, and the stored heat release from the fuel. The ROSA-III heater power is varied following the pre-determined time transient curve in Fig. 2.47 without considering the feedbacks from the changes in the heat transfer mode during experiment.

For the first 50 s after the initiation of blowdown the heat transfer rate in the BWR core was calculated by the RELAP4J⁽⁴⁾ code assuming a 200 % double-ended break at the recirculation pump suction. Moderator density feedback, Doppler feedback, and scram worth were considered in the calculation of fission power. The power curve was obtained by using the data at the lower portion of the core because there was no abrupt change in the heat transfer rate due to DNB or rewetting. The ROSA-III core is consisted of four half-length fuel bundles corresponding to 9 MW steady state power. However, the power supply to heater rods of ROSA-III is limited to 4.4 MW, therefore, the power is kept constant for the first 7.5s until the normalized heat transfer rate in the core decreases to 0.49 (=4.4 MW / 9 MW).

Between 50 and 260 s after the initiation of blowdown stored heat release rate was calculated assuming fuel temperature equals to saturation temperature. Decay power of fission products and actinides was calculated by the proposed ANS 5.1⁽⁵⁾ standard assuming thermal neutron fission of ^{235}U and production rate of ^{239}U per fission to be 0.59. Delayed-neutron fission power is negligible after 50 s.

After 260 s stored heat release also becomes negligible and the heat transfer rate to coolant was calculated as the decay power of fission products and actinides.

2.6 Characteristics of Jet Pump and Recirculation Pump

2.6.1 Jet Pump Characteristics

As described previously, four jet pumps are placed outside of the vessel, two in broken loop and the others in intact loop. Therefore, the jet pumps need additional pipings connecting to the downcomer and the lower plenum. The jet pump characteristics and the pressure drop across the pipings under the reverse flow condition are described in this section.

The jet pump for the ROSA-III consists of an inlet mixer, a driving flow nozzle and a diffuser, as shown in Fig. 2.48. Detailes of the driving flow nozzle are shown in Fig. 2.49.

The operation principle of the jet pump is the conversion of momentum to pressure. The efficiency η , the ratio of the total energy increase of the suction flow to the total energy decrease of the driving flow is given in the following equation.

$$\eta = \frac{G_2}{G_1} \cdot \frac{H_d - H_2}{H_1 - H_d}$$

, where G and H represent the mass flow and the head, respectively, and the subscripts 1, 2, and " d " refer to the driving flow, suction flow, and discharge flow, respectively.

The flow ratio M is defined as

$$M = \frac{G_2}{G_1} \approx \frac{Q_2}{Q_1}$$

, where the mass flow (G) ratio is approximated to the volumetric flow (Q) ratio because the fluid densities of the driving flow and suction flow are nearly the same.

The head ratio N is defined as

$$N = \frac{H_d - H_2}{H_1 - H_d}$$

Thus the efficiency can be written as

$$\eta = M \cdot N$$

Experimental results of jet pump characteristics in the ROSA-III test is shown in Fig. 2.50, comparing with the reference data for a LBWR⁽⁶⁾.

When the driving flow stops and the flow in the jet pump reverses from the diffuser to inlet mixer, the jet pump is only the piping with flow resistance. The pressures drop across the jet pump and additional pipings were measured under the reverse flow condition. The results are shown in figures 2.51, 52, and 53 as a function of flow rate at the jet pump diffuser. Distribution of the flow resistance in the jet pumps and additional pipings is summarised in Table 2.4. The friction factors are shown in Table 2.5.

2.6.2 Recirculation Pump Characteristics

The recirculation pump for the ROSA-III is non-seal type vertical centrifugal pump with design value shown in Table 2.6.

The single-phase pump head curve for the ROSA-III pump is shown in Fig. 2.54. The following definitions refer to this figure.

$$\text{head ratio} : h = H / H_r$$

$$\text{speed ratio} : \alpha = \omega / \omega_r$$

$$\text{Flow ratio} : v = Q / Q_r$$

, where H , ω and Q represent the head, angular speed and volumetric flow rate, respectively, and the subscript " r " denote the rated operating value.

The curves consist of 8 segments corresponding to the operation region as,

1 normal pump	h / v^2 ($\alpha > 0, v > 0, \alpha/v < 1$)
2 normal pump	h / α^2 ($\alpha > 0, v > 0, \alpha/v > 1$)
3 energy dissipation	h / v^2 ($\alpha > 0, v < 0, \alpha/v < 1$)
4 energy dissipation	h / α^2 ($\alpha > 0, v < 0, \alpha/v > 1$)
5 normal turbine	h / v^2 ($\alpha < 0, v < 0, \alpha/v < 1$)
6 normal turbine	h / α^2 ($\alpha < 0, v < 0, \alpha/v > 1$)
7 reverse pump	h / v^2 ($\alpha < 0, v > 0, \alpha/v < 1$)
8 reverse pump	h / α^2 ($\alpha < 0, v > 0, \alpha/v > 1$)

The single-phase homologous head curves can be used for the ROSA-III system analysis code (such as RELAP4/MOD5).

3. INSTRUMENTATION

The instrumentation system of the ROSA-III was designed to obtain thermo-hydraulic data in a BWR LOCE to contribute to assess the analytical code. The channel assignment for the instrumentation differs following the renewal of the simulated fuel assembly or remodeling of the loop system. The measurement list for the latest fuel assembly (No.3) is shown in Table 3.1. Locations of instrumentation are shown in Fig. 3.1 through Fig. 3.8 and Table 3.2 presents thermocouple locations in the fuel assembly No.4.

Measured quantities in the ROSA-III test are pressure, differential pressure, flow rate, electric power, pump revolution, signals, fluid temperature, liquid level, fluid density and momentum flux of coolant flow.

Pressure measurements are done with semi-conductor transducers measuring the piezoelectric resistance. The detector is cooled by water for the protection from high temperature environment.

Differential pressure transducers with two direct current cables convert displacement of a diaphragm to electric charge and then to proportional voltage. The pressure lead pipes are dual circular pipes for circulating cooling water to eliminate flashing of the fluid.

Flow rate is measured by orifice, venturi, turbine or electro-magnetic flow meters depending on the fluid condition and the measurement location.

Electric power for simulated fuel rods is controlled by the predetermined function of time and it is measured by fast response electric power meter.

Pump revolution speed is measured by electromagnetic counter on the pump shaft.

On-off signals such as valve position, pump revolution direction, blowdown initiation and pump power supply are converted to voltage or current and recorded in respective channels in order to specify the exact time of the signal.

Temperature of fluid, structure materials and fuel rods are measured with Chromel-Alumel thermocouples (CA T/C) of 1.6 mmφ or 1.0 mmφ.

Liquid levels are measured by means of needle type electrical conductivity probes developed in the ROSA-III program. The probes are attached on the walls of core barrel and channel boxes at several elevations and detect the existence of water or vapor at each level.

Fluid density in the pipe is measured by means of a gamma-ray densitometer. Each gamma-ray densitometer has two or three beams to estimate the flow regime. The gamma source is ^{137}Cs (~ 20 Ci) and the detector is a NaI scintillator which is cooled by water.

Momentum flux is measured by a drag disk, and the combination of two signals from a drag disk, a turbine meter and a gamma-ray densitometer is used to determine two-phase flow conditions.

In addition to the instrumentations described above, measurement technique of void fraction measurement and flow direction measurement are under development and prototypes of such detectors are being tested in the test facility.

The data acquisition system consists of DATAAC-2000B and FACOM M200 system computer. The DATAAC 2000B records measured data on a magnetic tape up to 750 channels and the data tape is processed by the FACOM M200 system computer at JAERI by off line. After the evaluation of each data by comparing the initial and the final values with the standard values of the pressure, for example, the data are re-processed using the correct conversion factors determined from the consistency examination.

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Table 2.1 Primary Characteristics of BWR6 and ROSA-III

a) Comparison of Major Design Parameters

	BWR6(251/848)	ROSA-III	Ratio($\frac{\text{BWR6}}{\text{ROSA-III}}$)
Reactor Type	BWR	Simulated BWR	
Number of			
Recirc. Loops	2	2	1
Steam Lines	4	1	4
Jet Pumps	24	4	6
Separators	212	1	212
Core Heat Generation	Nuclear Fission	Electric Heater	
Total Power(kW)	3.80×10^5	< 4450	> 854
Active Fuel Length(m)	3.759	1.880	2
Number of Fuel Assemblies	848	4	212
Total Volume(m^3)	621	1.42	437
Operating Conditions			
Pressure(MPa)	7.27	7.27	
Core Flow(kg/s)	1.54×10^4	< 3.64	> 424
Steam Flow(kg/s)	2.06×10^3	< 4.86	> 424
Recirc. Pump Flow Rate per 1 Pump (kg/s)	2.24×10^3	< 5.26	> 424
Feed Water Temp.(K)	489	489	1

Table 2.1 (continued)

b) ECCS Conditions

	BWR6(251/848)	ROSA-III	Ratio($\frac{\text{BWR6}}{\text{ROSA-III}}$)
HPCS			
Number of Lines	1	1	
Injection Flow Rate(m^3/s)			
at 7.90MPa	0.104	0.425×10^{-3}	424* See Fig.2.44
at 1.38MPa	0.442	0.820×10^{-3}	
Water Temp.(K)	300 ~ 344	up to 393	
Injection Location	upper plenum	upper plenum	
LPCS			
Number of Lines	1	1	
Injection Flow Rate(m^3/s)			
at 0.84MPa	0.442	0.94×10^{-3}	424* See Fig.2.45
Water Temp.(K)	300 ~ 344	up to 393	
Injection Location	upper plenum	upper plenum	
LPCI(RHR)			
Number of Lines	3	1	
Injection Flow Rate($\text{m}^3/\text{s}/\text{pump}$)			
at 0.14MPa	0.470	4.27×10^{-3}	424* See Fig.2.46
Water Temp.(K)	300 ~ 344	up to 393	
Injection Location	in-shroud	in-shroud	c.f.Fig.2.17

Note: * Design scaling ratio

Table 2.1 (continued)

c) Volume Distribution and Main Component Dimension

Item	BWR6(251/848)	ROSA-III	Ratio($\frac{\text{BWR6}}{\text{ROSA-III}}$)
Lower Plenum & Guide Tubes m ³	123	0.177	695
Lower Plenum m ³	79.0	0.112	705
Guide Tubes m ³	43.8	0.0651	673
Core m ³	59.8	0.134	446
Core in Channels m ³	35.4	0.0814	435
Core Bypass m ³	24.4	0.0524	465
Upper Plenum & Steam Separators m ³	80.5	0.185	435
Upper Plenum m ³	52.5	0.124	423
Steam Separators m ³	28.0	0.0610	459
Steam Dome *1) m ³	206	0.439	468
Downcomer *2) m ³	123	0.233*3)	528
Above Jet Pump Suction m ³	74.2*	0.164*4)	452
Between Jet Pump Suction and Recirculation Outlet m ³	36.8*	0.0600*3)	613
Below Recirculation Outlet m ³	12.2	0.00900	1360
Recirculation Loops & Jet Pumps m ³	29.6	0.171*4)	173
Total Volume m ³	621	1.421	437
Pressure Vessel Dimension			
Inner Height m	22.3*	6.01	3.71
Inner Diameter m	6.38*	0.492*5)	13.0
Water Level m	14.1*	4.62	3.04
Jet Pump Suction Level m	8.28*	2.82	2.93
Lower Core End Level m	5.49*	1.60*6)	3.43
Recirculation Line Level m	3.88*	0.938	4.13
Recirculation Loop Pipe Inner Diameter m	0.54	≤ 0.0495	

Note : * BWR 5

*1)above normal water level

*2)below normal water level

*3)include jet pump suction lines

*4)not include jet pump suction lines

*5)out diameter of lower downcomer

*6)bottom of active fuel

Table 2.1 (continued)
d) Thermal Characteristics

	BWR6(251/848)	ROSA-III	Ratio ($\frac{\text{BWR6}}{\text{ROSA-III}}$)
Active Core Length (m)	3.708	1.880	1.972
Number of Fuel Rods	52576	248	212
Number of Water Rods	1696	8	212
Rods Array	8 x 8 square	8 x 8 square	
Fuel Rod O.D. (mm)	12.27	12.27	1
Cladding Thickness (mm)	0.864	1.3	0.665
Fuel Rod Pitch (mm)	16.16	16.16	1
Total Fuel Heat Transfer Area (m ²)	7.515×10^3	1.797×10^1	418
Cladding Material	Zircalloy	Inconel 600	
Average Linear Rod Power (kW/m)	19.49	≤ 9.54	≥ 2.04
Core Average Heat Flux (kW/m ²)	505.7	≤ 247.6	≥ 2.04
Core Coolant Flow Rate* (kg/s)	$1.54 \times 10^4***$	< 36.4	> 424
Core Inlet Velocity** (m/s)	2.16***	1.11	1.95
Total Core Flow Area (m ²)	8.56***	0.0392	218
Peaking Factor			
Local P.F.	1.18	1.10	1.073
Axial P.F.	1.30	1.40	0.929
Radial P.F.	1.35	1.40	0.964
Gross P.F.	1.8	1.96	0.918
Total P.F.	2.1	2.20	0.955

* Include core bypass

** Exclude core bypass flow rate assuming it as 10% of core coolant flow rate

*** Current 8 x 8 fuel rods

Table 2.2 Valve Characteristics of Steam Discharge Line

Valve	Close to Open (s)	Open to Close (s)
AV165 (MSIV Valve)	0.1	1.5
AV168 (Steady State Line)	-	0.1
AV169 (ADS Valve)	0.3	2.0
Orifice	Diameter (mm)	Area (mm ²)
OR3	Not Used	-
OR4	15.5	188.7
OR5	16.8	221.7

Table 2.3 Power Curve for ROSA-III

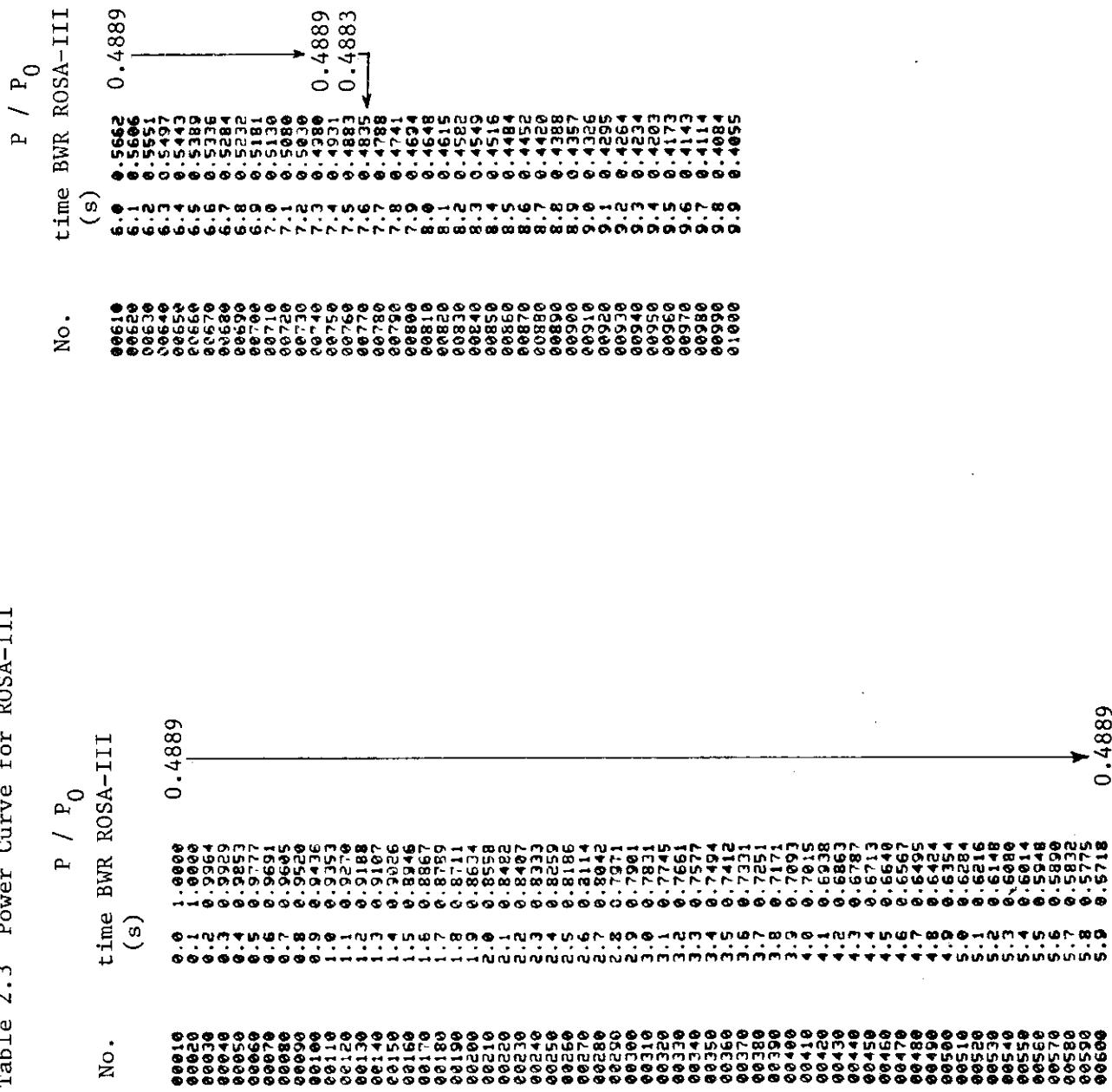


Table 2.3 (Continued)

No.	time (s)	P / P_0	time (s)	P / P_0
01610	0.1626	0.2664	16.0	0.2652
01620	0.1597	0.2639	16.1	0.2639
01630	0.1569	0.2615	16.2	0.2615
01640	0.1540	0.2602	16.3	0.2602
01650	0.1512	0.2599	16.4	0.2599
01660	0.1492	0.2578	16.5	0.2578
01670	0.1473	0.2555	16.6	0.2555
01680	0.1454	0.2554	16.7	0.2554
01690	0.1435	0.2554	16.8	0.2554
01700	0.1416	0.2554	16.9	0.2554
01710	0.1397	0.2554	17.0	0.2554
01720	0.1378	0.2536	17.1	0.2536
01730	0.1359	0.2519	17.2	0.2519
01740	0.1340	0.2507	17.3	0.2507
01750	0.1321	0.2495	17.4	0.2495
01760	0.1302	0.2483	17.5	0.2483
01770	0.1283	0.2472	17.6	0.2472
01780	0.1264	0.2460	17.7	0.2460
01790	0.1245	0.2449	17.8	0.2449
01800	0.1226	0.2437	17.9	0.2437
01810	0.1207	0.2426	18.0	0.2426
01820	0.1188	0.2414	18.1	0.2414
01830	0.1169	0.2403	18.2	0.2403
01840	0.1150	0.2391	18.3	0.2391
01850	0.1131	0.2372	18.4	0.2372
01860	0.1112	0.2356	18.5	0.2356
01870	0.1093	0.2339	18.6	0.2339
01880	0.1074	0.2322	18.7	0.2322
01890	0.1055	0.2305	18.8	0.2305
01900	0.1036	0.2288	18.9	0.2288
01910	0.1017	0.2271	19.0	0.2271
01920	0.0998	0.2255	19.1	0.2255
01930	0.0979	0.2238	19.2	0.2238
01940	0.0960	0.2222	19.3	0.2222
01950	0.0941	0.2206	19.4	0.2206
01960	0.0922	0.2190	19.5	0.2190
01970	0.0903	0.2174	19.6	0.2174
01980	0.0884	0.2158	19.7	0.2158
01990	0.0865	0.2142	19.8	0.2142
02000	0.0846	0.2126	19.9	0.2126
02010	0.0827	0.2111	19.9	0.2111

Table 2.3 (Continued)

No.	time (s)	P / P_0
92610	0.2095	0.1511
92610	0.2080	0.1492
92610	0.2065	0.1483
92610	0.2050	0.1474
92610	0.2035	0.1465
92610	0.2020	0.1457
92610	0.2011	0.1448
92610	0.1992	0.1439
92610	0.1984	0.1430
92610	0.1975	0.1422
92610	0.1966	0.1413
92610	0.1958	0.1405
92610	0.1949	0.1396
92610	0.1940	0.1388
92610	0.1932	0.1379
92610	0.1923	0.1371
92610	0.1914	0.1363
92610	0.1906	0.1354
92610	0.1897	0.1346
92610	0.1889	0.1338
92610	0.1880	0.1330
92610	0.1872	0.1323
92610	0.1864	0.1320
92610	0.1855	0.1317
92610	0.1847	0.1315
92610	0.1839	0.1312
92610	0.1830	0.1309
92610	0.1822	0.1306
92610	0.1814	0.1303
92610	0.1806	0.1300
92610	0.1795	0.1297
92610	0.1785	0.1294
92610	0.1774	0.1291
92610	0.1764	0.1289
92610	0.1753	0.1286
92610	0.1743	0.1283
92610	0.1733	0.1280
92610	0.1722	0.1277
92610	0.1712	0.1274
92610	0.1702	0.1271
92610	0.1692	0.1268
92610	0.1682	0.1265
92610	0.1672	0.1262
92610	0.1662	0.1259
92610	0.1652	0.1256
92610	0.1642	0.1253
92610	0.1632	0.1250
92610	0.1623	0.1247
92610	0.1613	0.1244
92610	0.1604	0.1241
92610	0.1594	0.1238
92610	0.1585	0.1235
92610	0.1576	0.1232
92610	0.1566	0.1229
92610	0.1557	0.1226
92610	0.1548	0.1223
92610	0.1538	0.1220
92610	0.1529	0.1217
92610	0.1520	0.1214
92610	0.1511	0.1211

Table 2.3 (Continued)

No.	time (s)	P / P_0
03610	39.0	0.1289
03620	39.2	0.1275
03630	39.4	0.1271
03640	39.6	0.1267
03650	39.8	0.1262
03660	31.8	0.1253
03670	31.2	0.1249
03680	31.4	0.1244
03690	31.6	0.1240
03700	31.8	0.1236
03710	32.0	0.1231
03720	32.2	0.1227
03730	32.4	0.1223
03740	32.6	0.1218
03750	32.8	0.1214
03760	33.0	0.1210
03770	33.2	0.1206
03780	33.4	0.1201
03790	33.6	0.1197
03800	33.8	0.1193
03810	34.0	0.1189
03820	34.2	0.1185
03830	34.4	0.1180
03840	34.6	0.1176
03850	34.8	0.1172
03860	35.0	0.1168
03870	35.2	0.1164
03880	35.4	0.1160
03890	35.6	0.1156
03900	35.8	0.1152
03910	36.0	0.1148
03920	36.2	0.1144
03930	36.4	0.1140
03940	36.6	0.1136
03950	36.8	0.1132
03960	37.0	0.1128
03970	37.2	0.1124
03980	37.4	0.1120
03990	37.6	0.1116
04000	37.8	0.1112
04010	38.0	0.1108
04020	38.2	0.1104
04030	38.4	0.1100
04040	38.6	0.1096
04050	38.8	0.1092
04060	39.0	0.1088
04070	39.2	0.1085
04080	39.4	0.1081
04090	39.6	0.1077
04100	39.8	0.1073
04110	40.0	0.1070
04120	40.2	0.1066
04130	40.4	0.1059
04140	40.6	0.1055
04150	40.8	0.1051
04160	41.0	0.1047
04170	41.2	0.1043
04180	41.4	0.1040

Table 2.4 Pressure drop across the jet pumps and additional pipings under the reverse flow condition ($Q = 200\text{ l/min}$)

Pipings	Pressure drop (kg/cm^2)	Rate (%)
Jet Pump Discharge to Suction	0.45	56.0
Jet Pump Suction to Downcomer	0.29	36.5
Y Branch	0.06	7.5
Total	0.8	100.0

Table 2.5 Friction factor of the jet pumps and additional pipings under the reverse flow condition

Pipings	Inner Diameter (mm)	Friction Factor
Jet Pump Discharge to Suction	19.3 (throat)	$0.63 < K < 0.89$
Jet Pump Suction to Downcomer	38.4 ($1 \frac{1}{2}B$)	$6.2 < K < 9.3$
	62.0 ($2 \frac{1}{2}B$)	$42 < K < 63$
Y Branch	49.5 (2B)	$3.5 < K < 6.5$
	62.0 ($2 \frac{1}{2}B$)	$8.5 < K < 16$
	73.9 (3B)	$17 < K < 31$

Table 2.6 Design parameters of ROSA-III recirculation pump

Items	Design Value
Rated Flow	(l/min) 450
Rated Head	(m) 262
Rated Velocity	(rpm) 3600
Fluid Temperature	(K) 555
NPSH	(m) 4
Moment of Inertia	(kgm^2) 1.7
Rated Torque	(kgm) 18.8
Impeller Diameter	(mm) 315

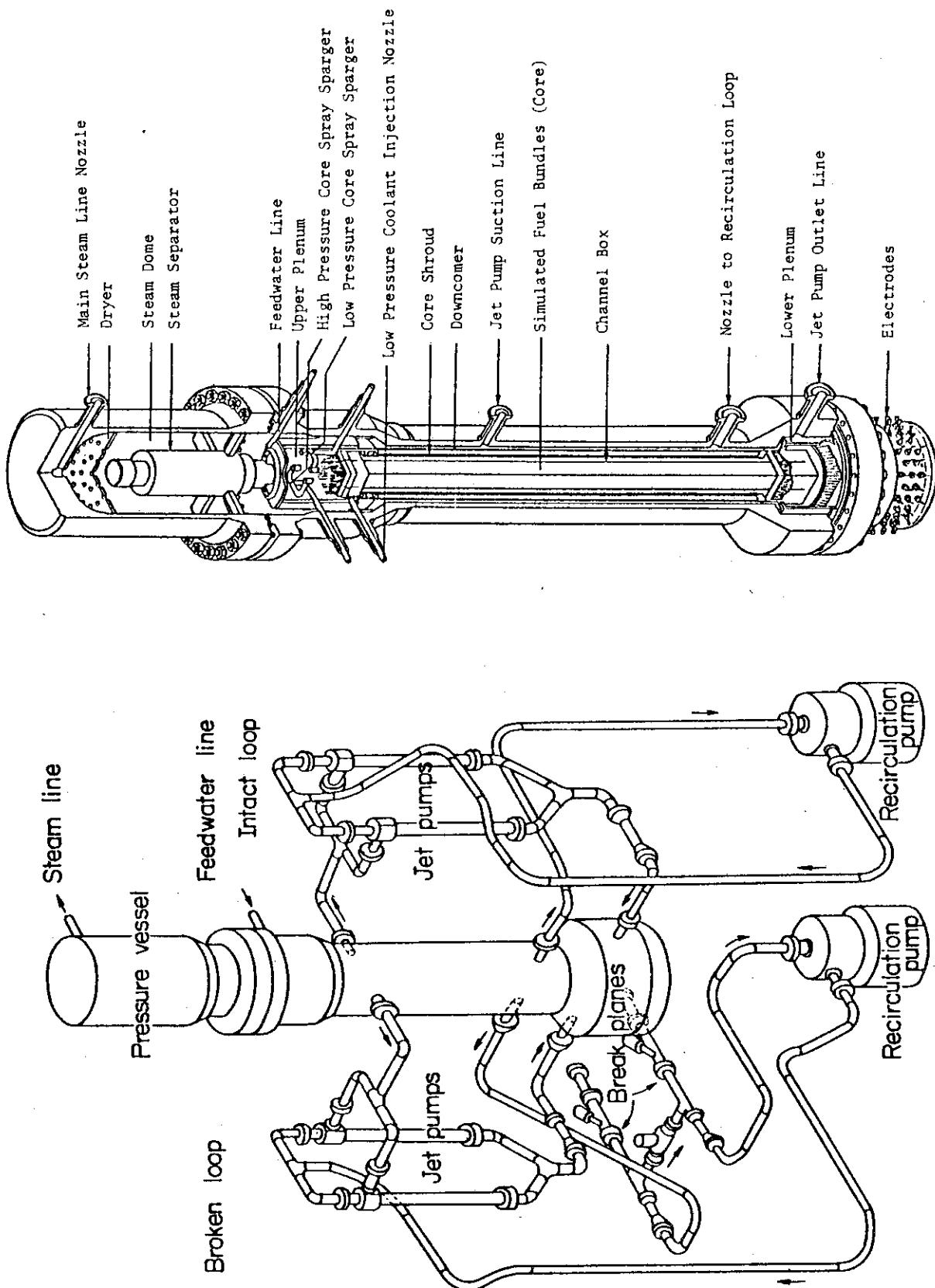


Fig. 2.1 Schematic Diagram of ROSA-III Test Facility

Fig. 2.2 Internal Structure of Pressure Vessel of ROSA-III

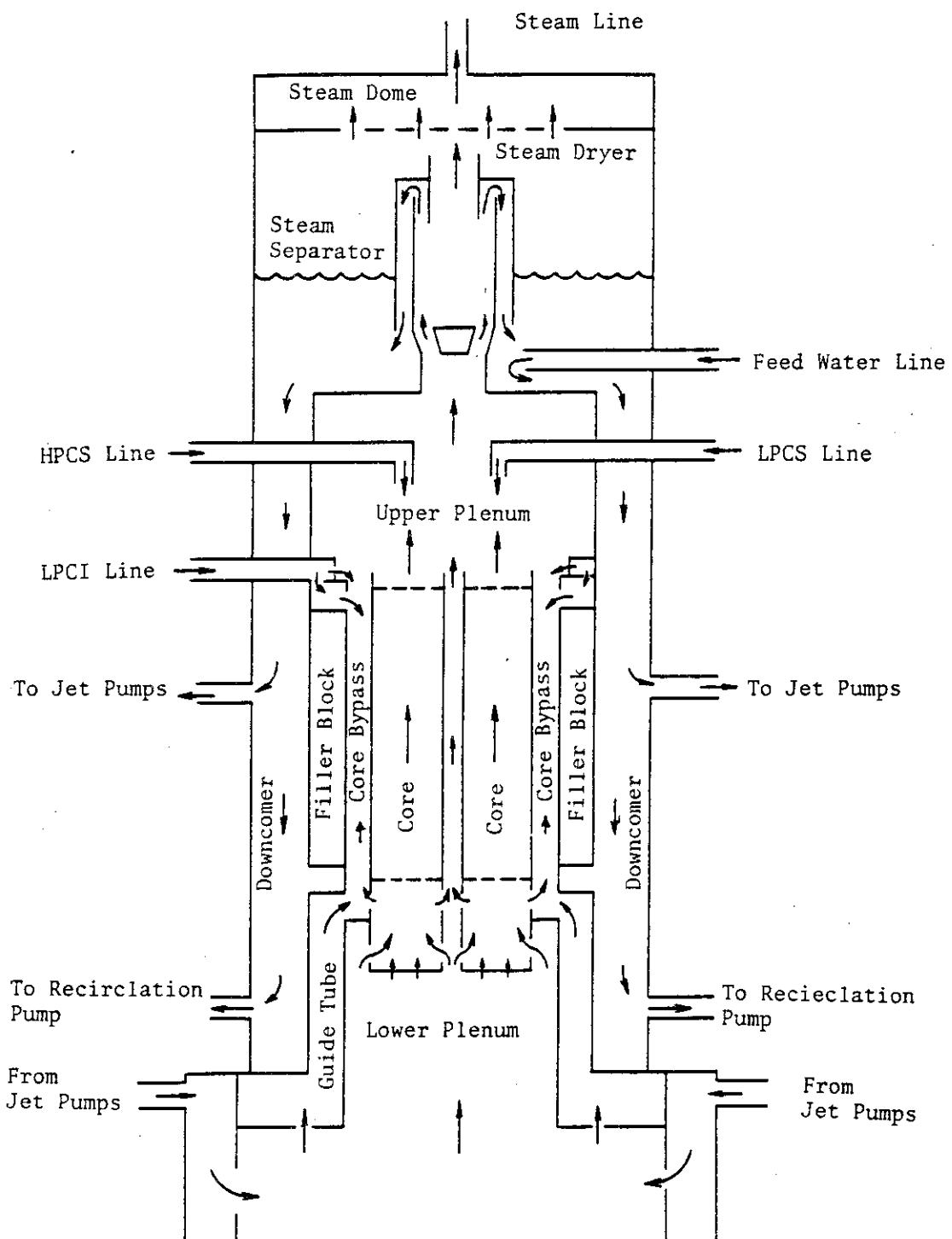


Fig. 2.3 Steady State Coolant Flow in the Vessel and ECC Flow During LOCA

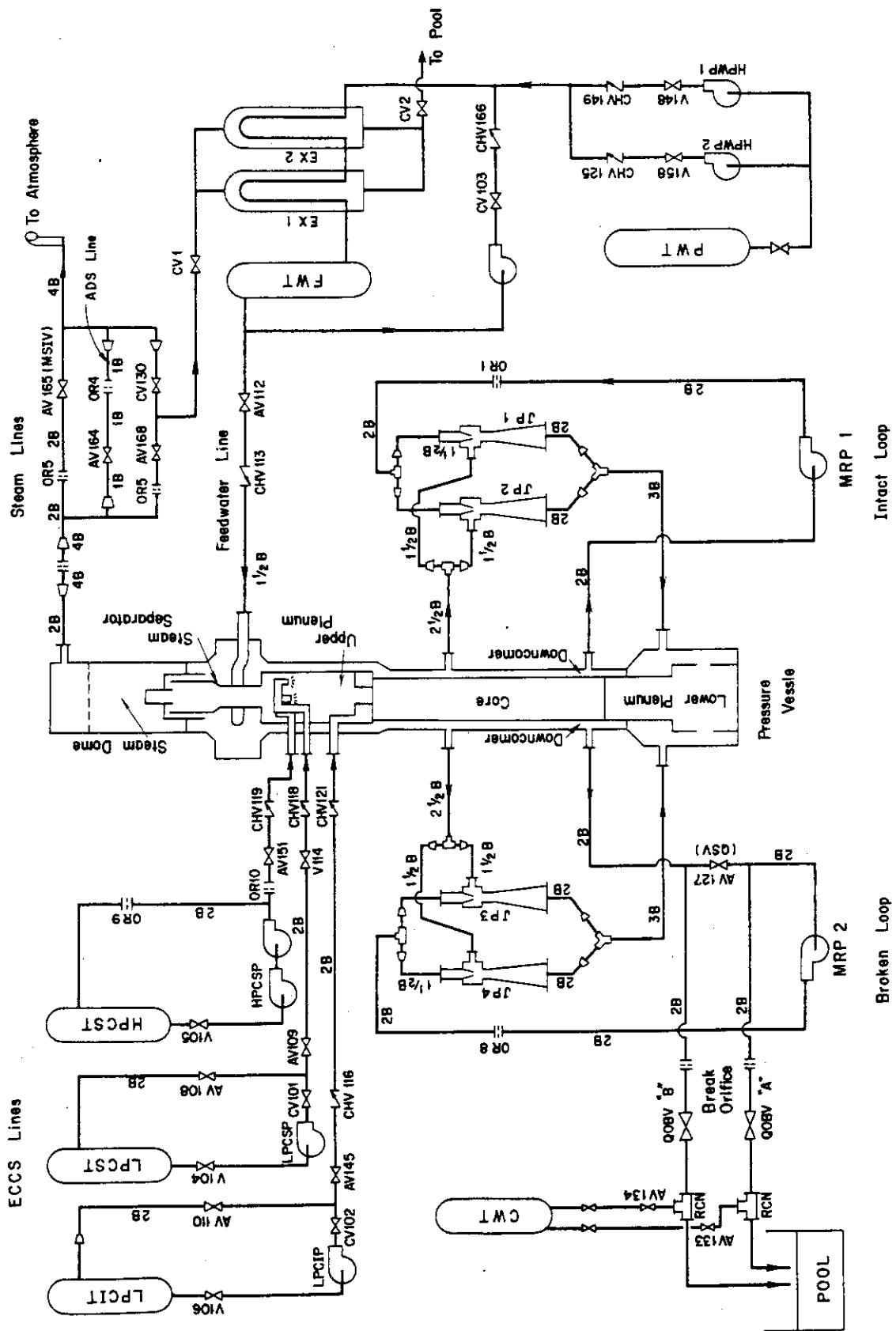


Fig. 2.4 ROSA-III Piping Schematic

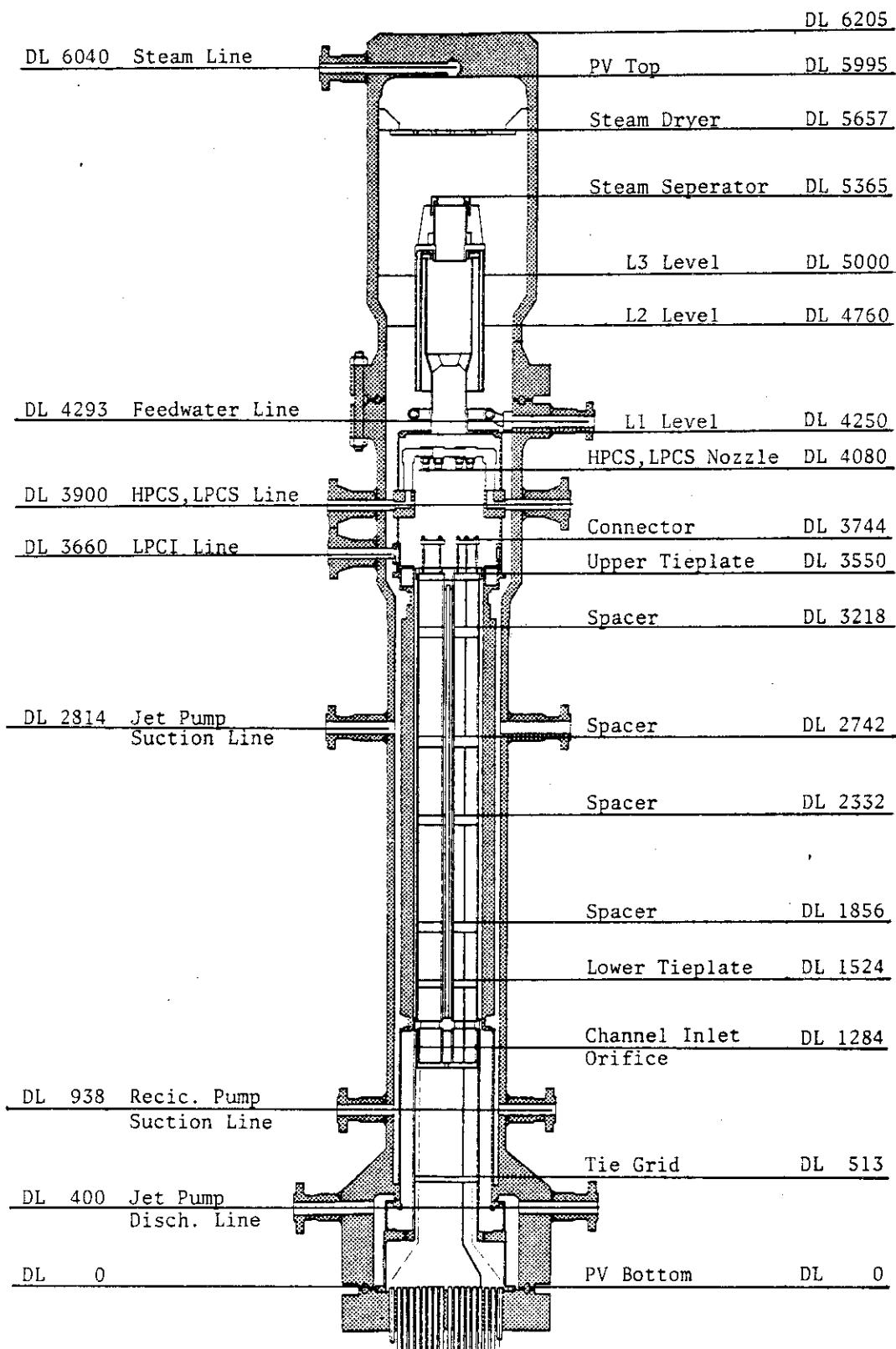


Fig. 2.5 Pressure Vessel Internals Arrangement

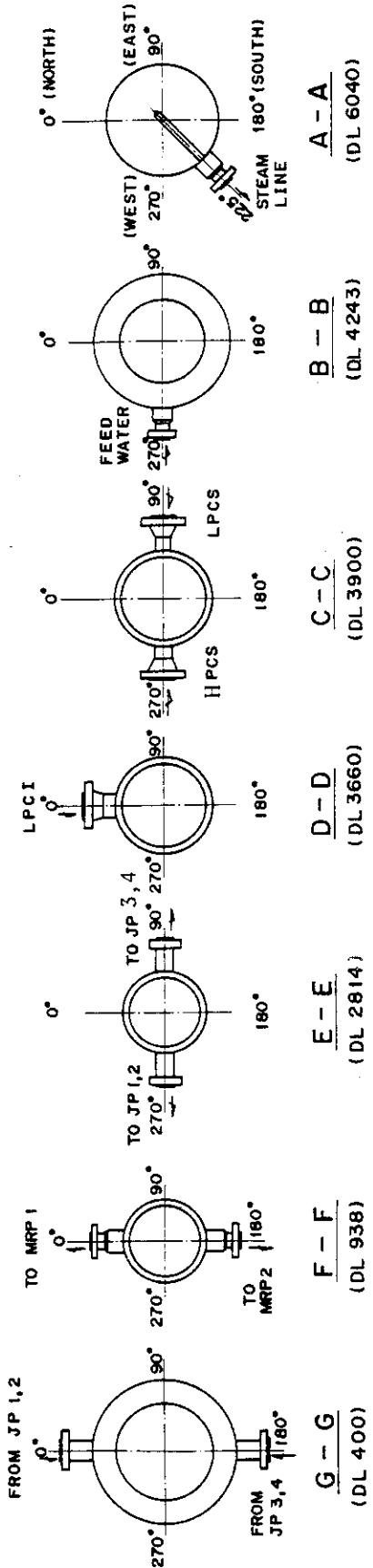
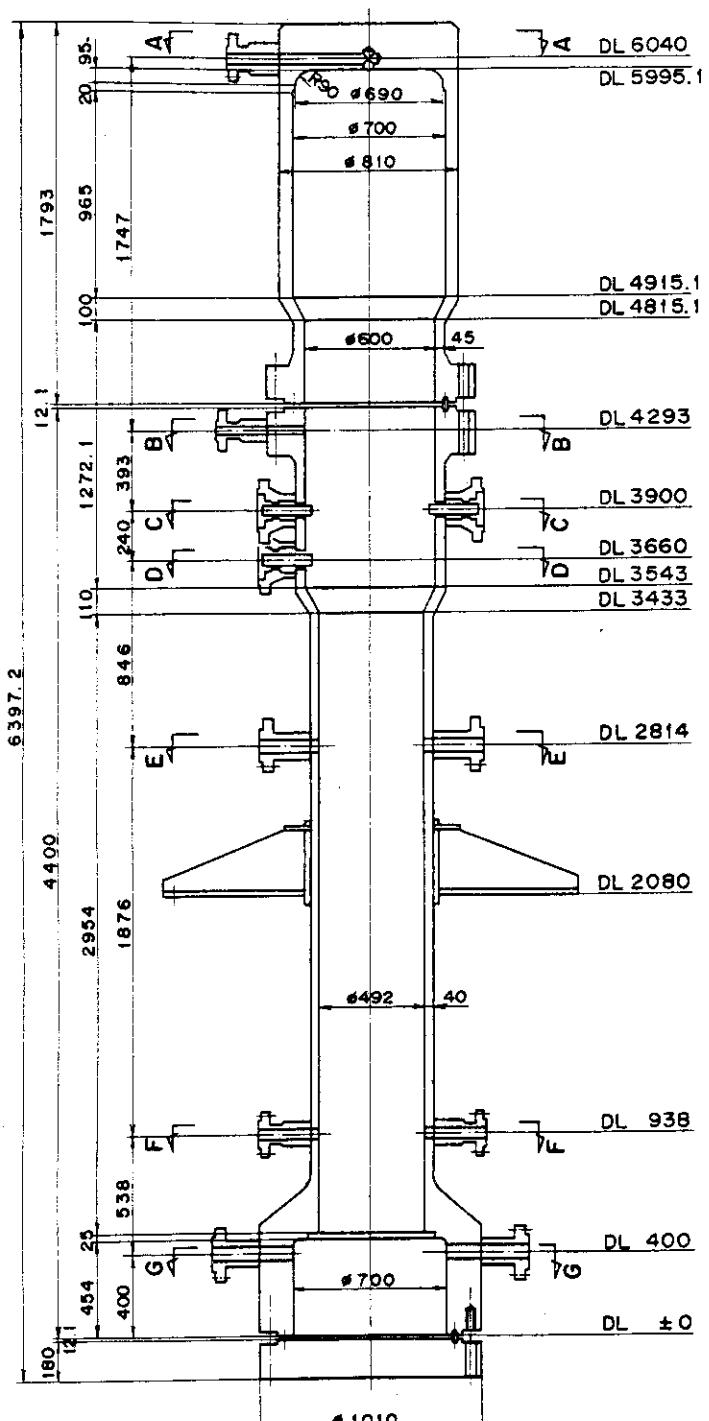


Fig. 2.6 Pressure Vessel with Nozzles

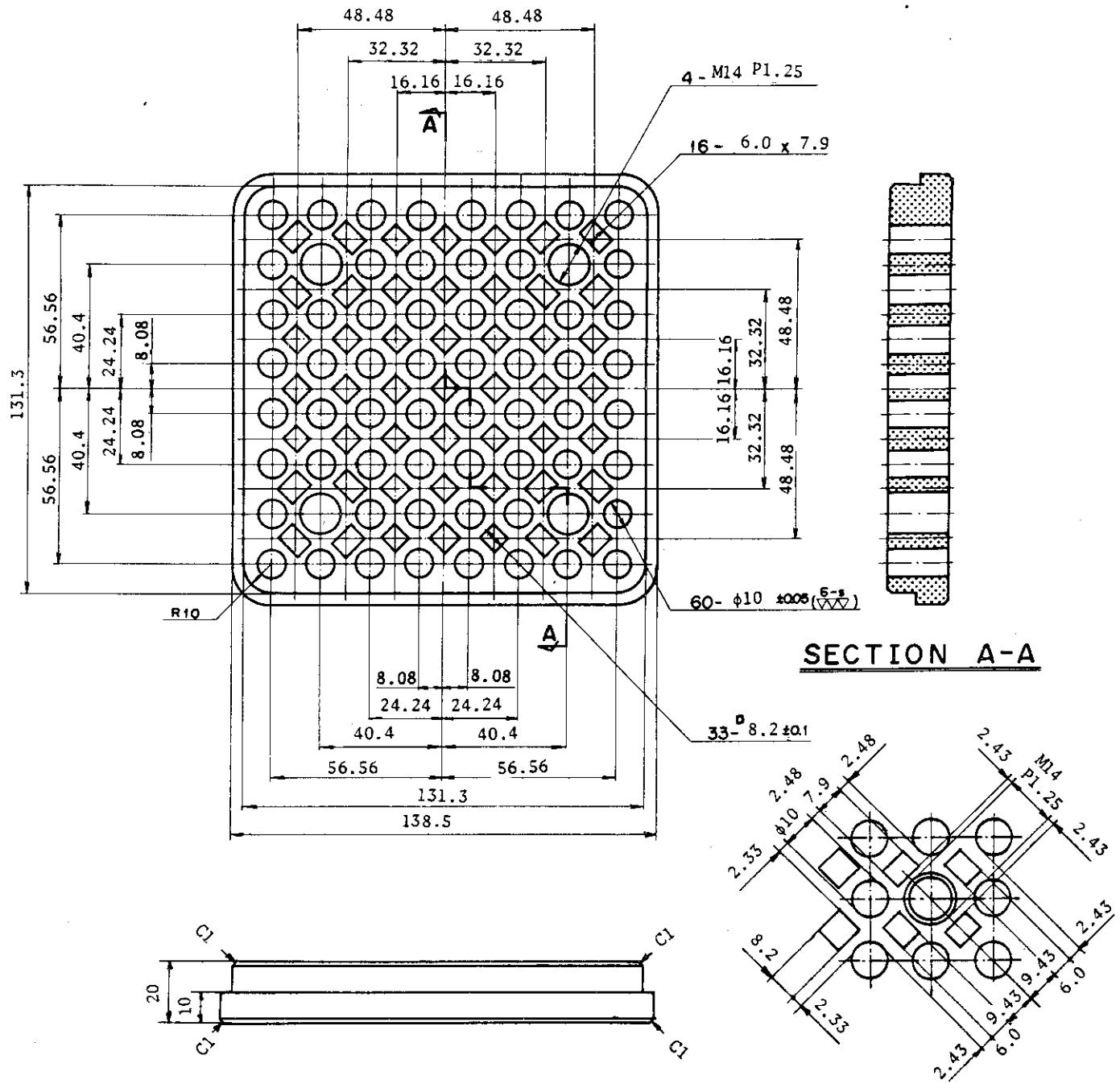


Fig. 2.7 Upper Tie Plate

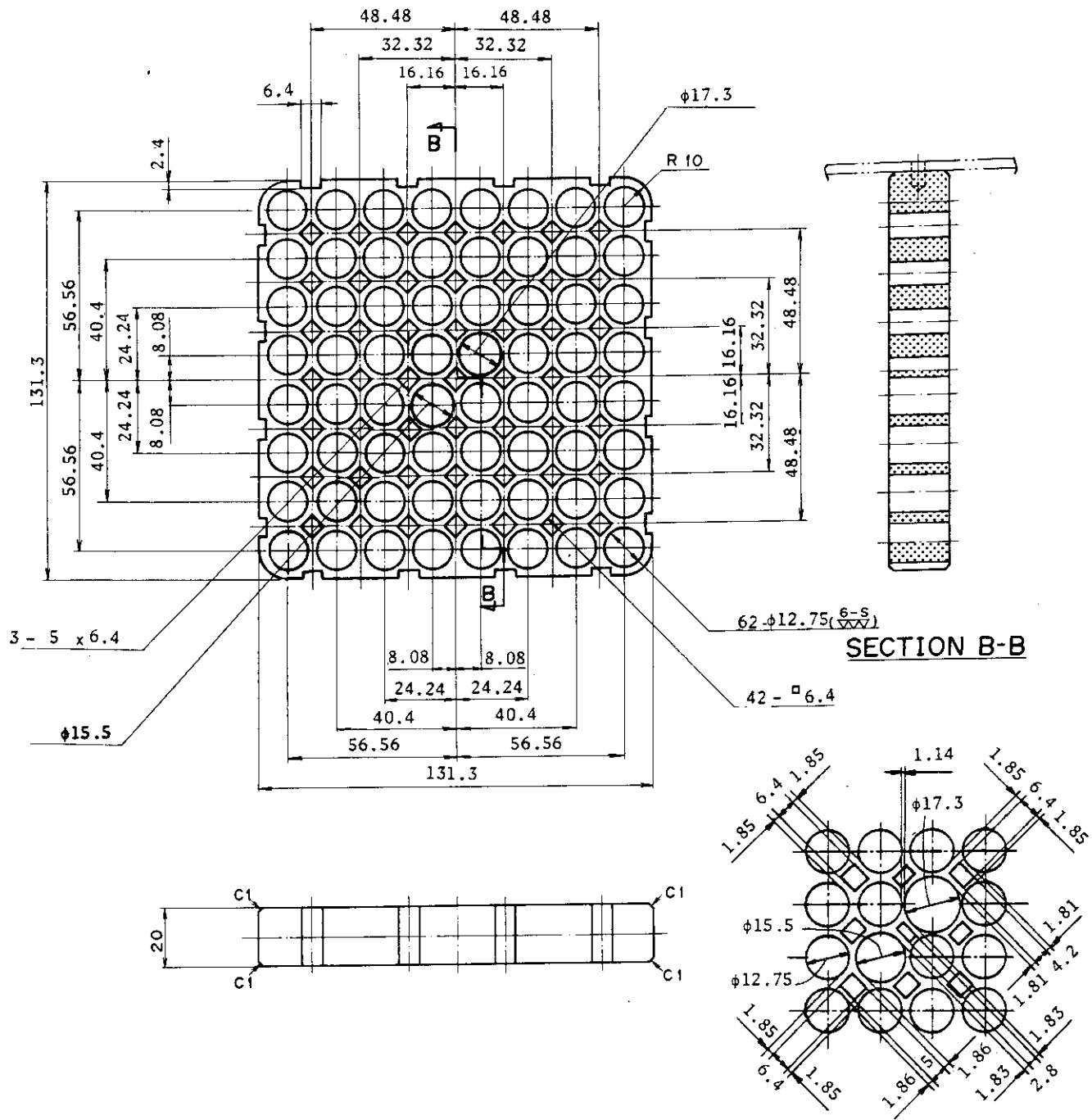


Fig. 2.8 Lower Tie Plate

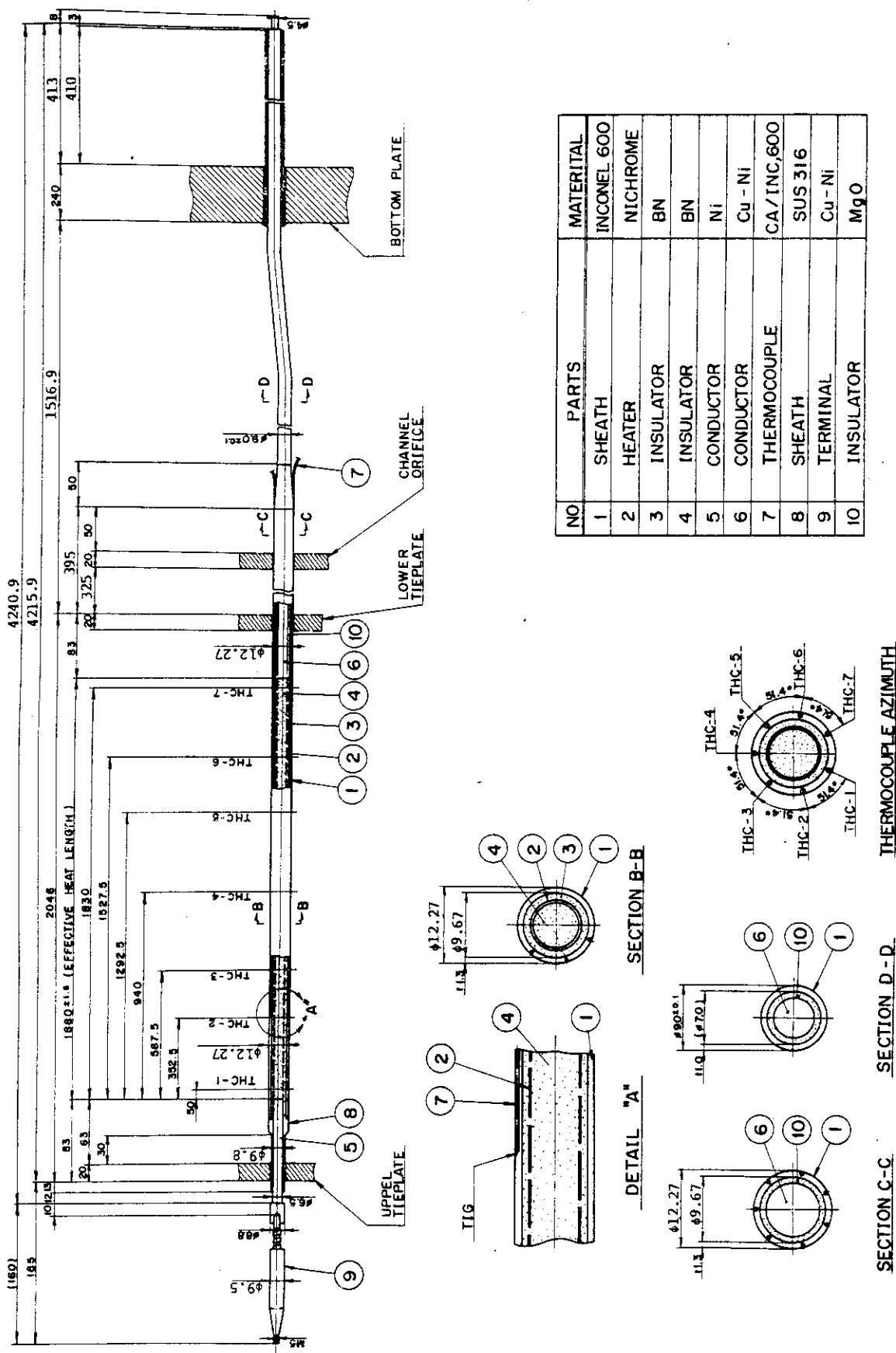
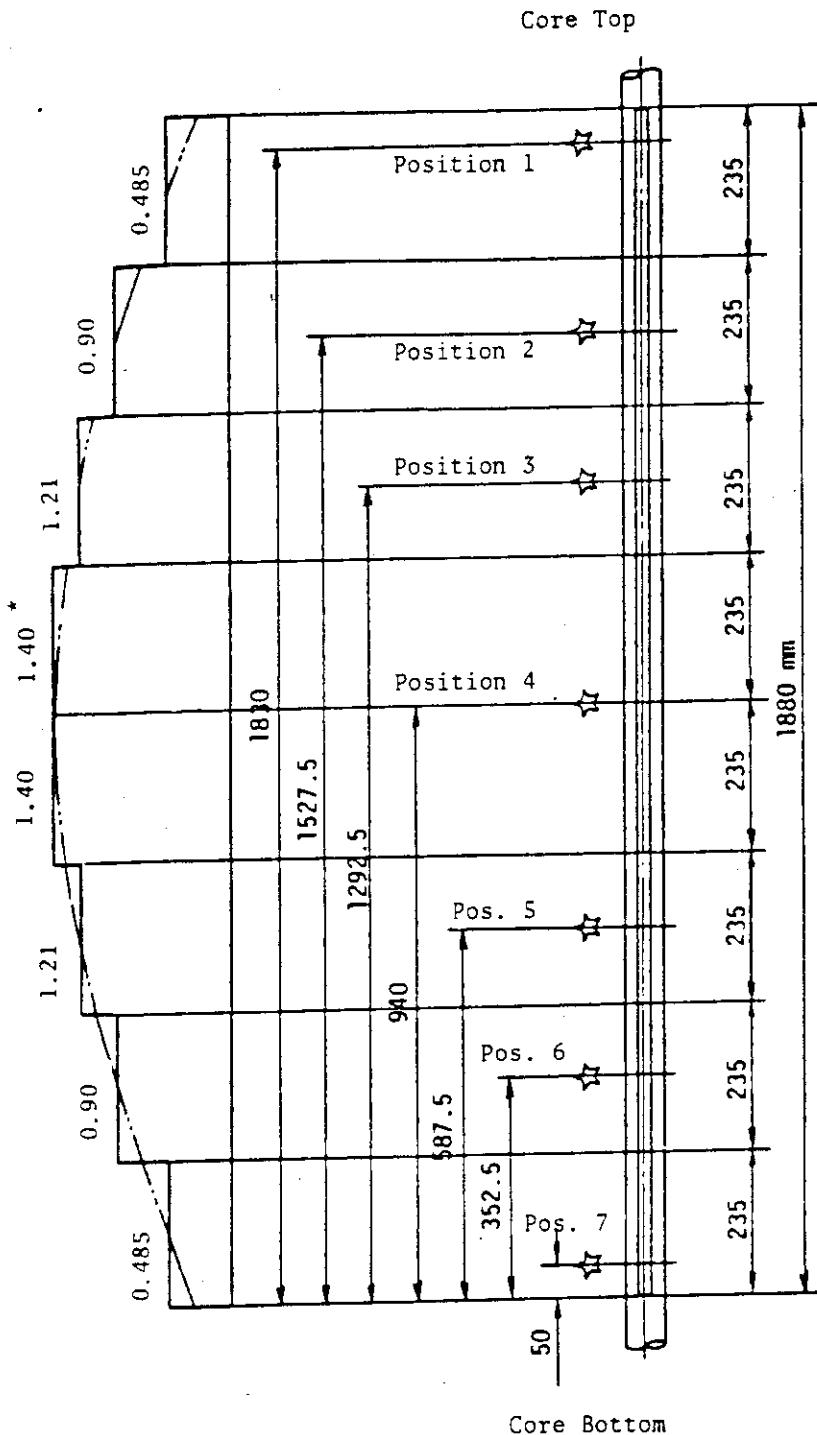


Fig. 2.9 Simulated Fuel Rod of ROSA-III



☆ indicates position of thermocouple. * Axial Peaking Factor

Fig.2.10(a) Axial Power Distribution of Heater Rod

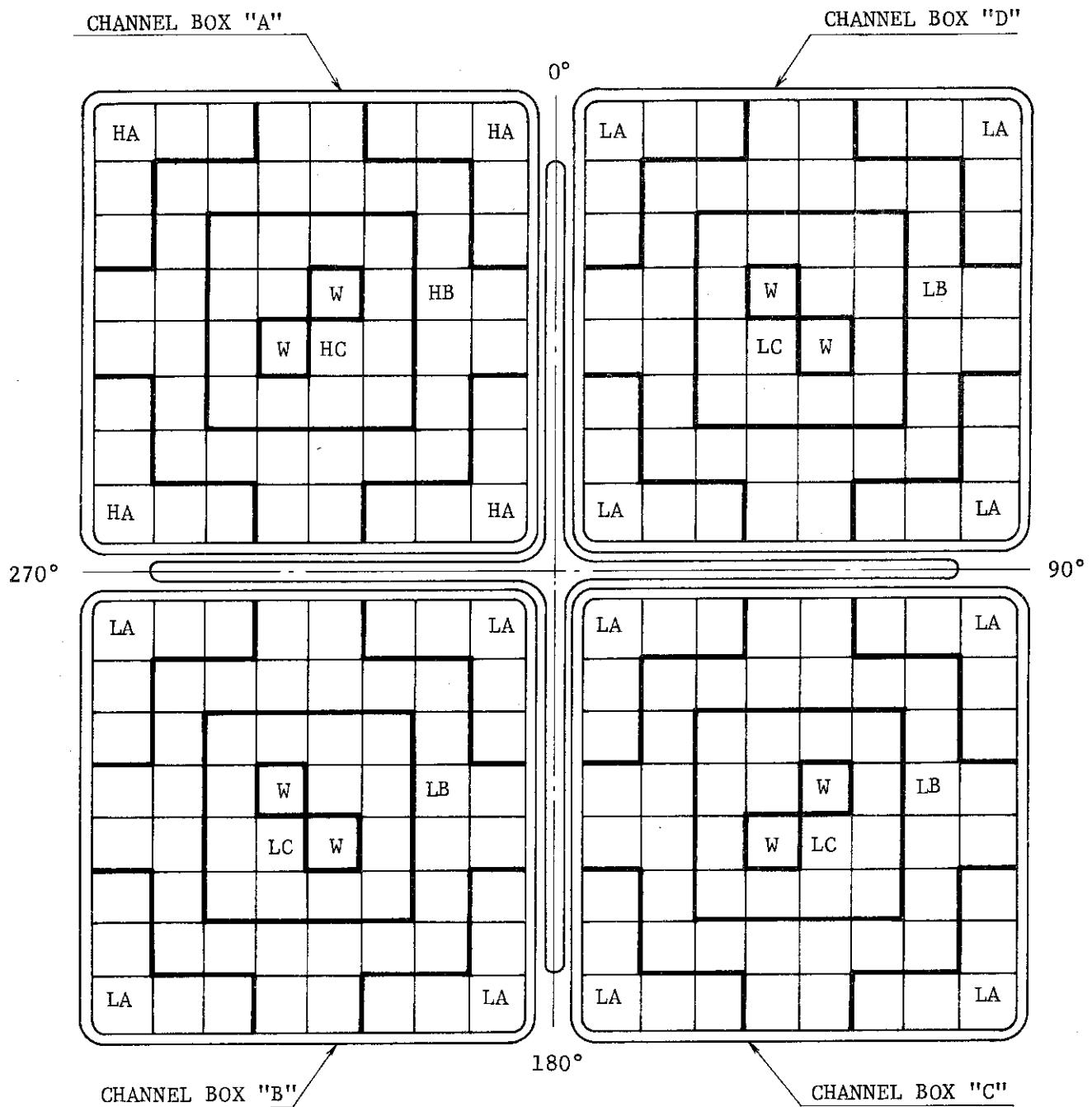


Fig. 2.10(b) Radial Power Distribution of Core

Region	HA	HB	HC	LA	LB	LC	W
Linear Heat Rate (kw/m)	18.5	16.81	14.41	13.21	12.01	10.29	0.0
Local Peaking factor	1.1	1.0	0.875	1.1	1.0	0.875	0.0
No. of Rods	20	28	14	60	84	42	8

* note : Radial Peaking factor is 1.4

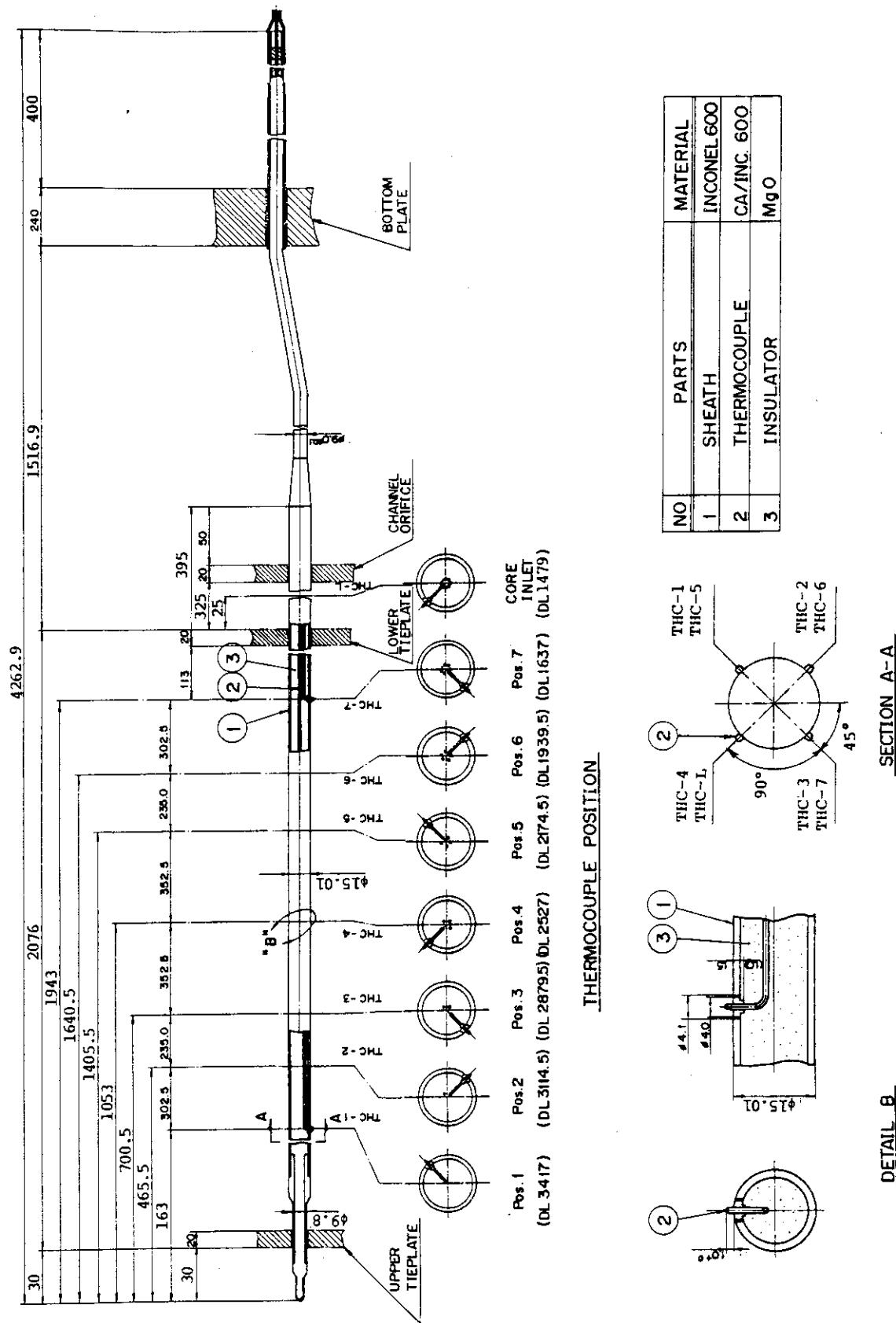


Fig. 2.11(a) Water Rod Simulator with Thermocouples

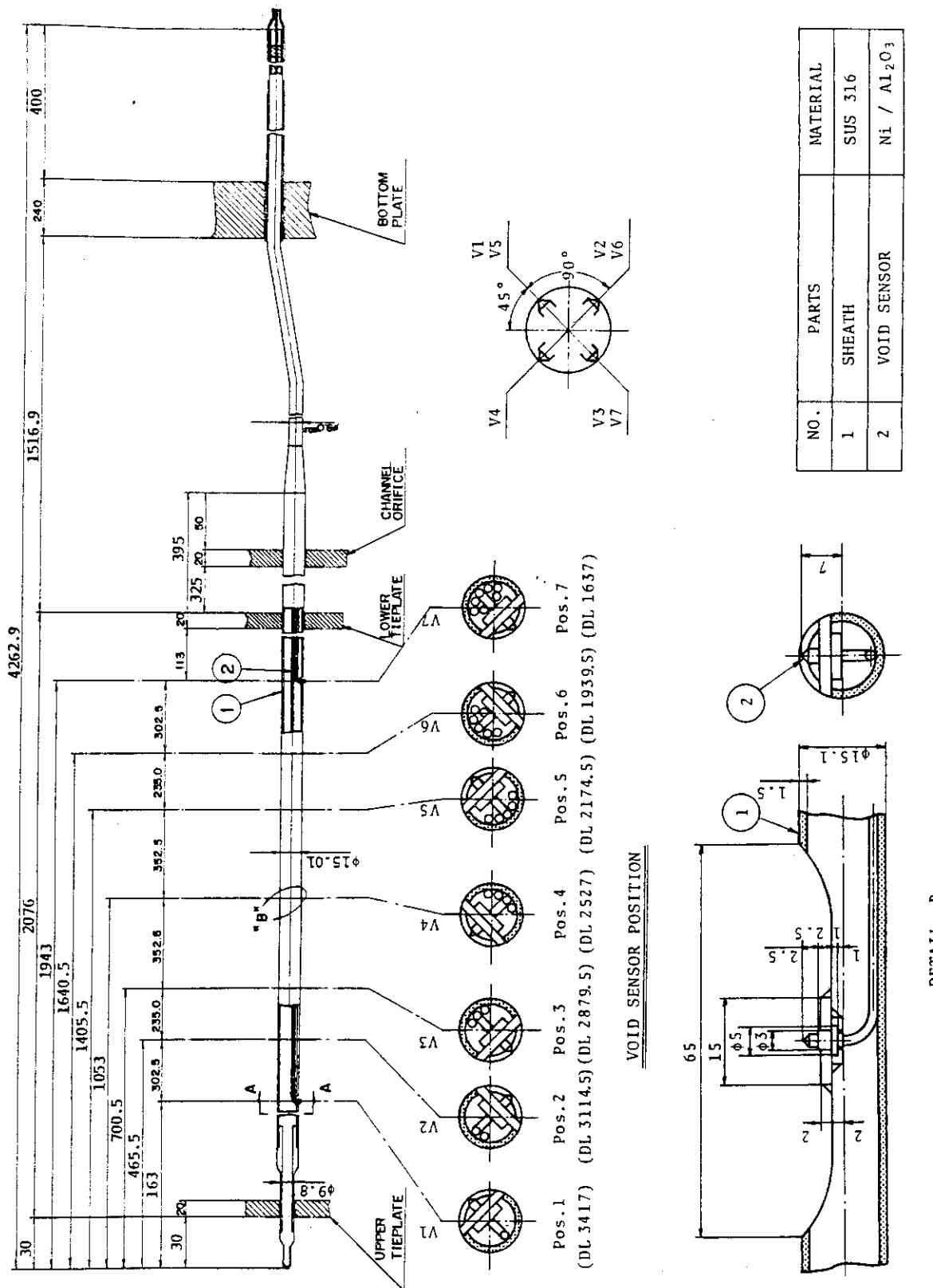


Fig. 2.11(b) Water Rod Simulator with Void Sensors

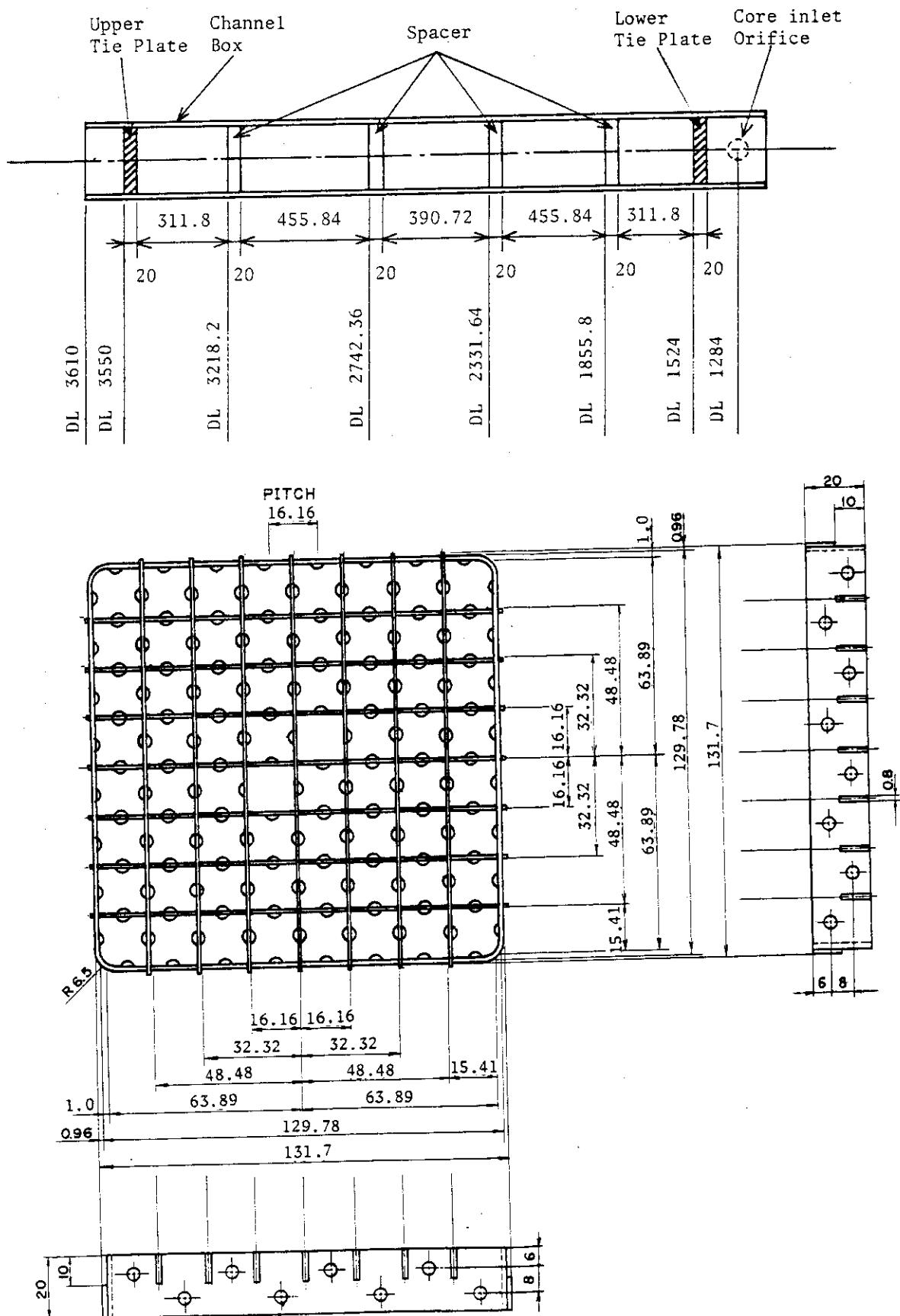


Fig. 2.12 Spacer for Heater Rods

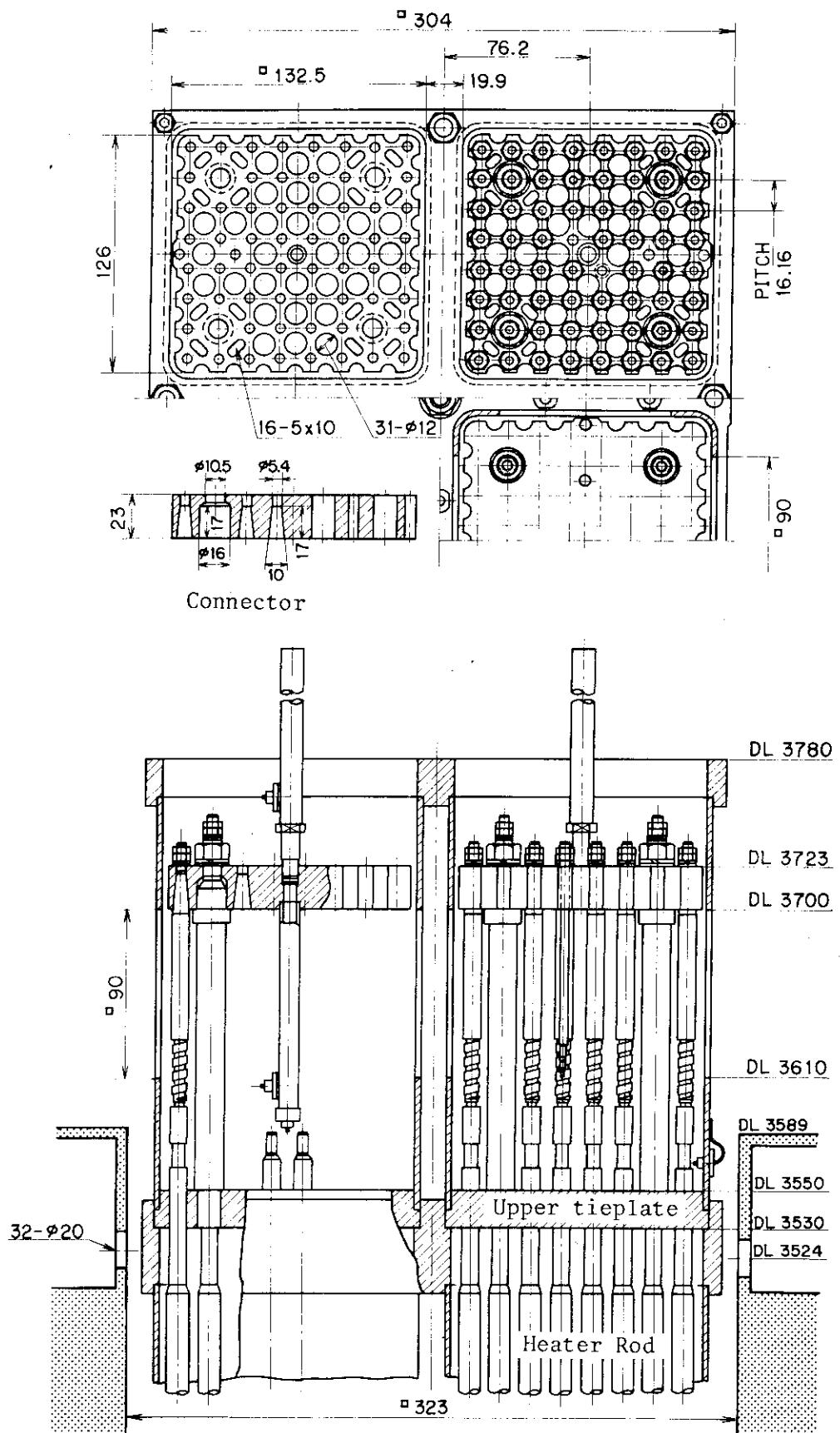
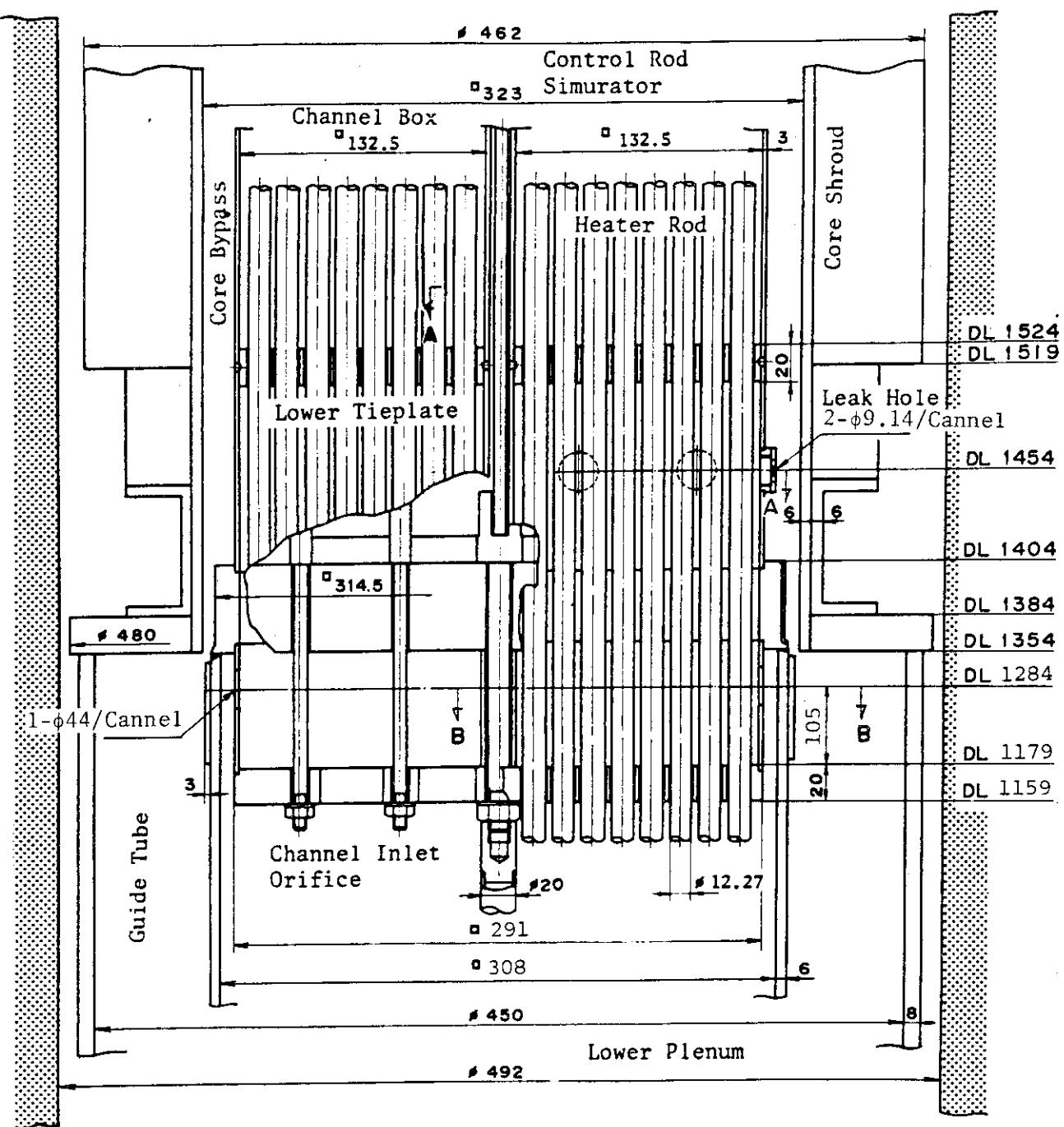


Fig. 2.13 Top connectors of Heater Rods



(a) Elevation.

Fig. 2.14 Core Inlet Orifice

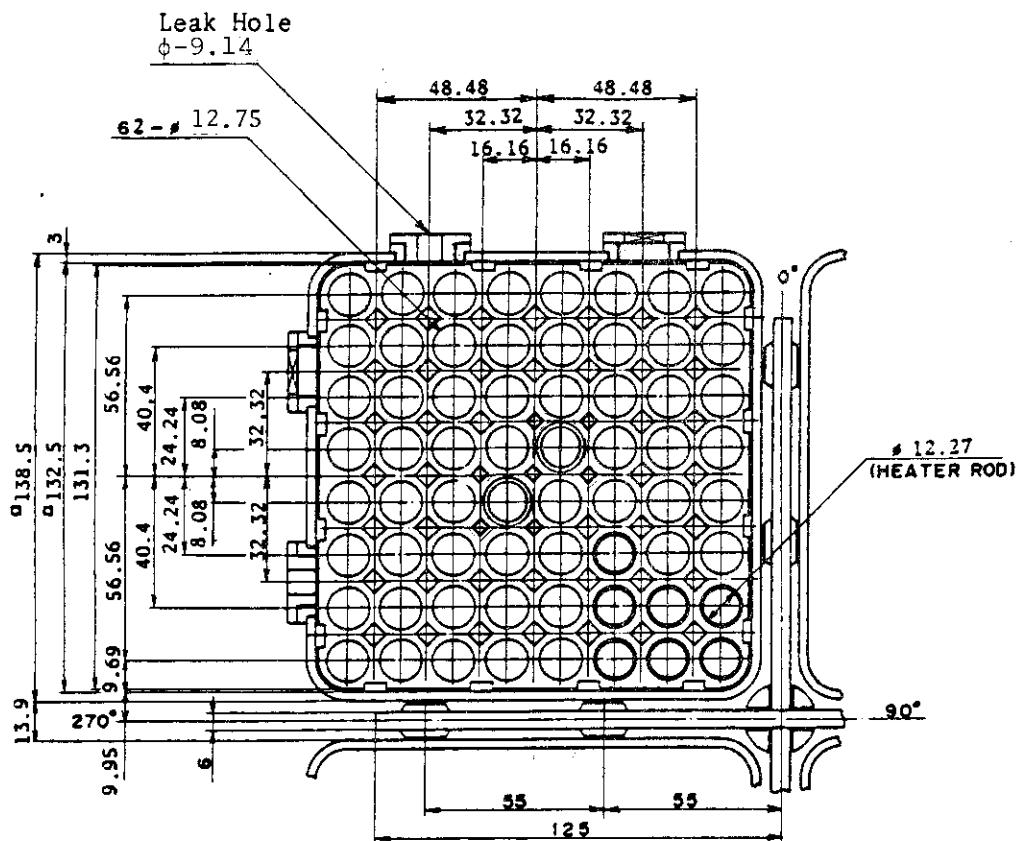
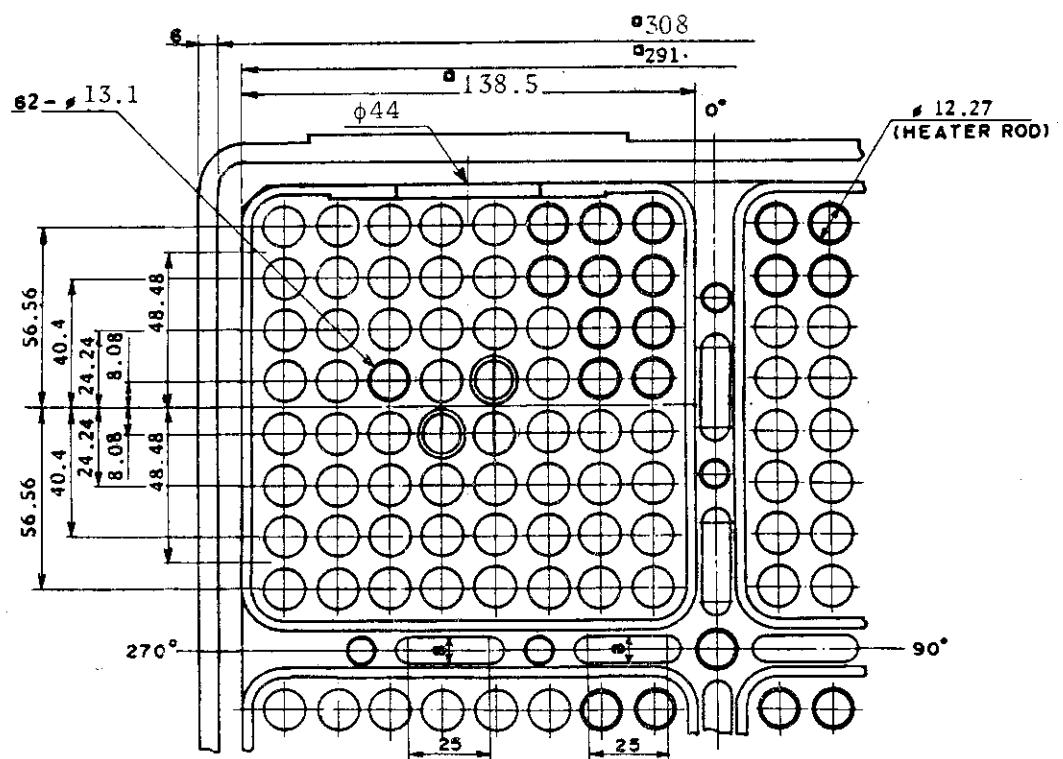
SECTION A - A

Fig.2.14 (b) Sections

SECTION B - B

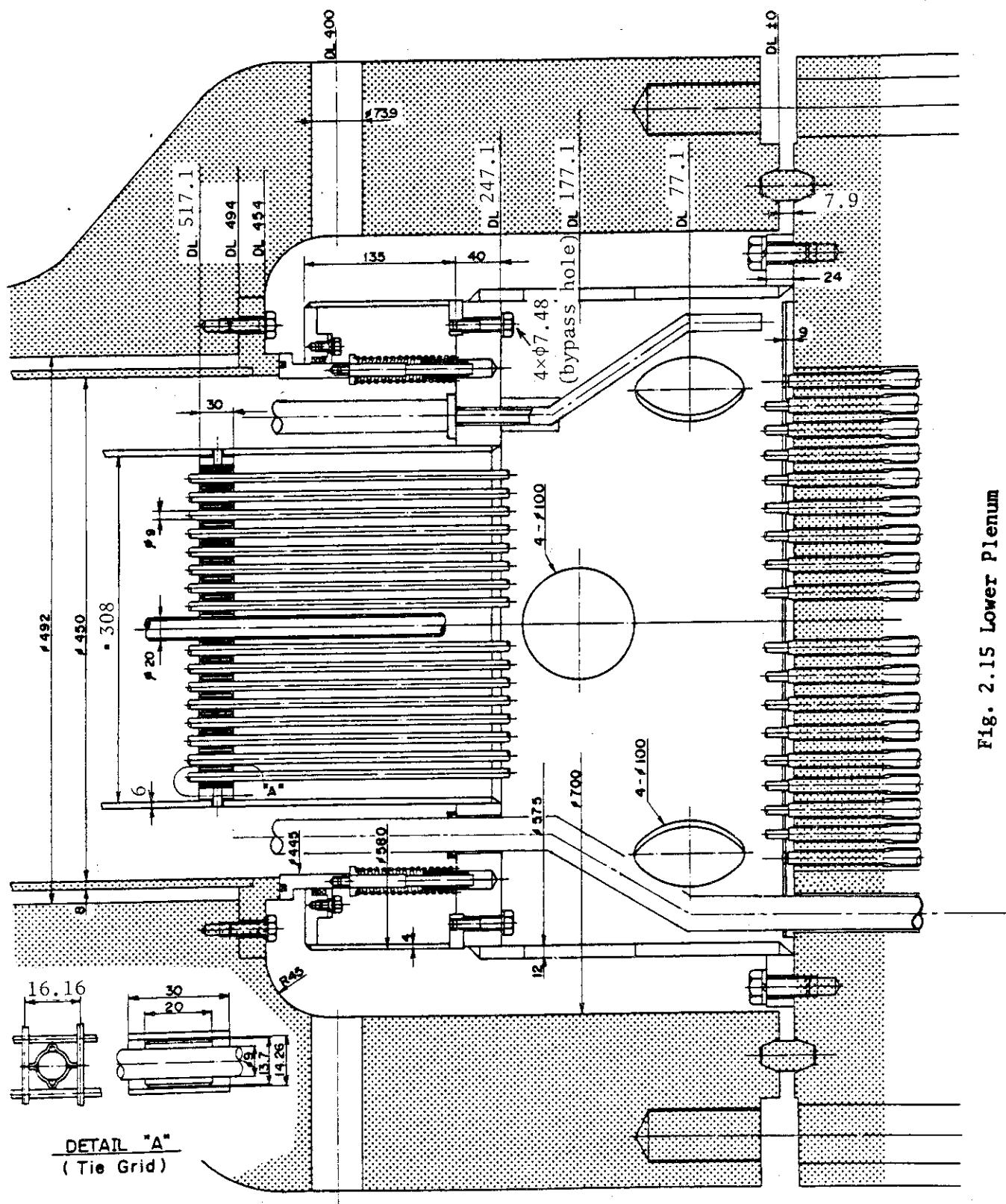


Fig. 2.15 Lower Plenum

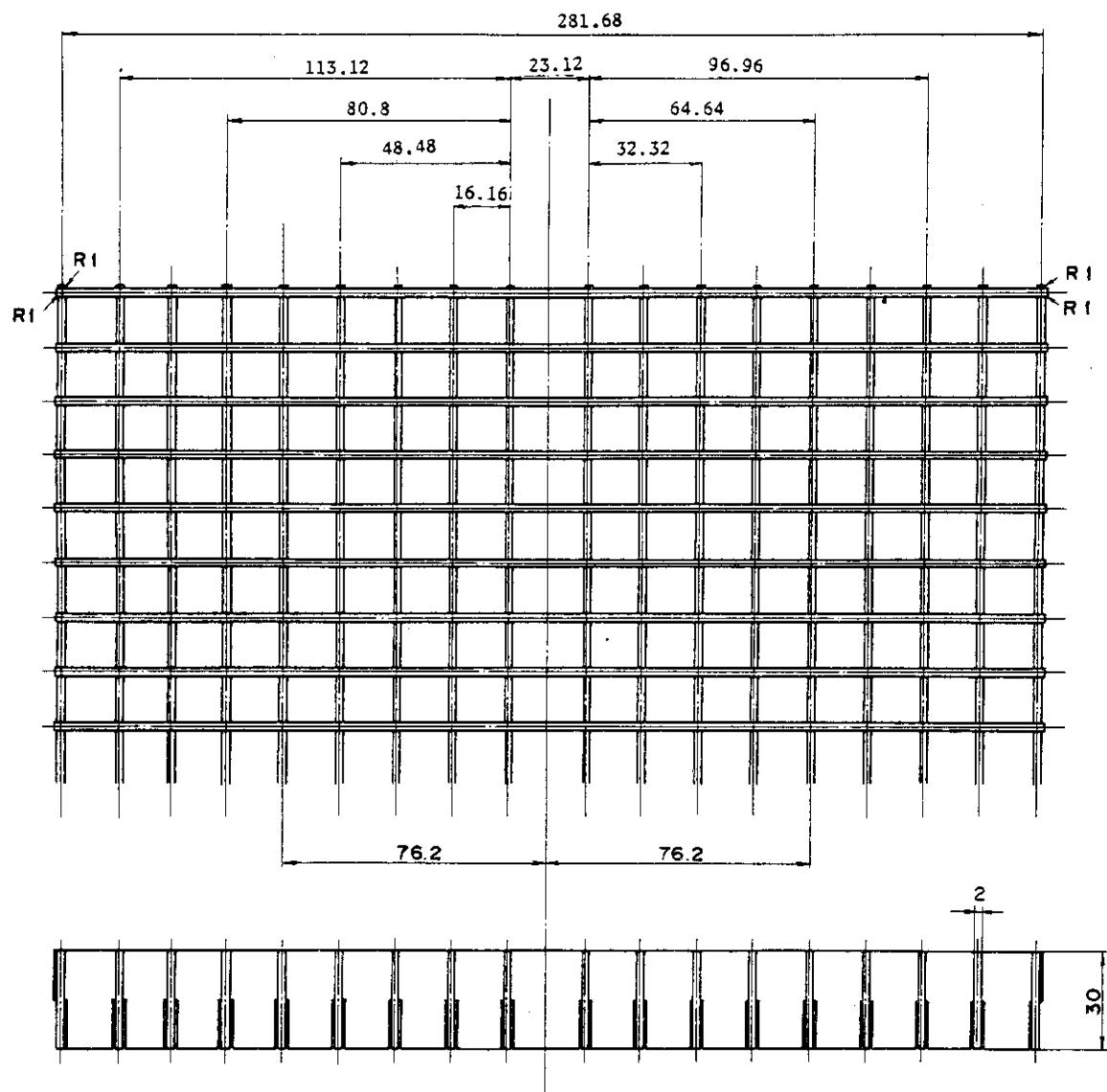
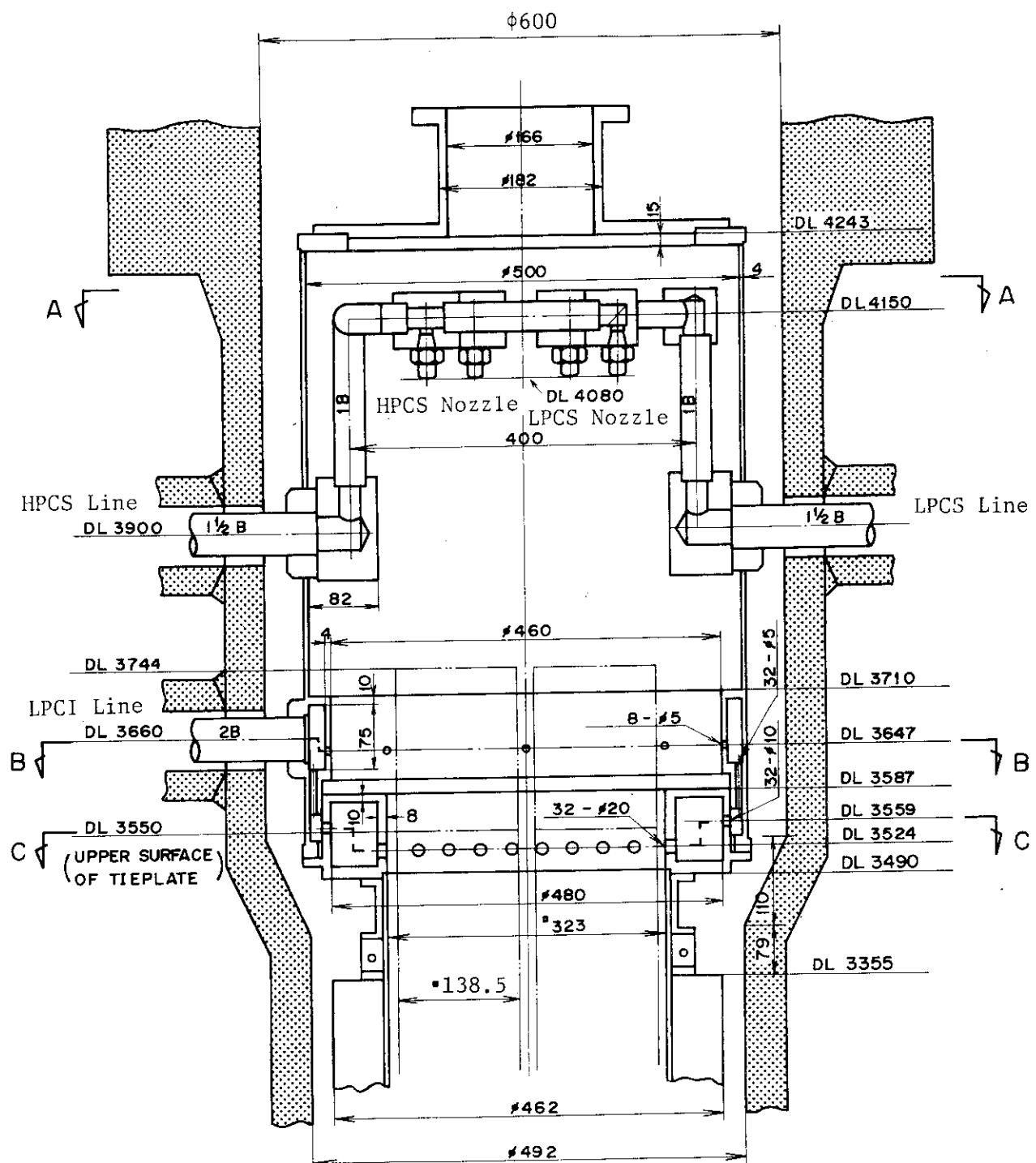


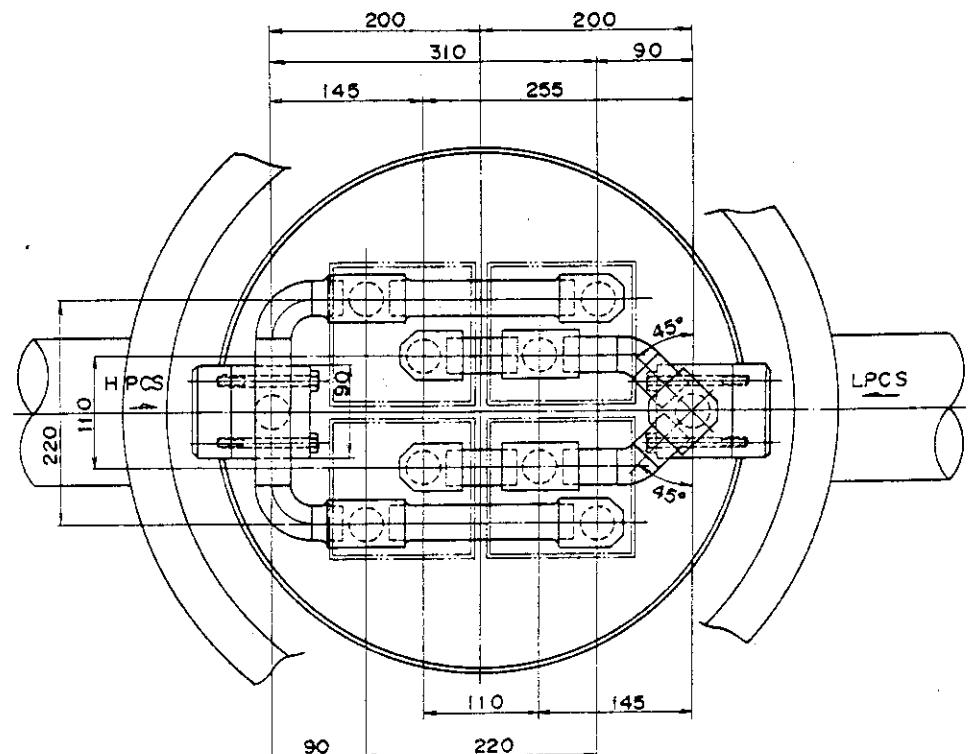
Fig. 2.16 Tie Grid



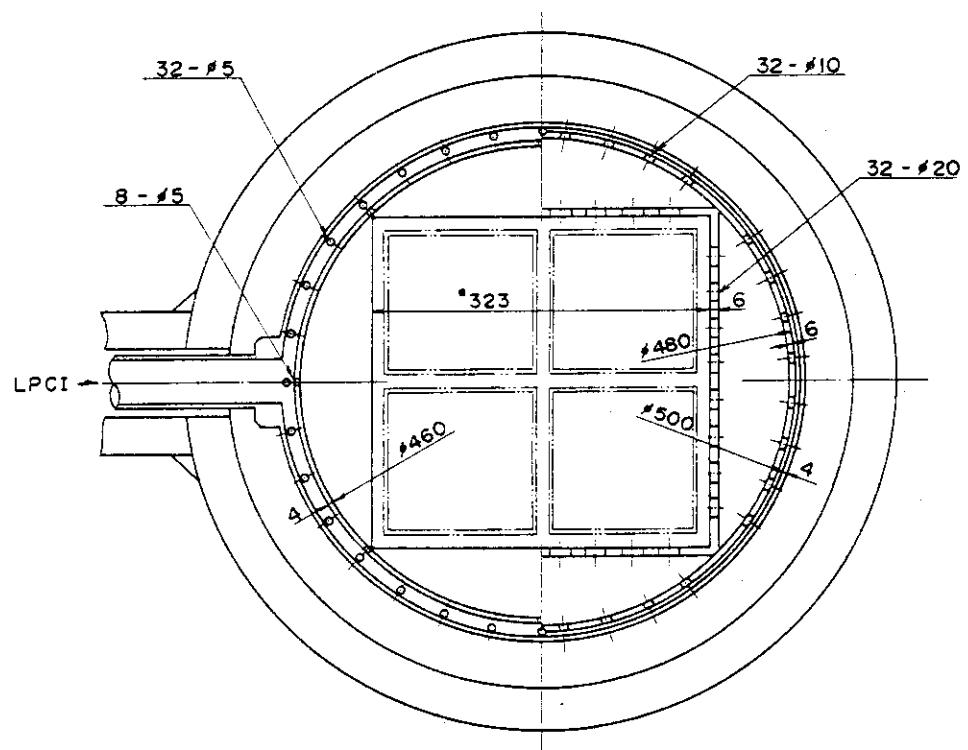
(a) Elevation.

Fig. 2.17 Upper Plenum

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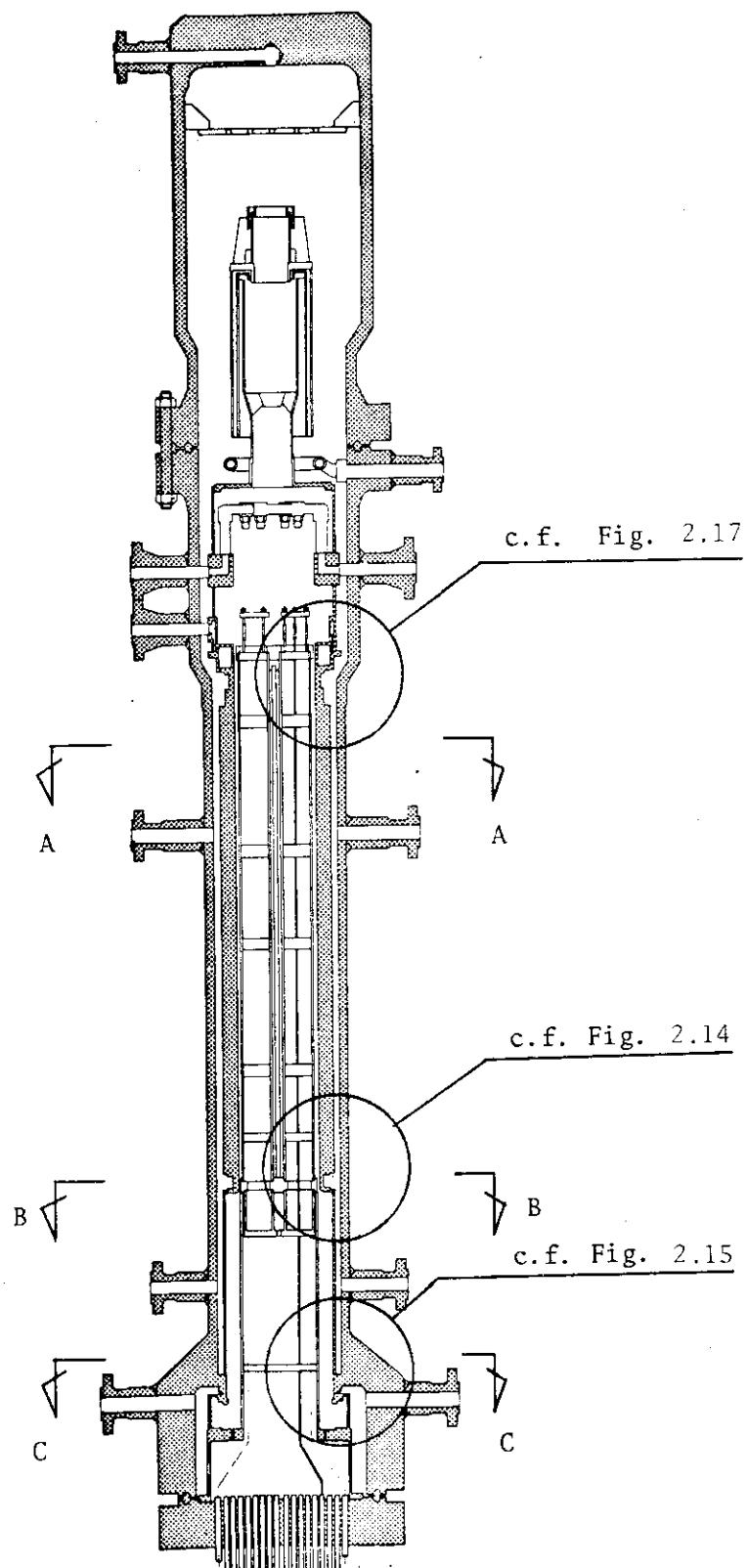
VIEW A - A



SECTION B - B

SECTION C - C

Fig. 2.17 (b) Sections



(a) Elevation.

Fig. 2.18 Downcomer

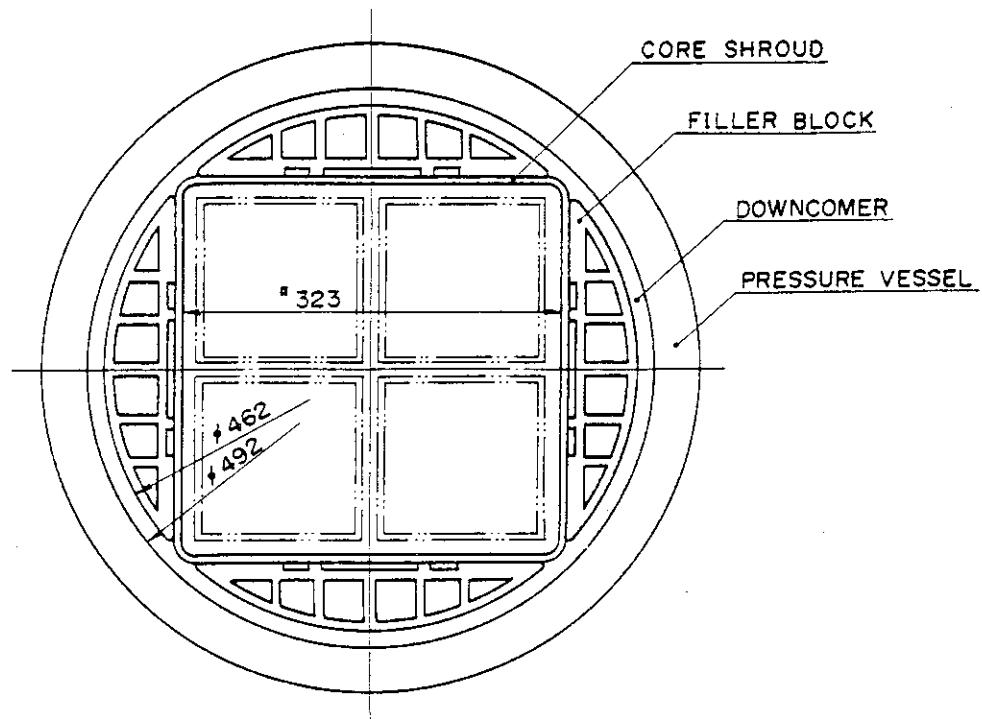
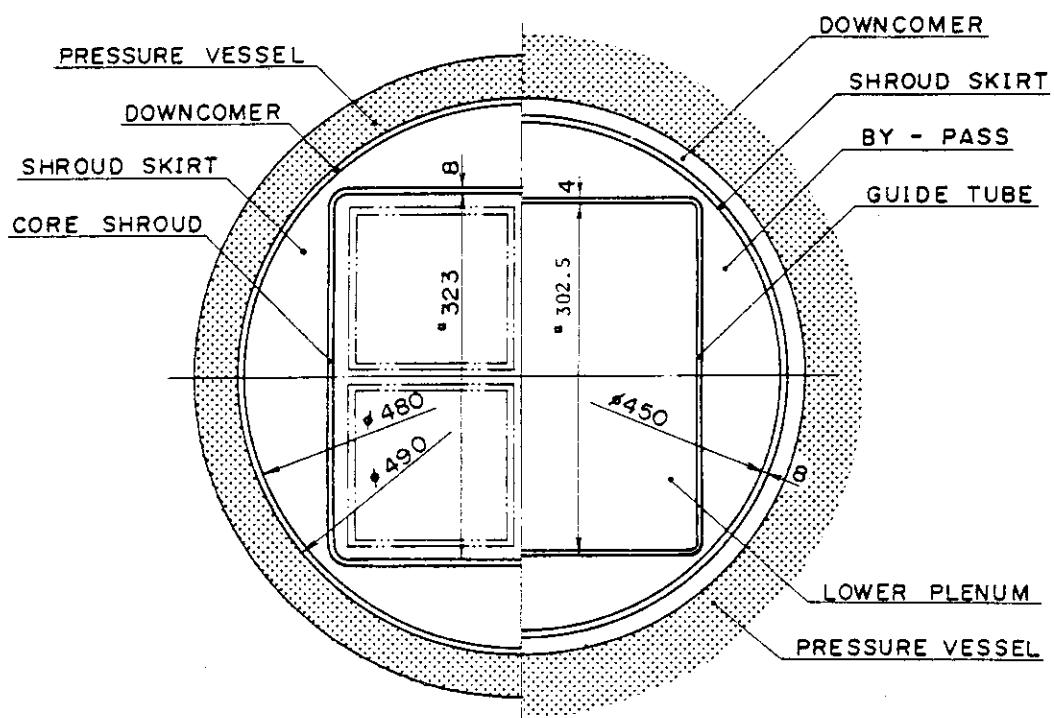
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Fig. 2.18 (b) Sections

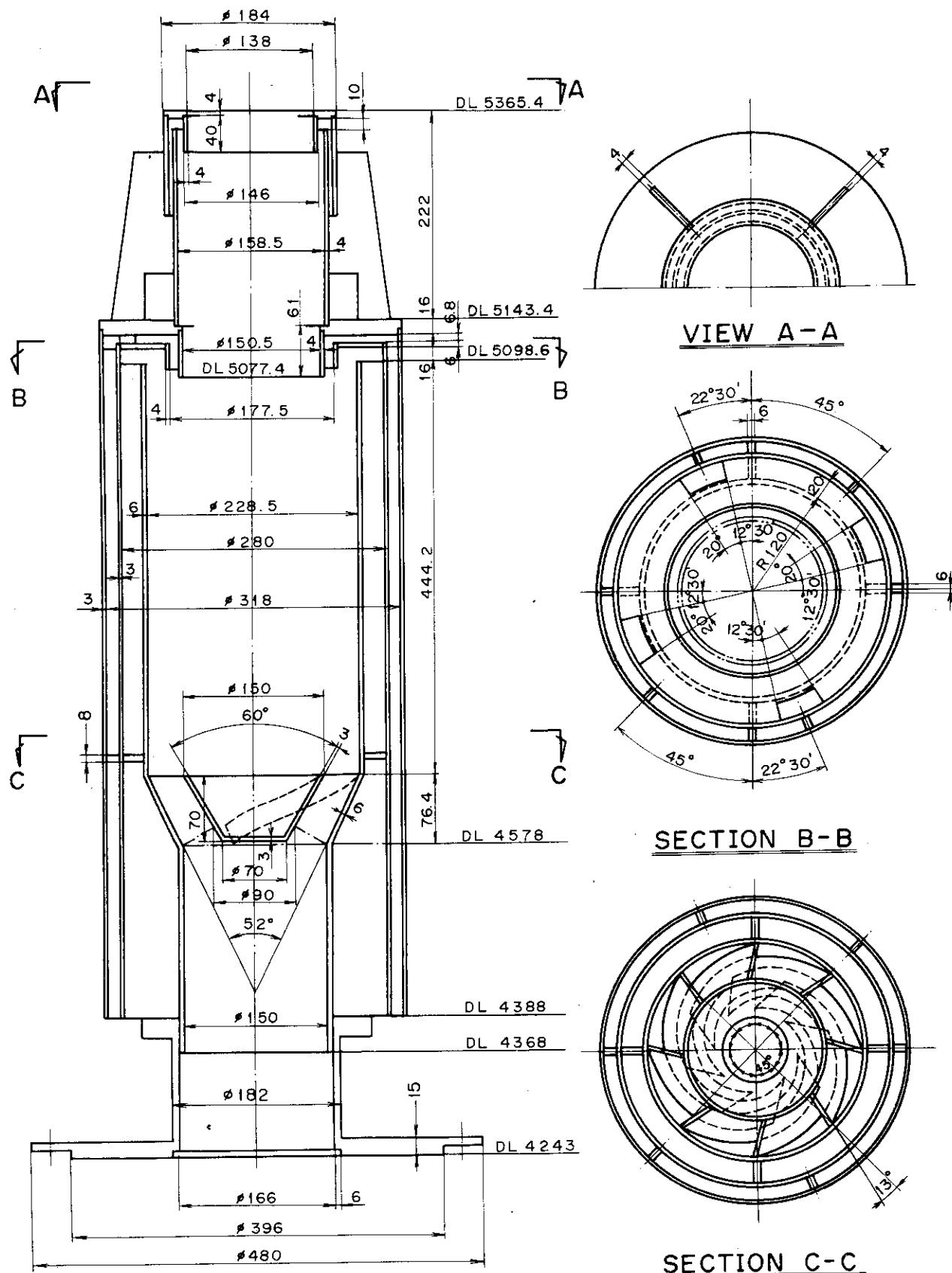


Fig. 2.19 Steam Separator

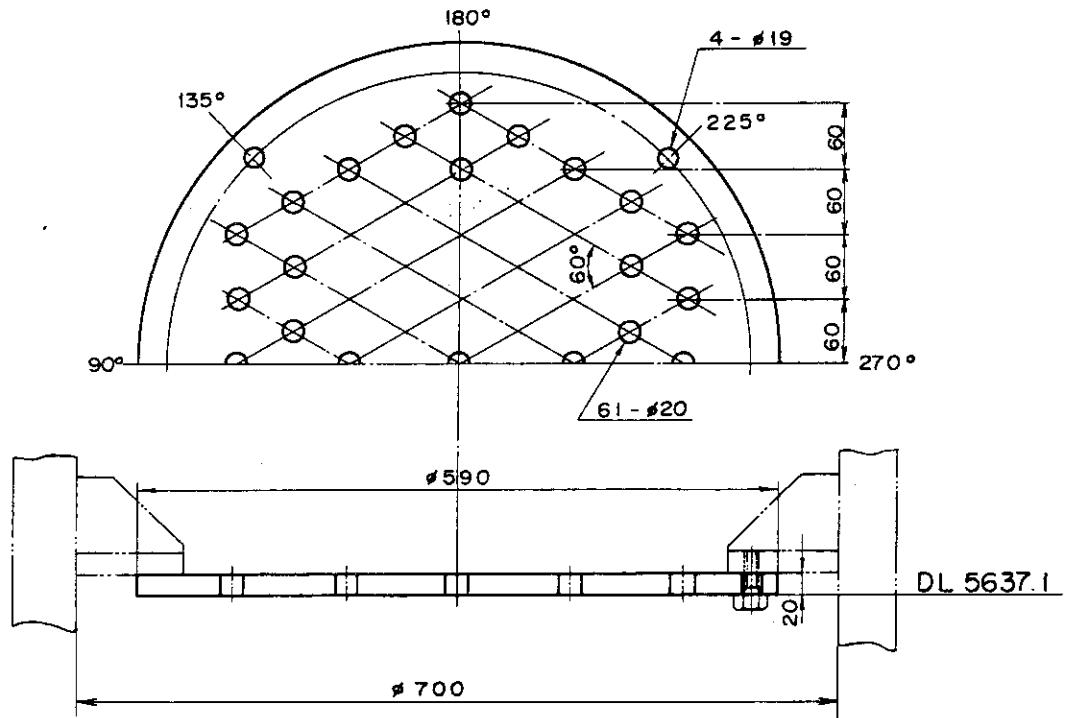


Fig. 2.20 Steam Dryer Plate

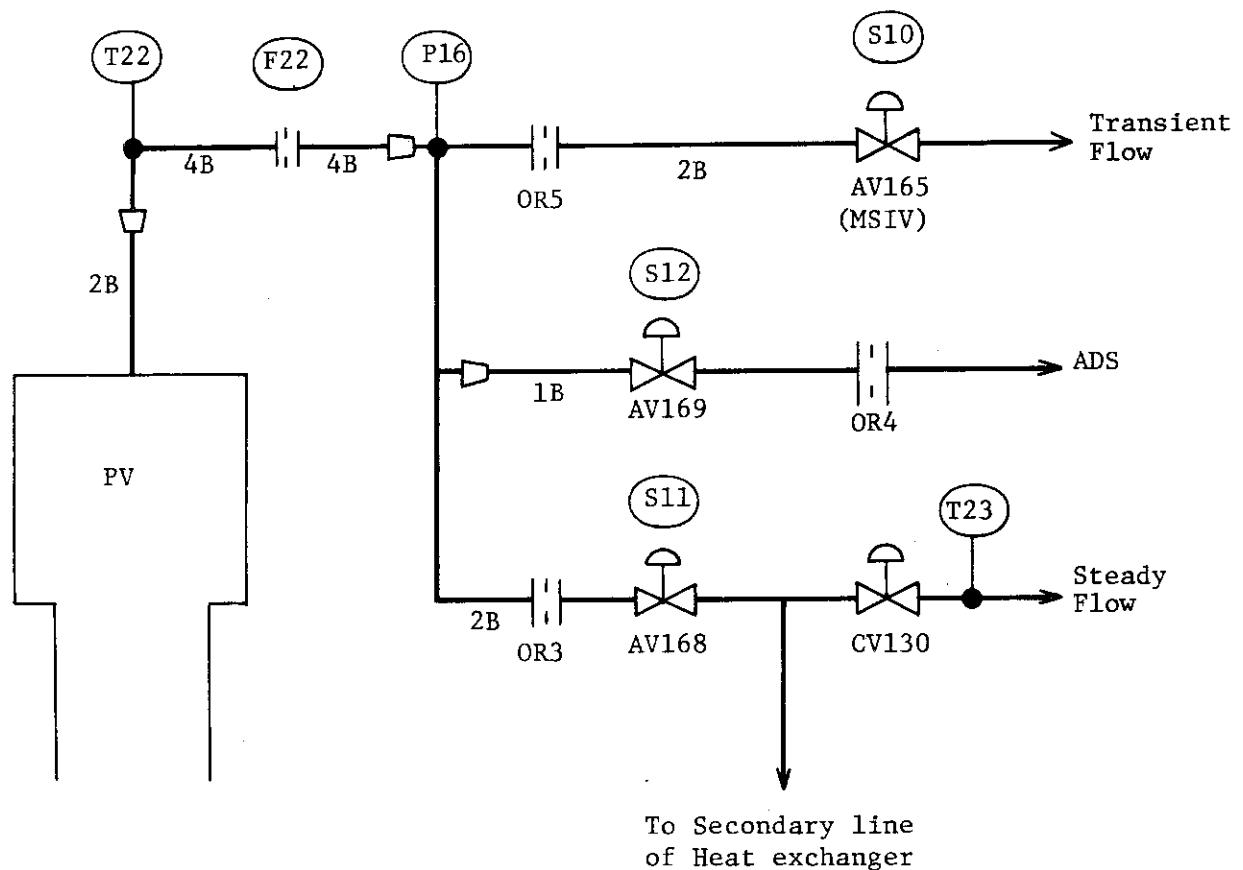


Fig. 2.21 Main Steam Line Schematic

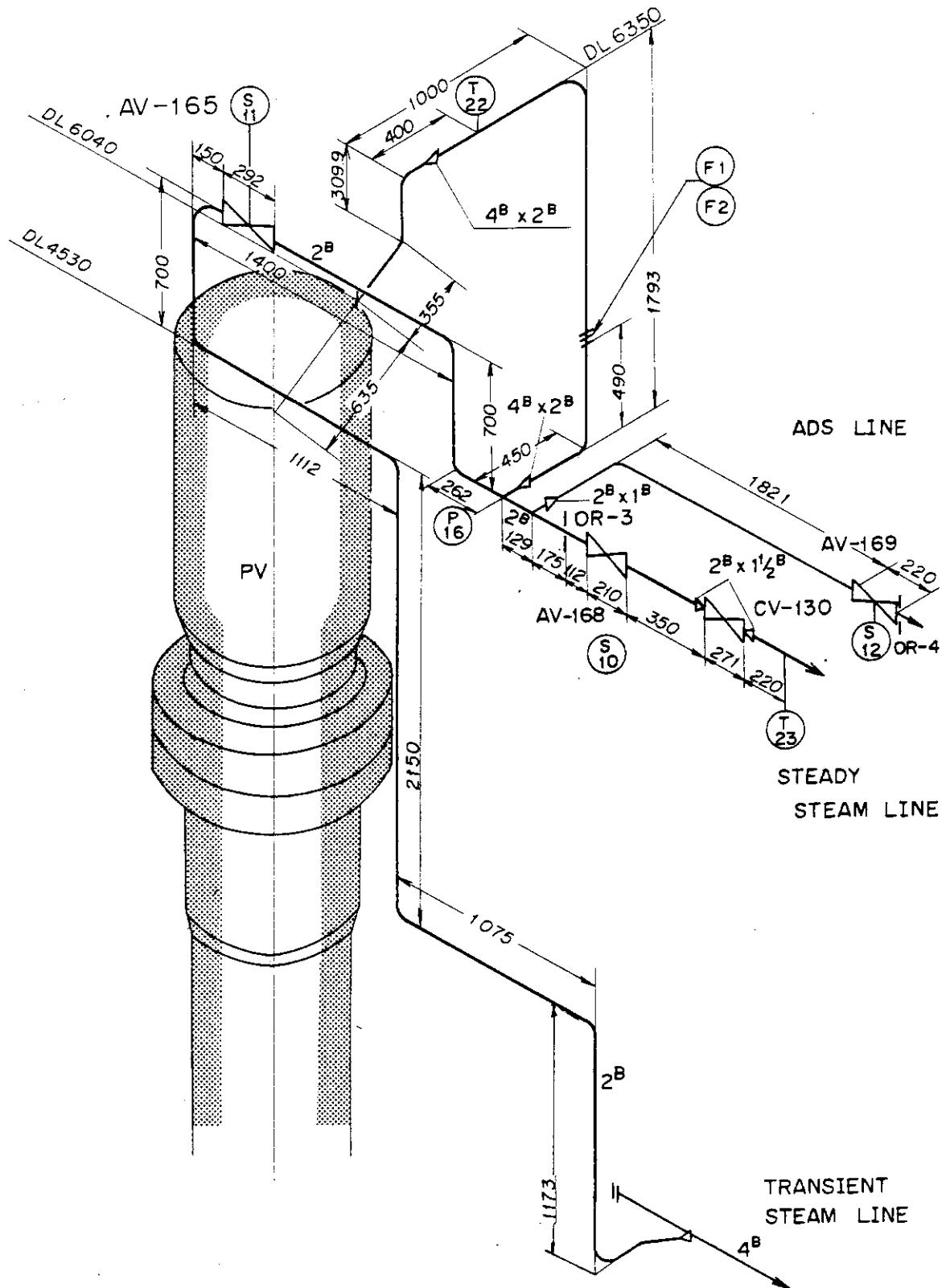


Fig. 2.22 Main Steam Line Piping Layout

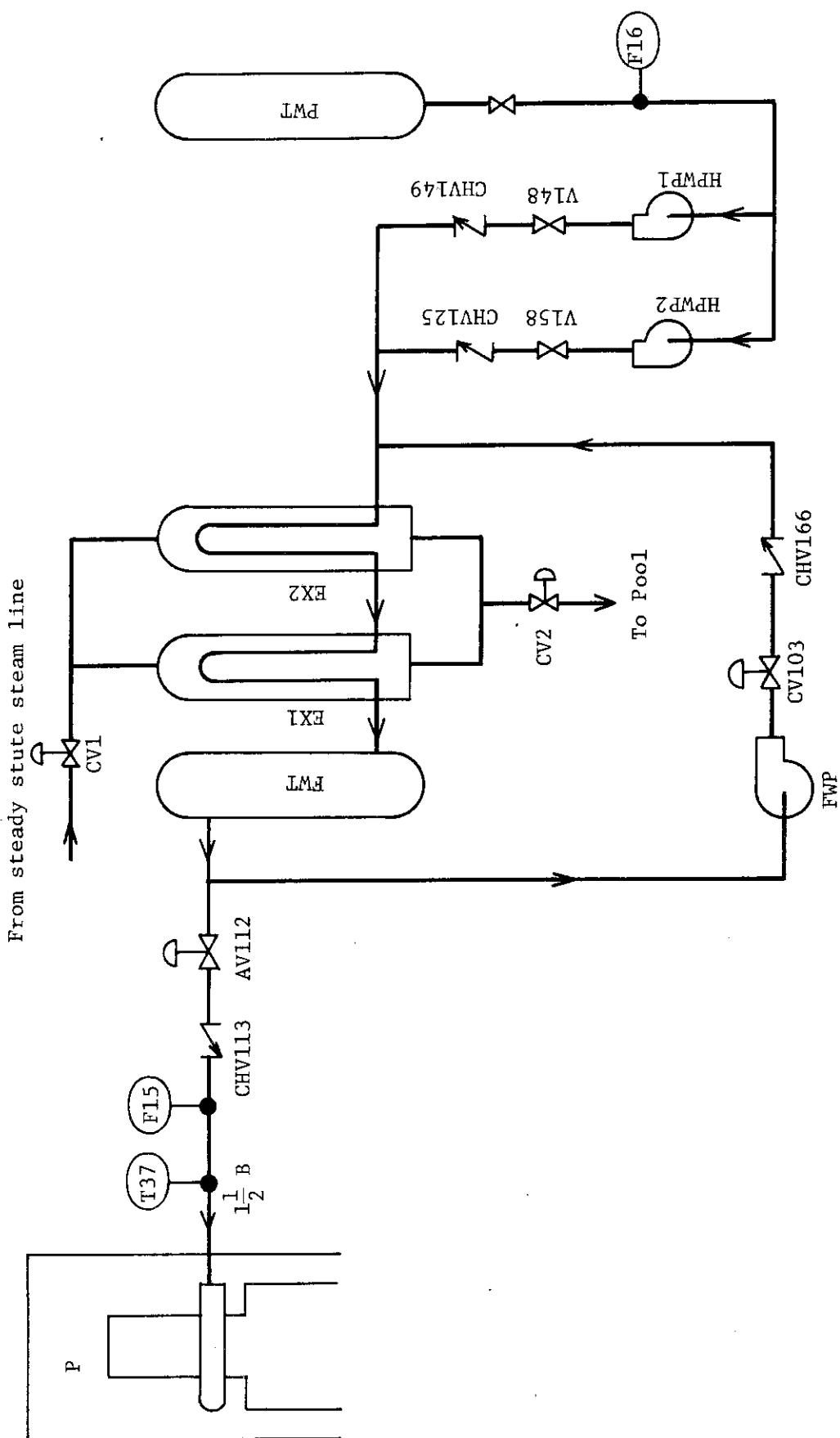


Fig. 2.23 Feed Water Line Schematic

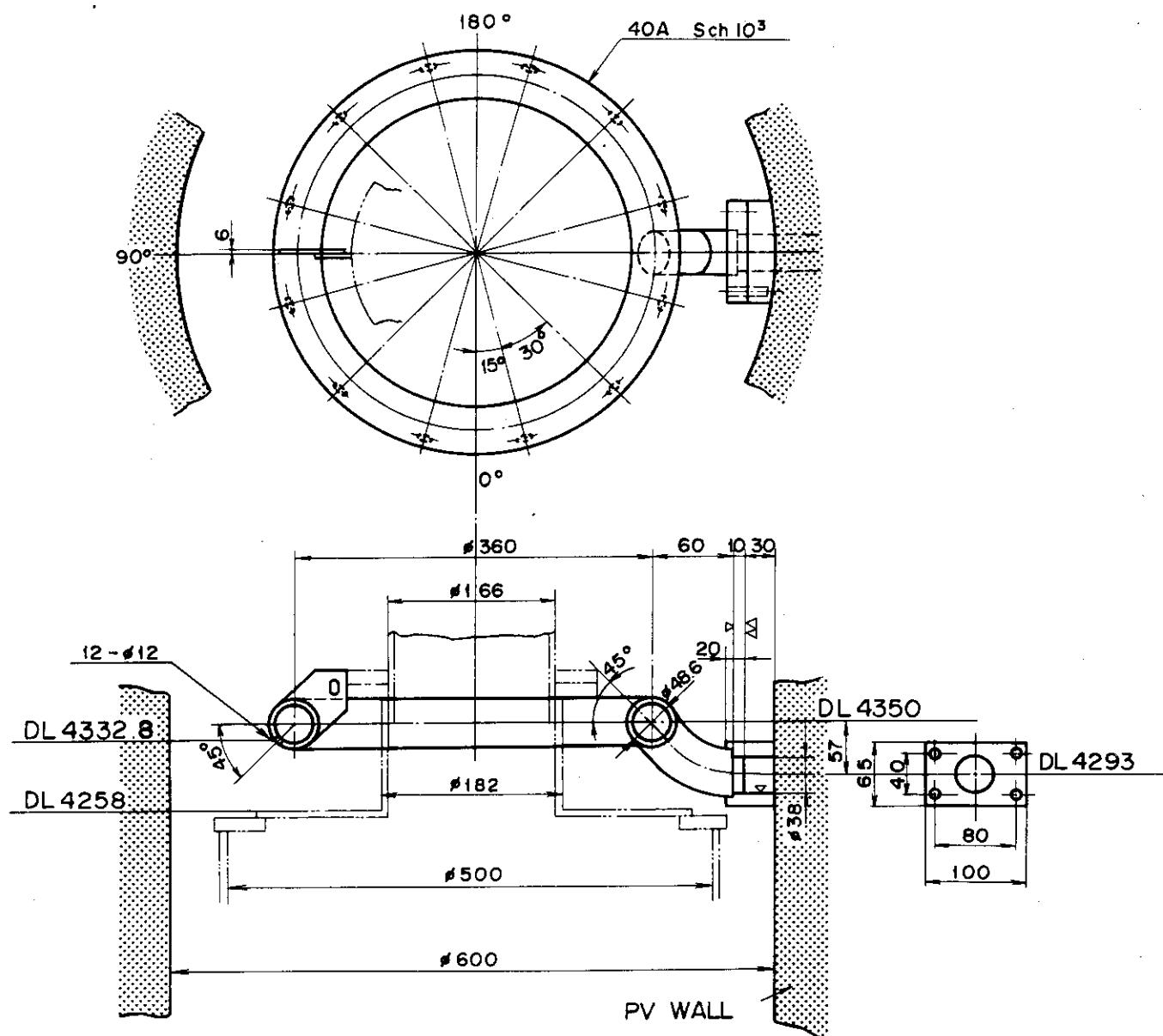
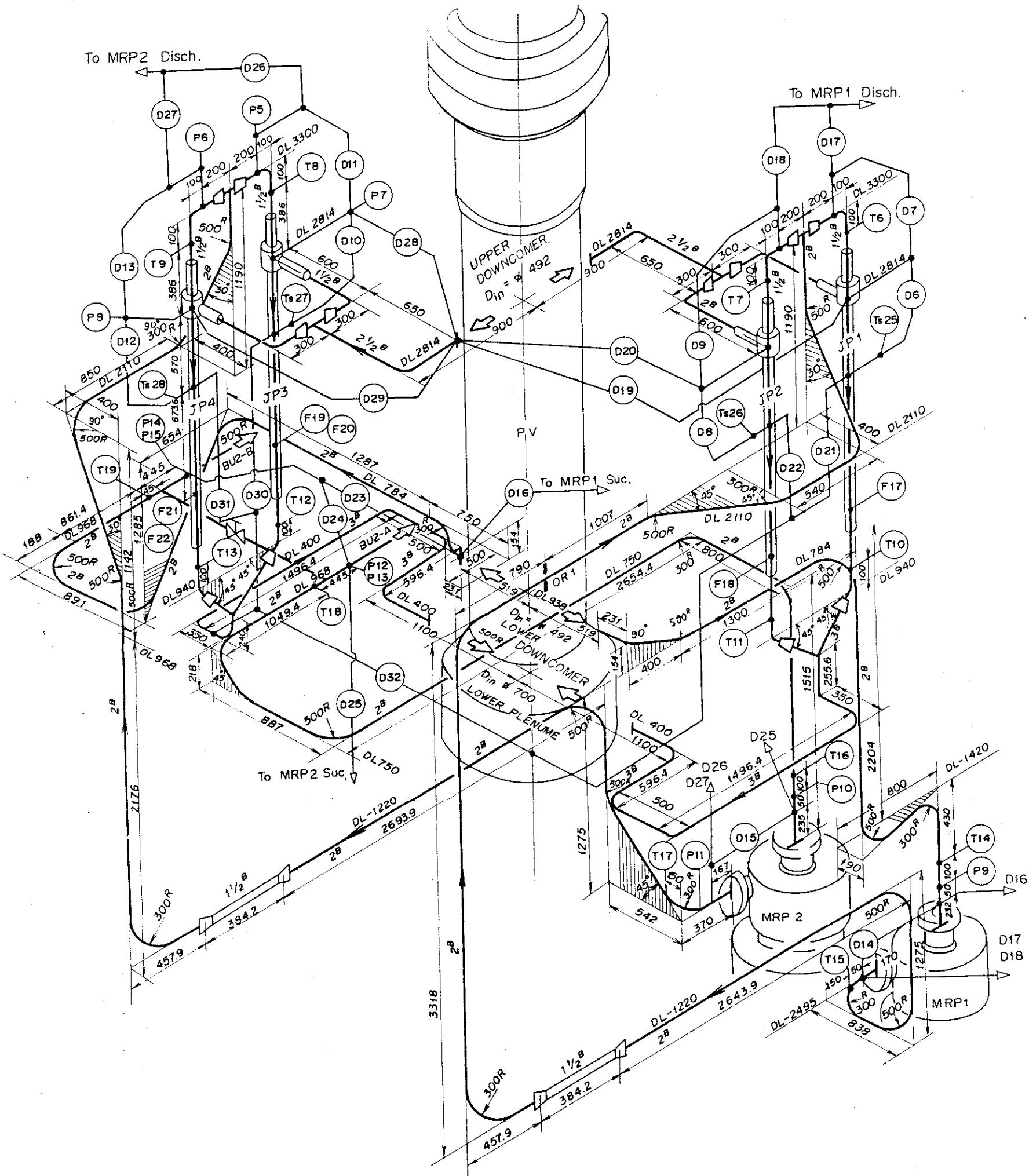
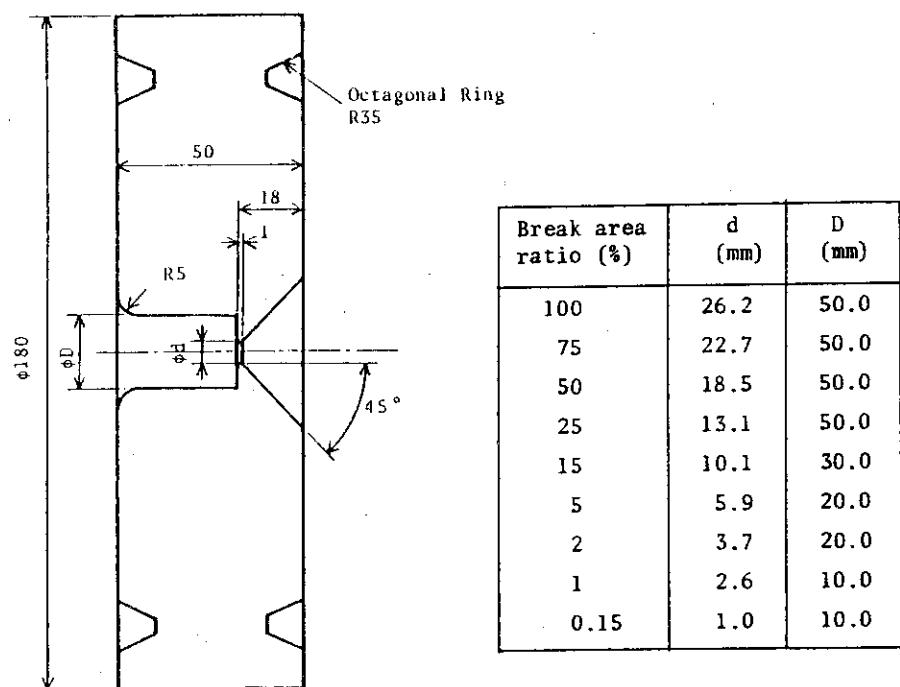


Fig. 2.24 Feed Water Sparger



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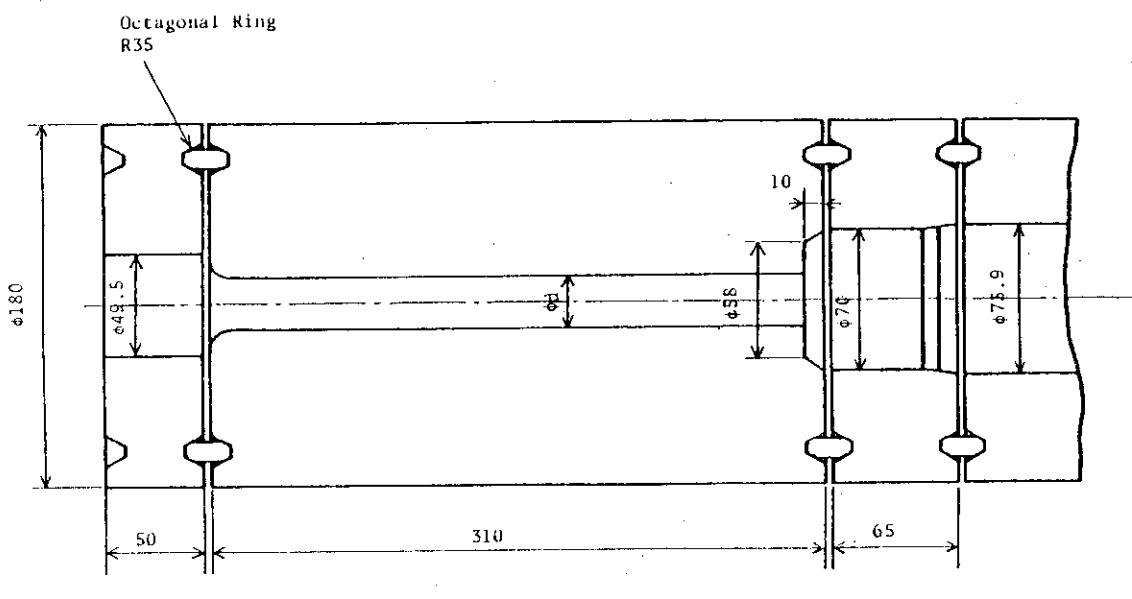
Fig. 2.25 Piping Layout of Recirculation Loops and Jet Pumps.



Material SUS304

Dimension in mm

Fig. 2.26 Break Orifice Details



Material SUS304

Dimension in mm

Break area ratio (%)	d (mm)
100	26.2
15	10.1

Fig. 2.27 Break Nozzle Details

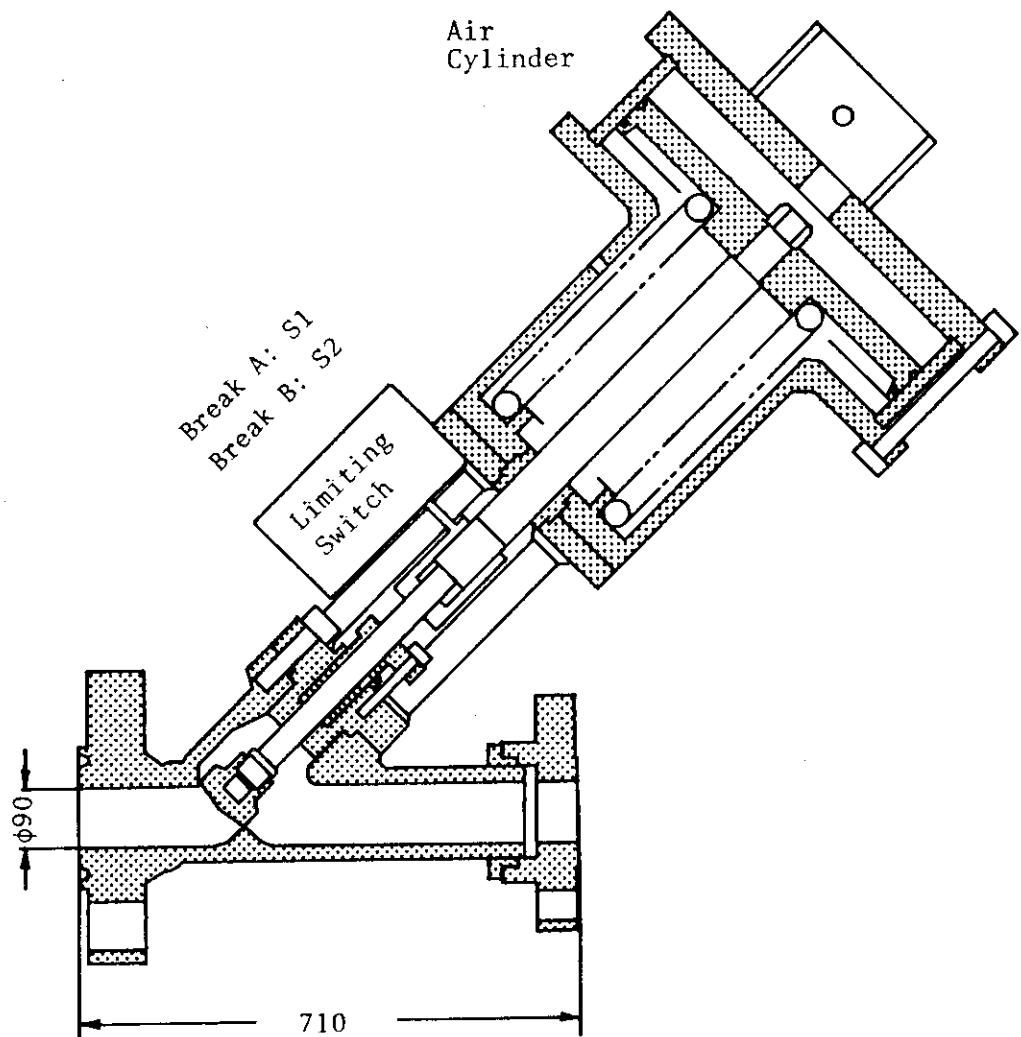


Fig. 2.28 Quick Opening Blowdown Valve

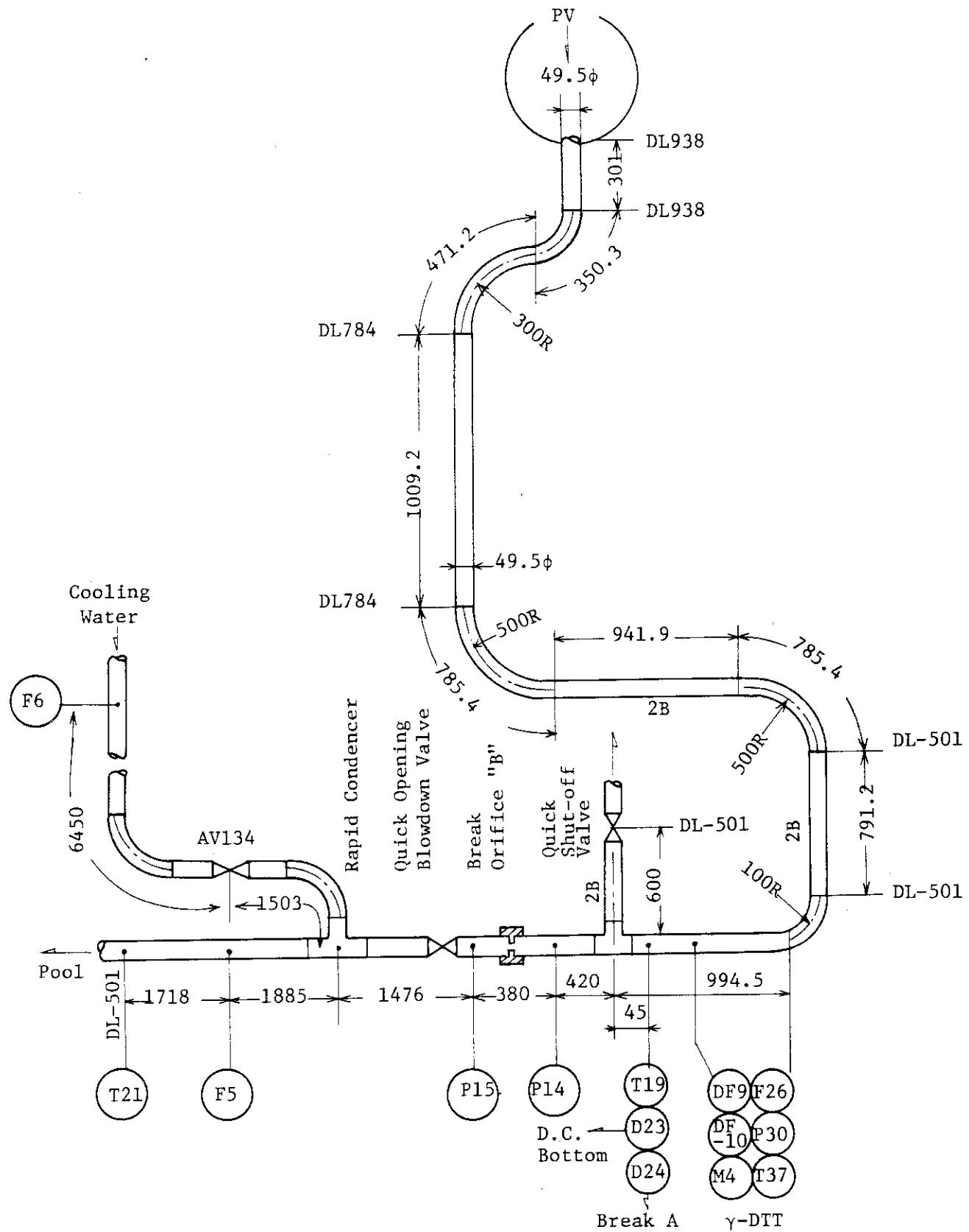


Fig. 2.29 Piping from Pressure Vessel to Break B

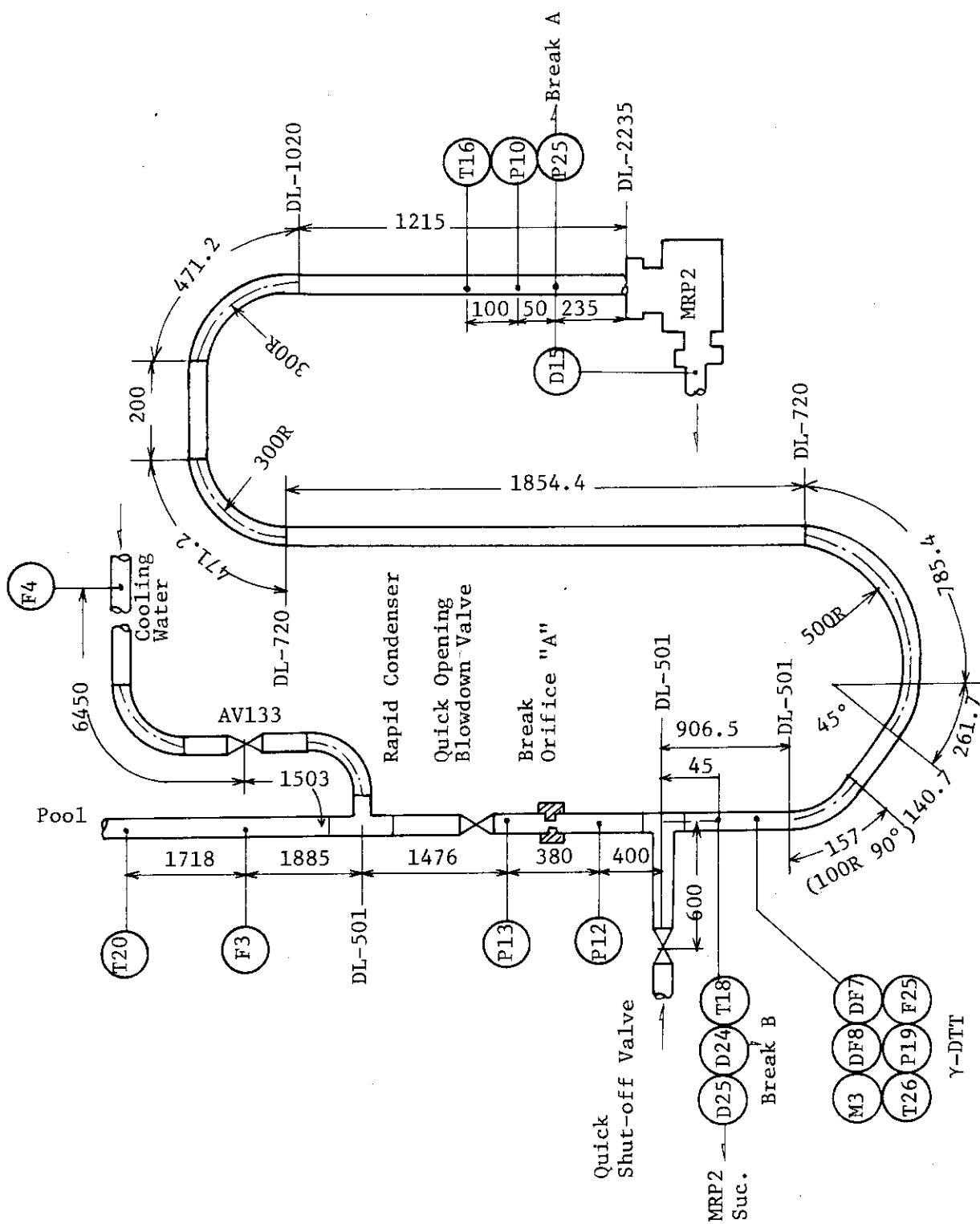


Fig. 2.30 Piping from Blowdown Loop Recirculation Pump (MRP2) to Break A

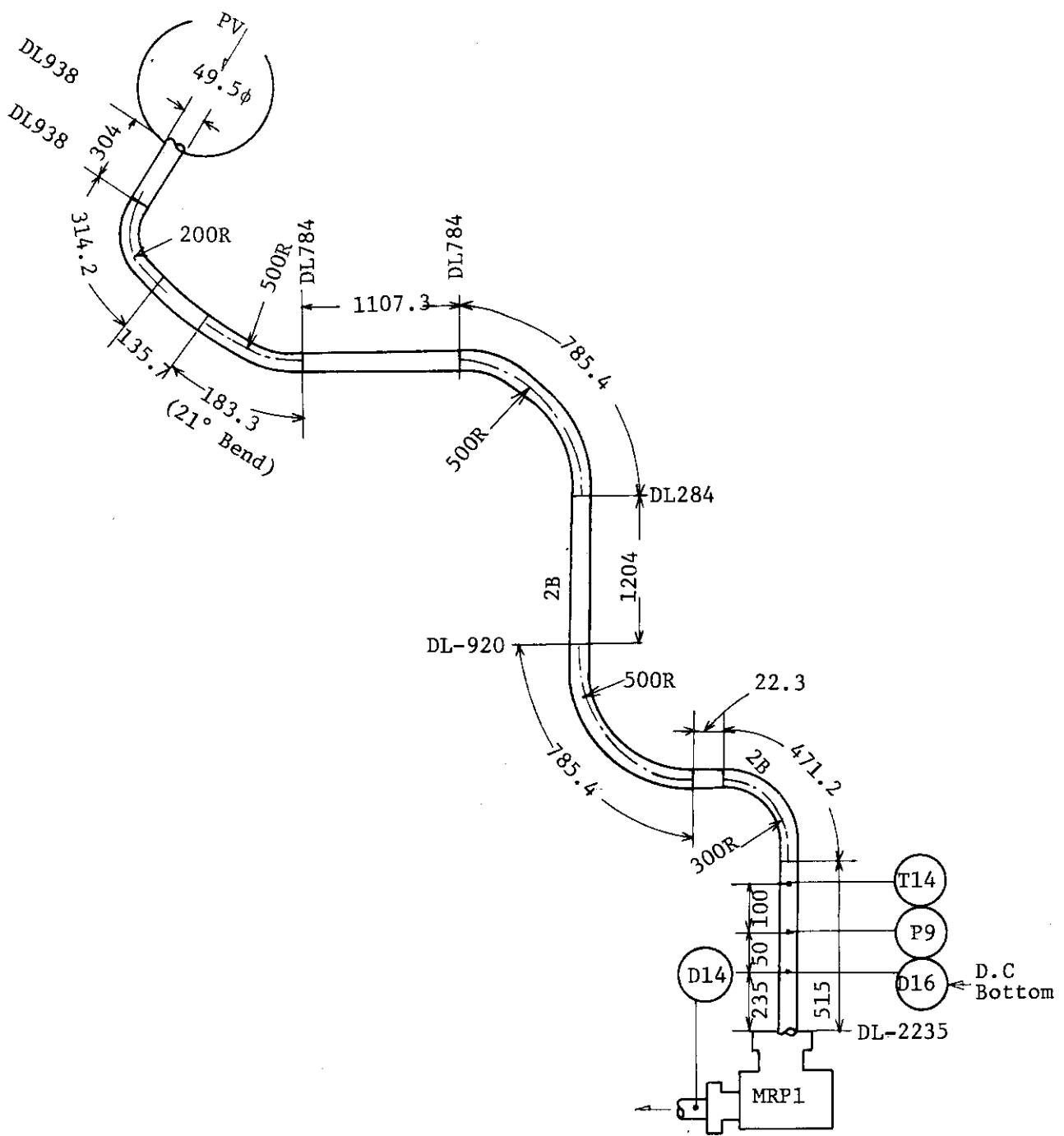
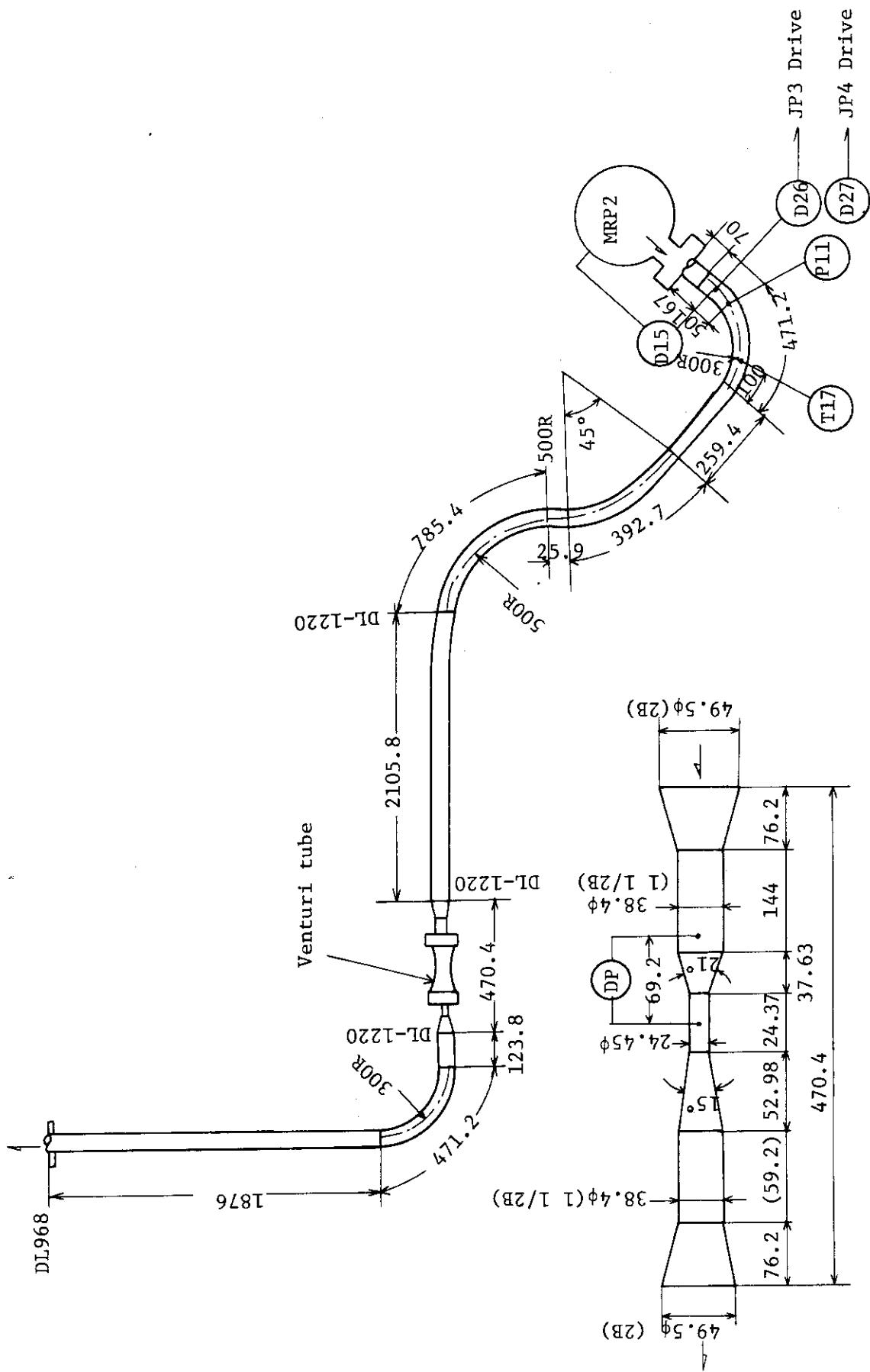


Fig. 2.31 Piping from Pressure Vessel to Intact Loop Recirculation Pump (MRP1)



Venturi tube detail

Fig. 2.32 Piping from Blowdown Loop Recirculation Pump (MRP2) to Venturi Flow Meter

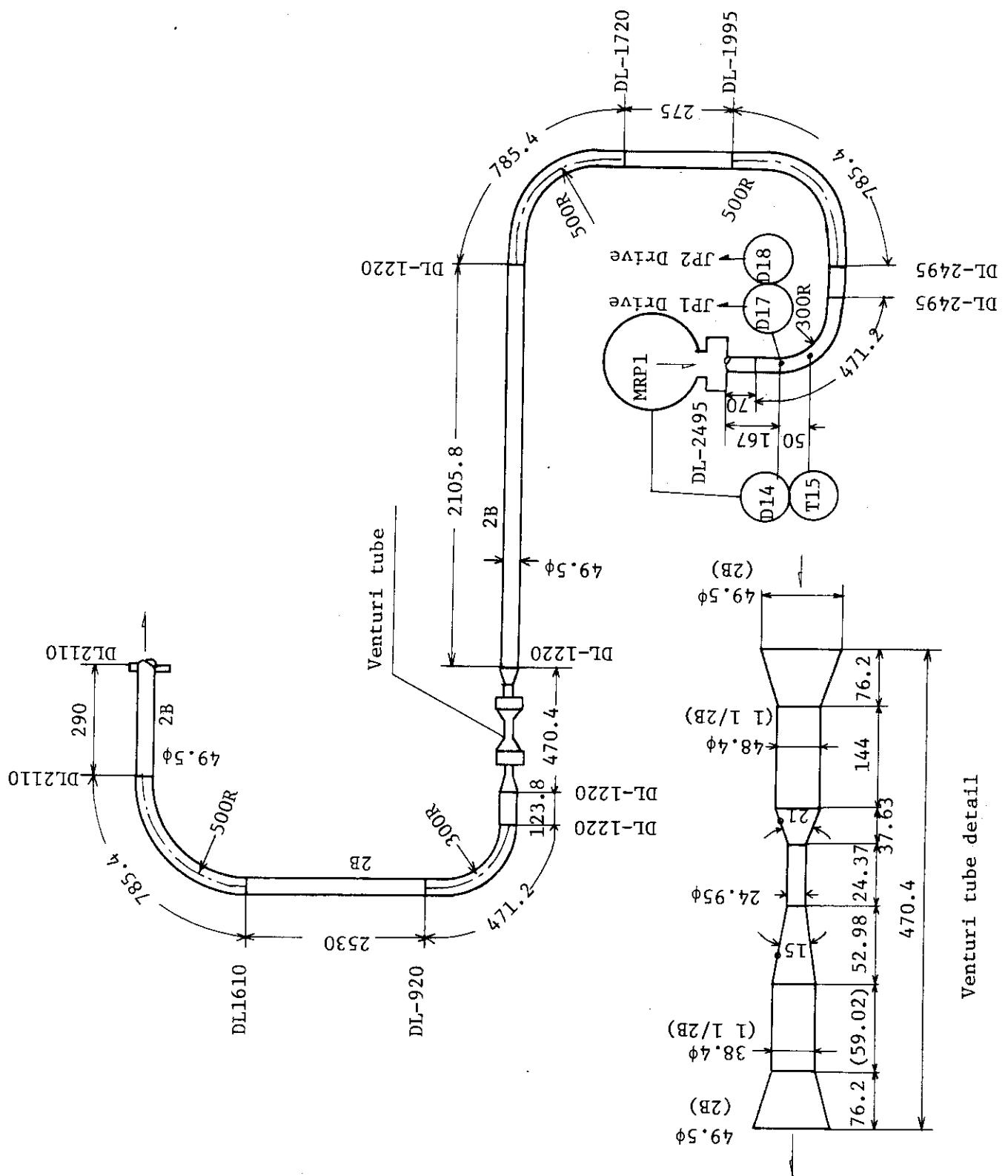


Fig. 2.33 Piping from Intact Loop Recirculation Pump (MRP1) to Venturi Flow Meter

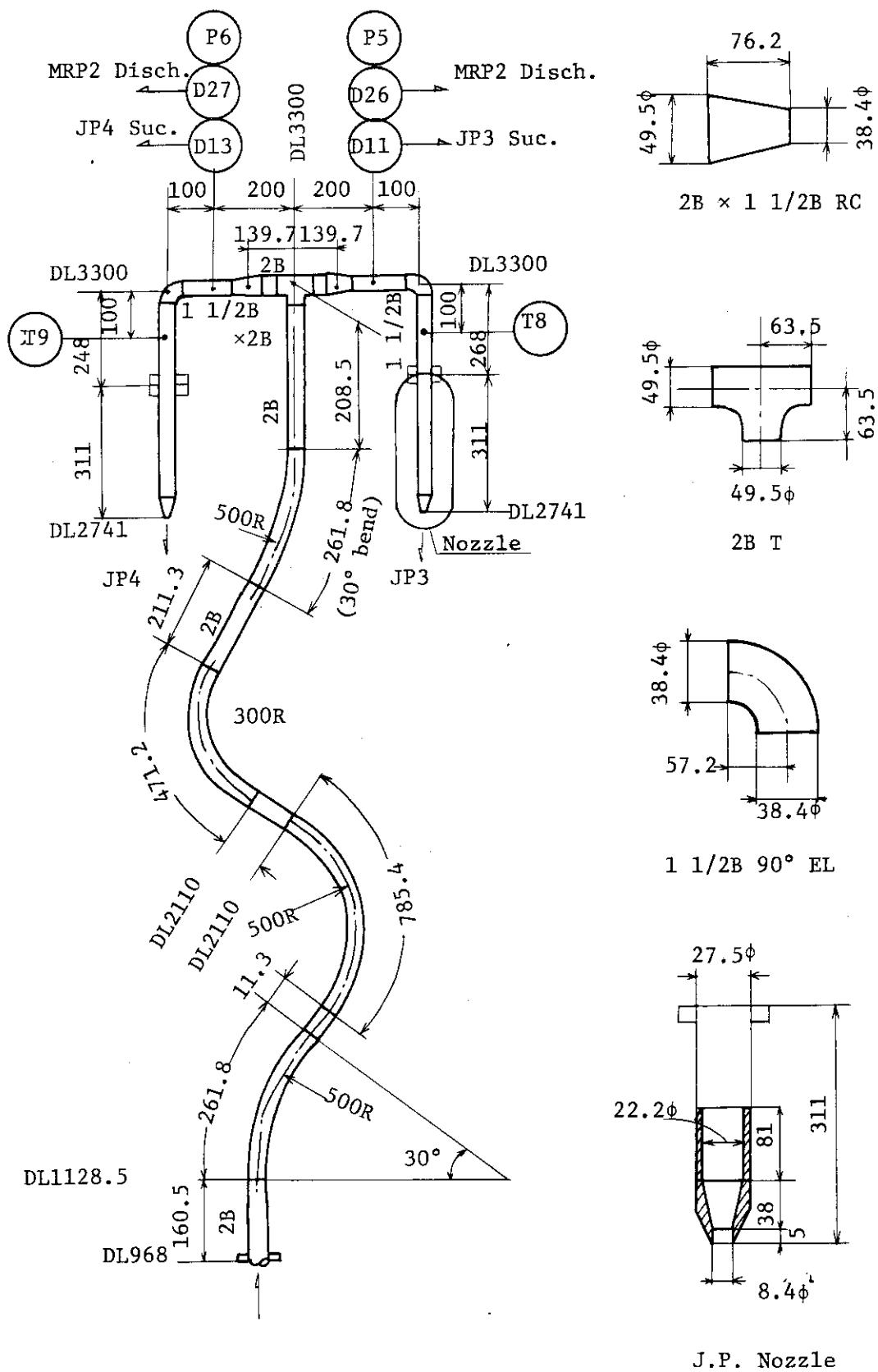


Fig. 2.34 Piping to Blowdown Loop Jet Pump Drive Nozzles (JP3, JP4)

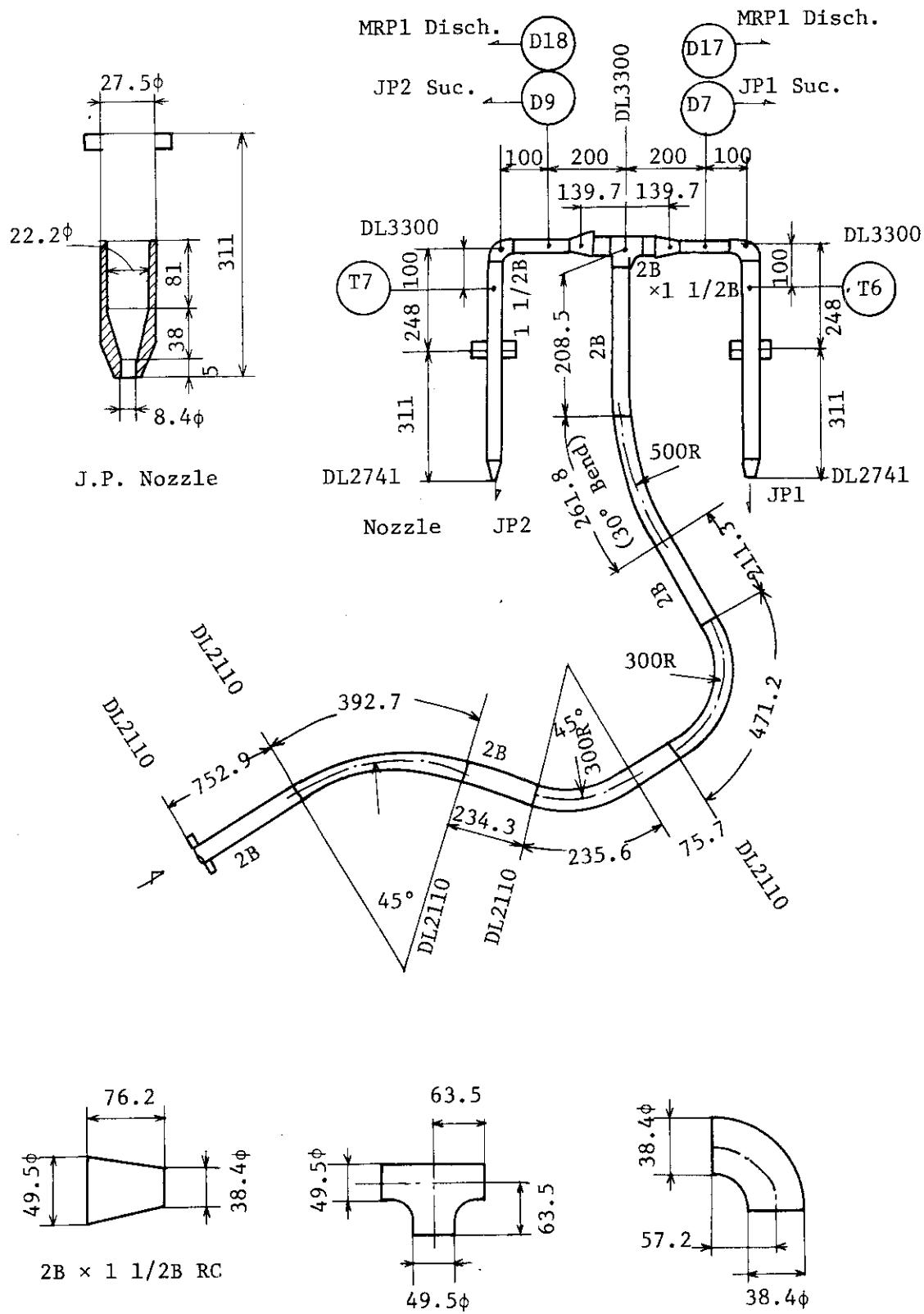


Fig.2.35 Piping to Intact Loop Jet Pump Drive Nozzles (JP1,JP2)

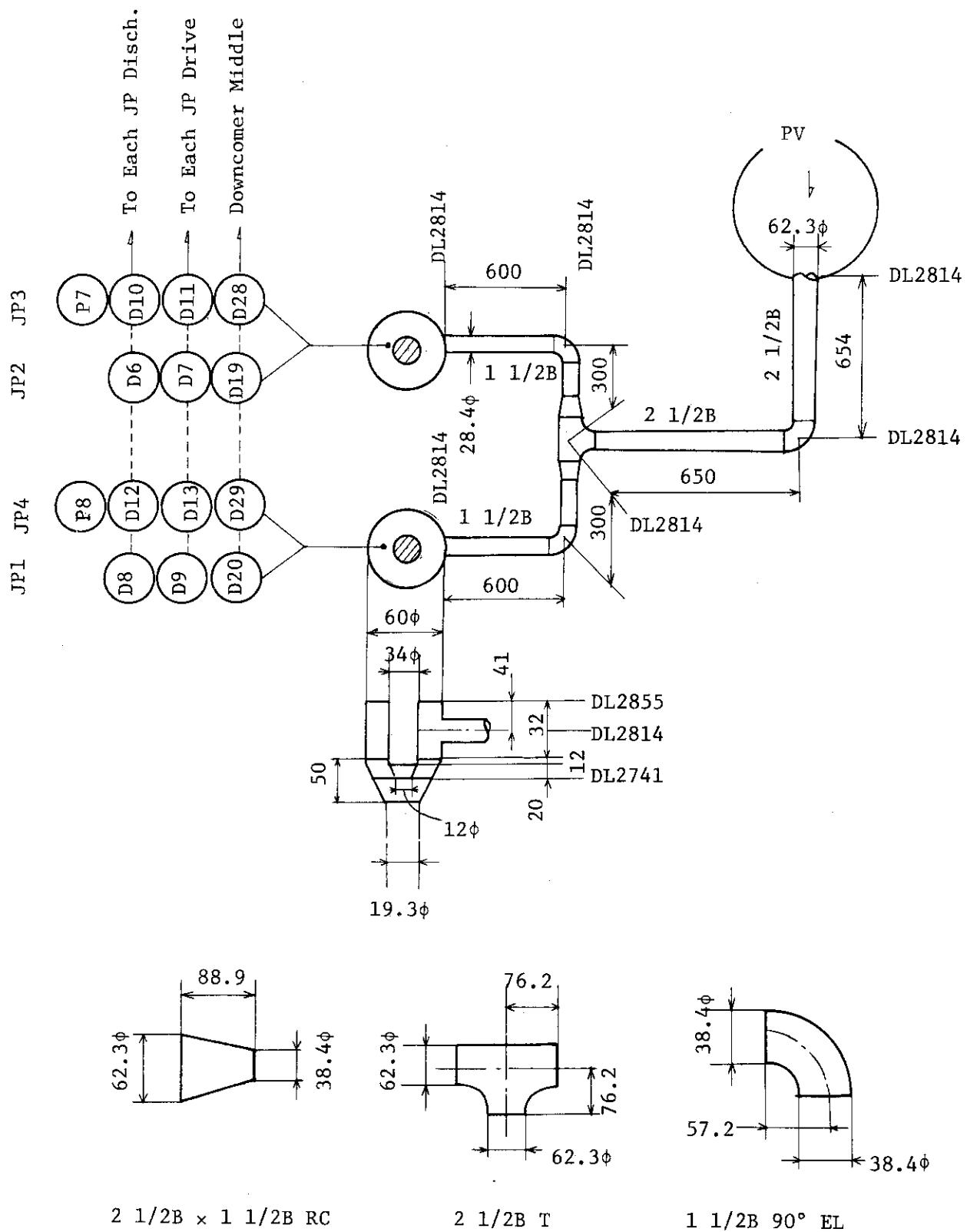


Fig. 2.36 Jet Pump Suction Line

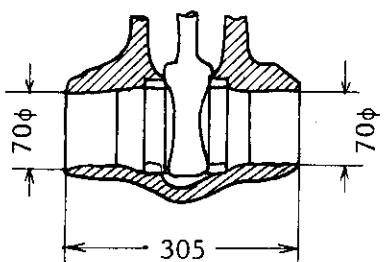
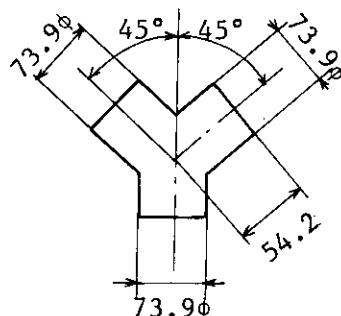
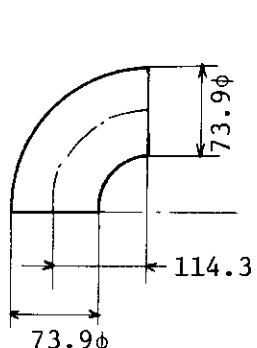
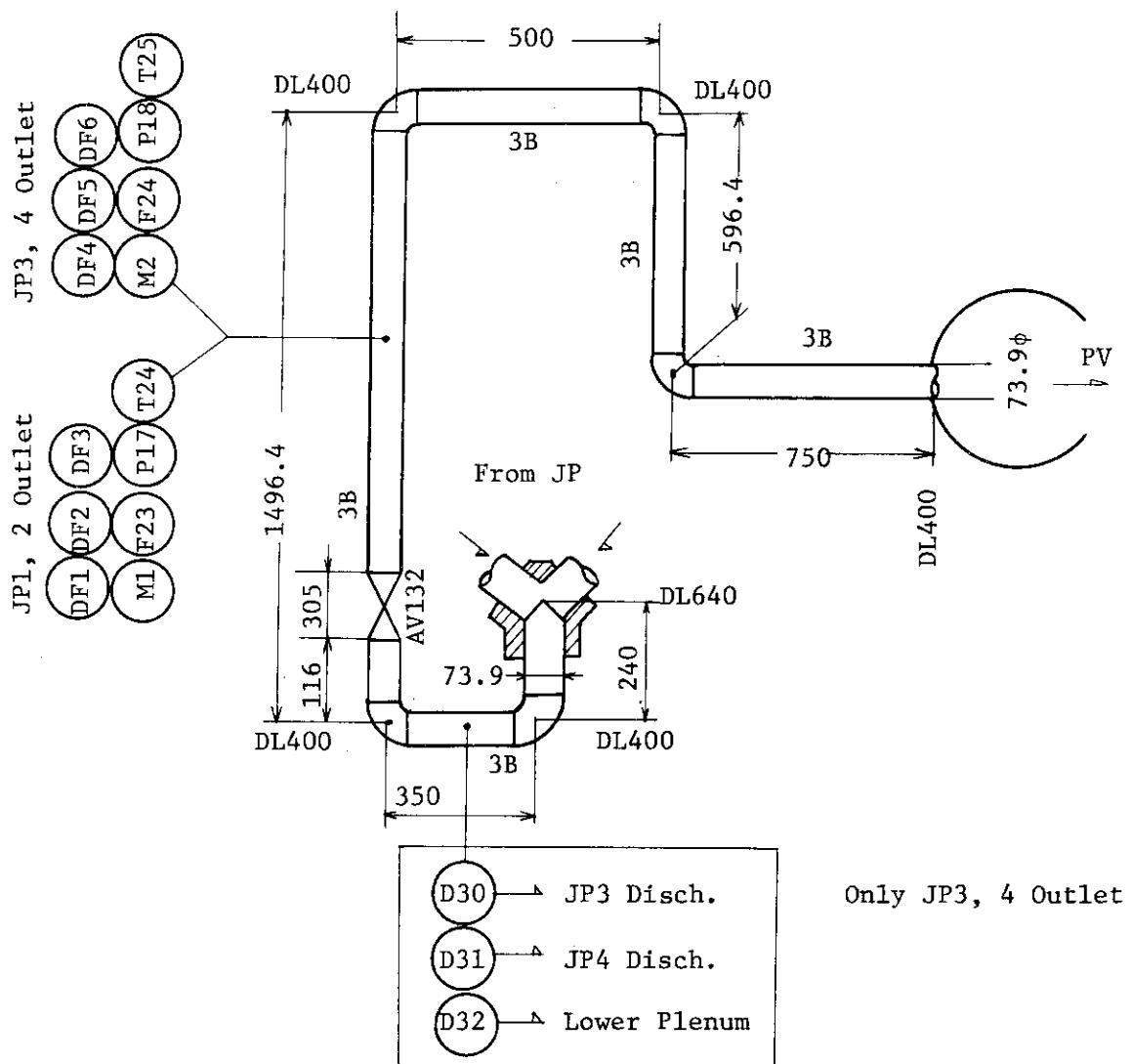


Fig. 2.37 Piping from Jet Pump Discharge to Lower Plenum

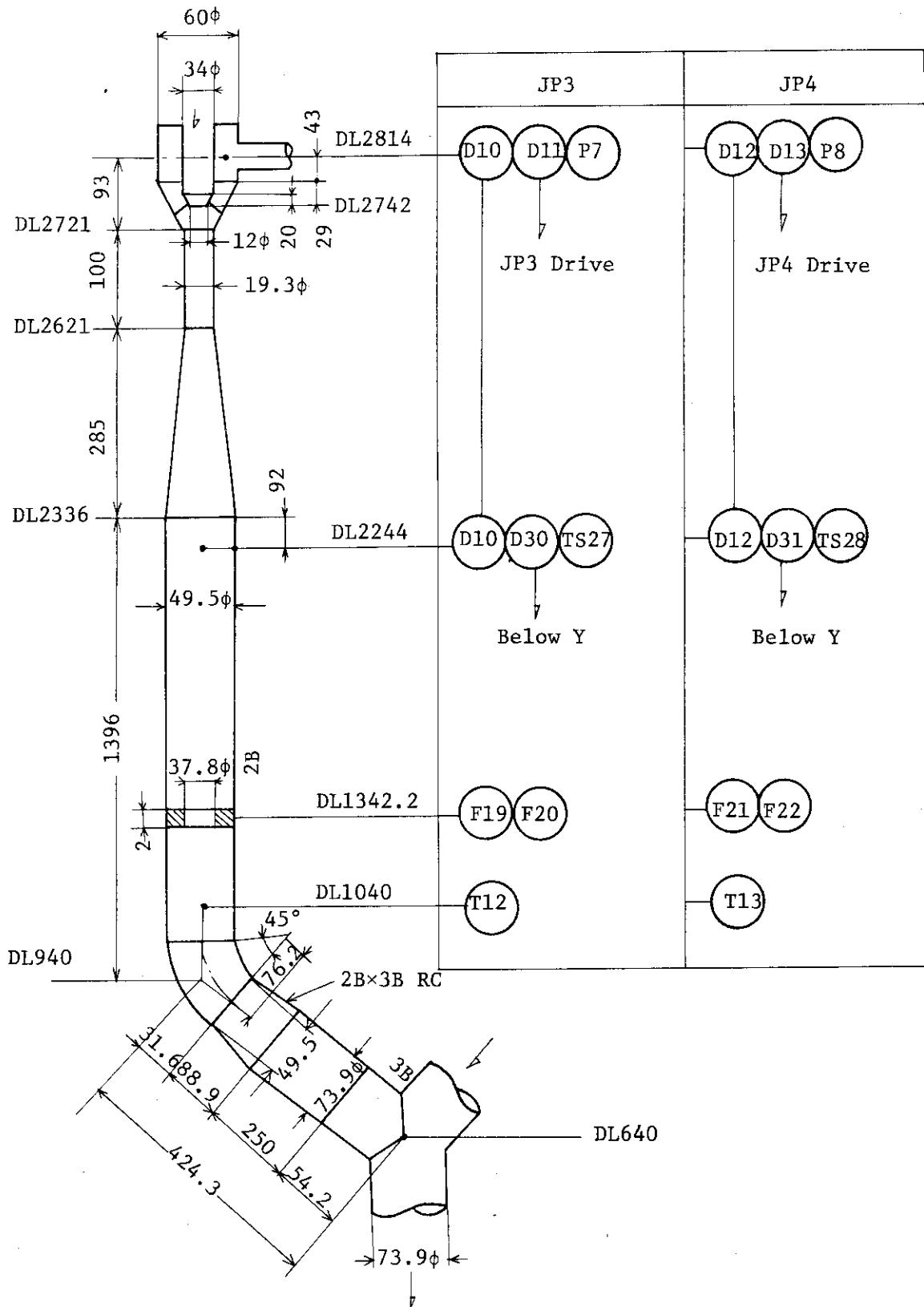


Fig. 2.38 Blowdown Loop Jet Pump Piping

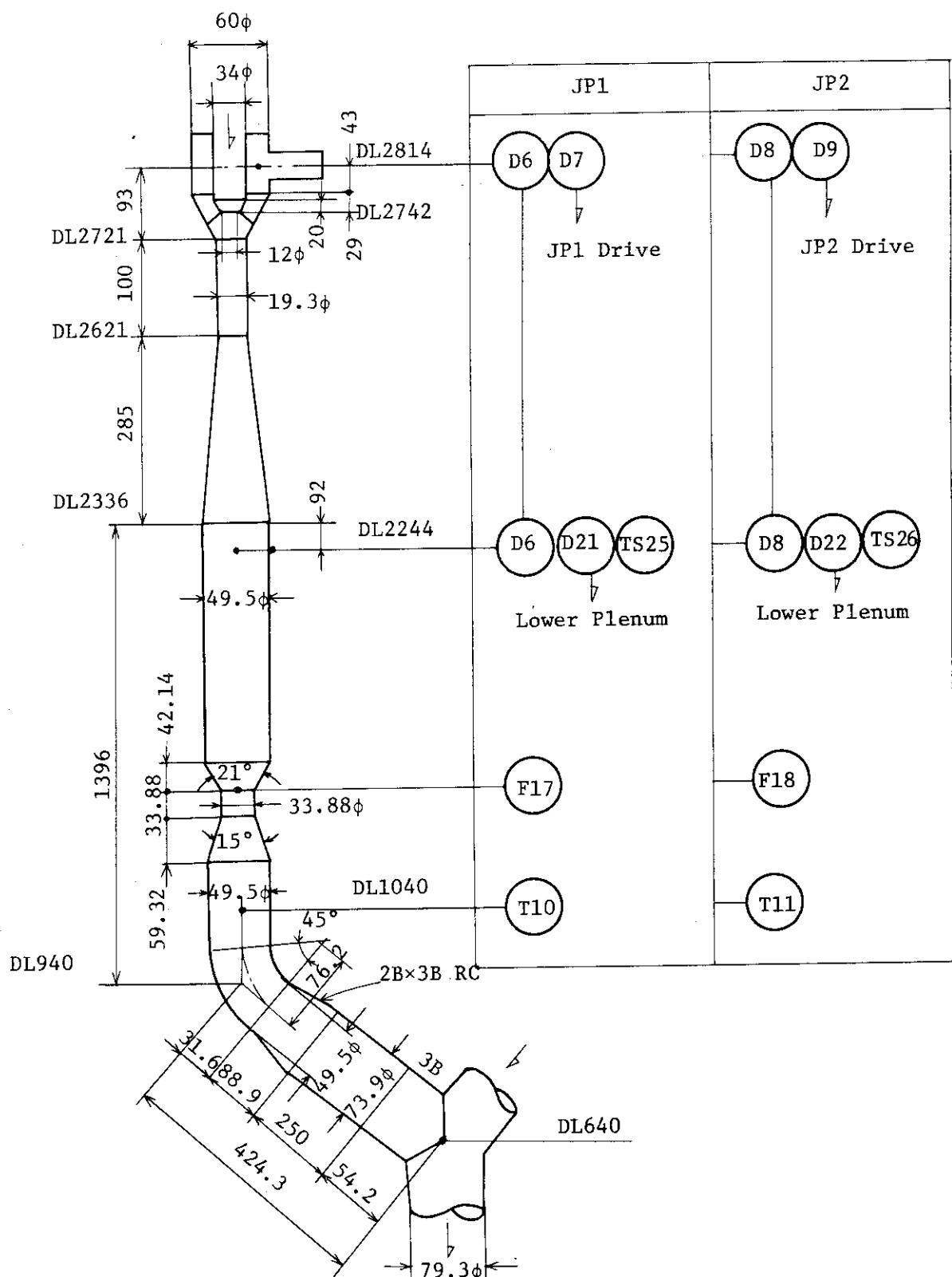


Fig. 2.39 Intact Loop Jet Pump Piping

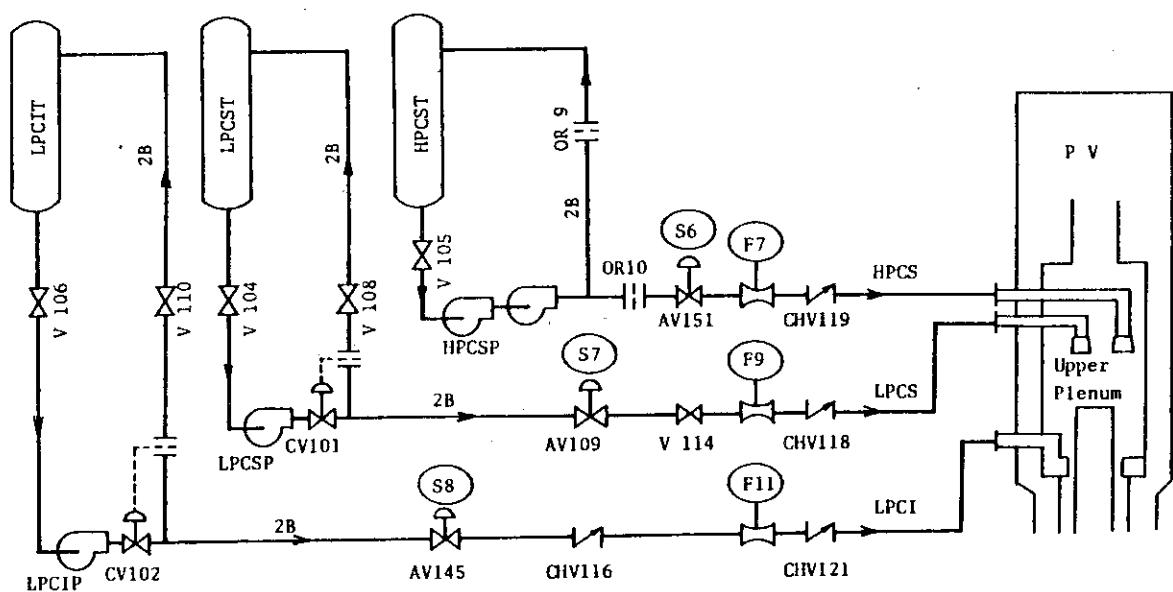


Fig. 2.40 ECC Systems Piping Schematic

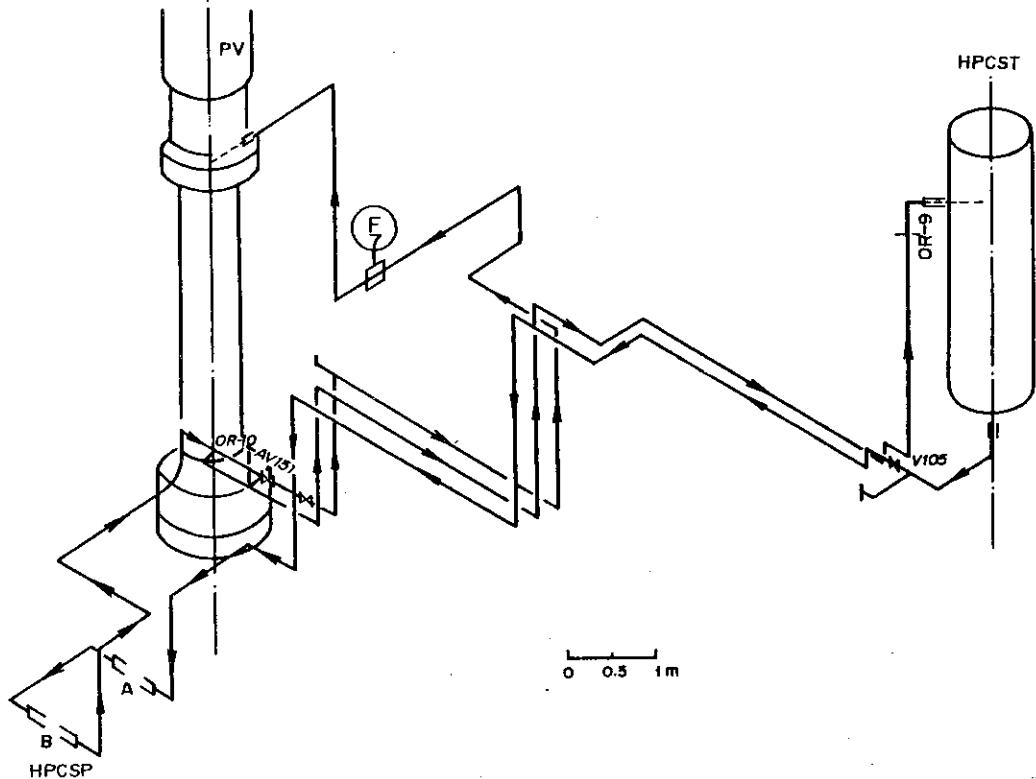


Fig. 2.41 HPCS System Piping Layout

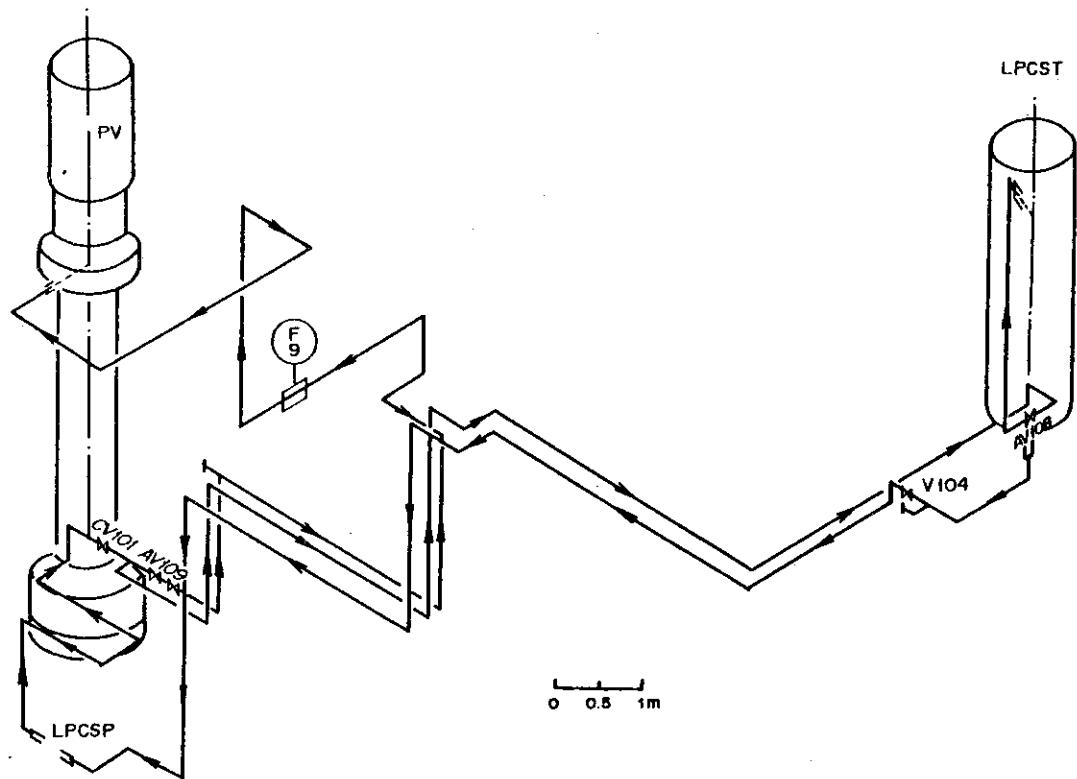


Fig. 2.42 LPCS System Piping Layout

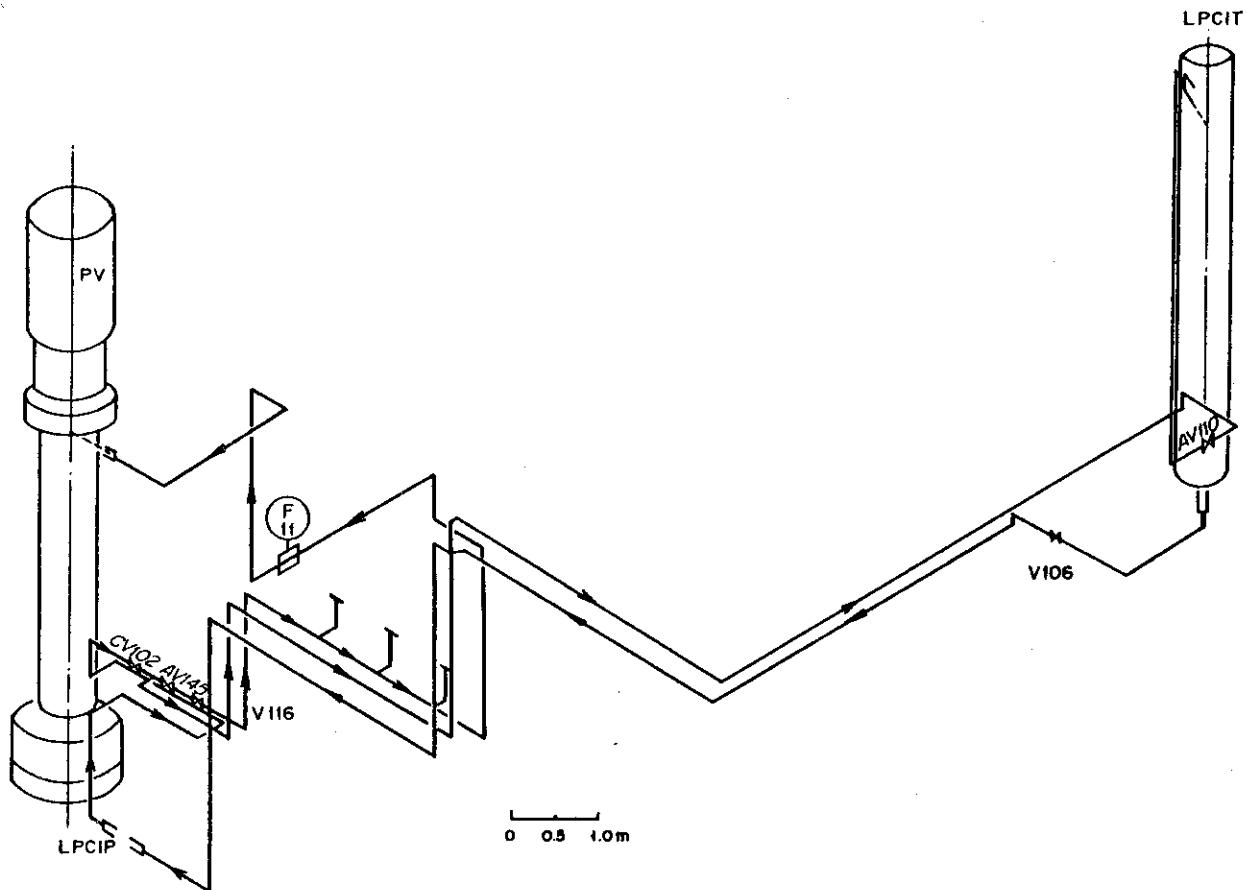


Fig. 2.43 LPCI System Piping Layout

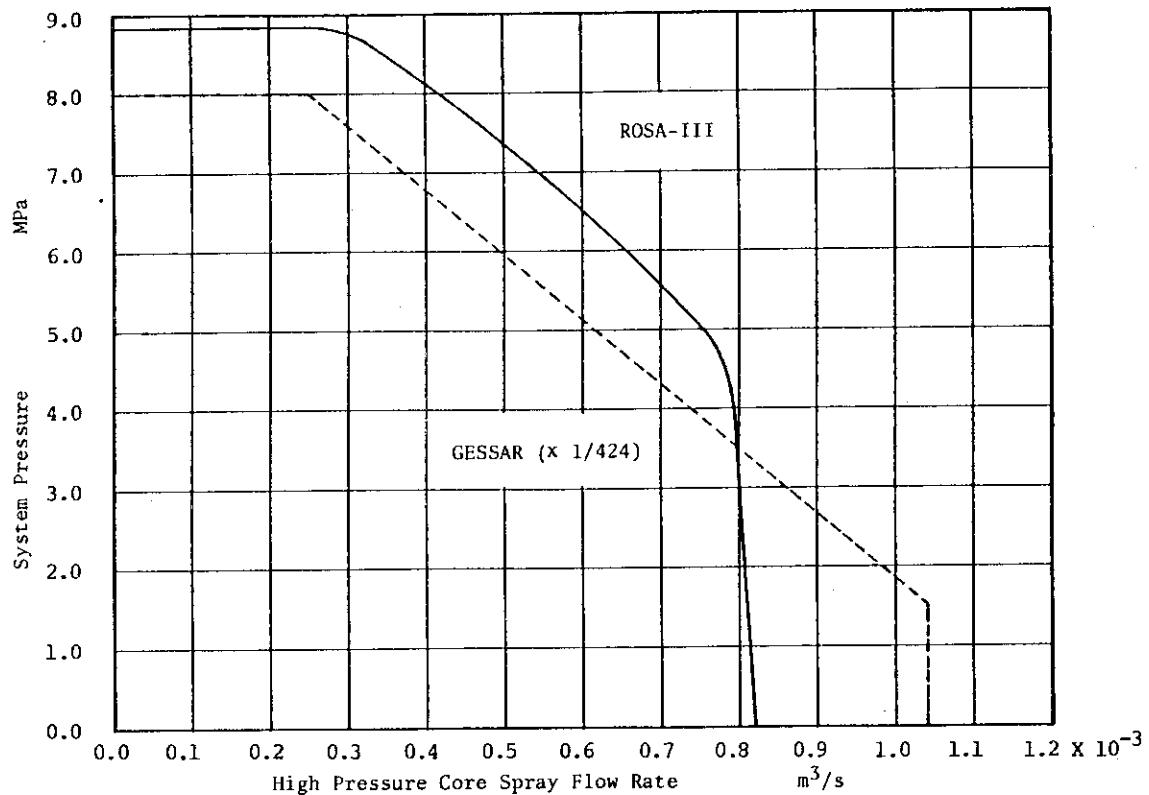


Fig. 2.44 HPCS Flow versus System Pressure

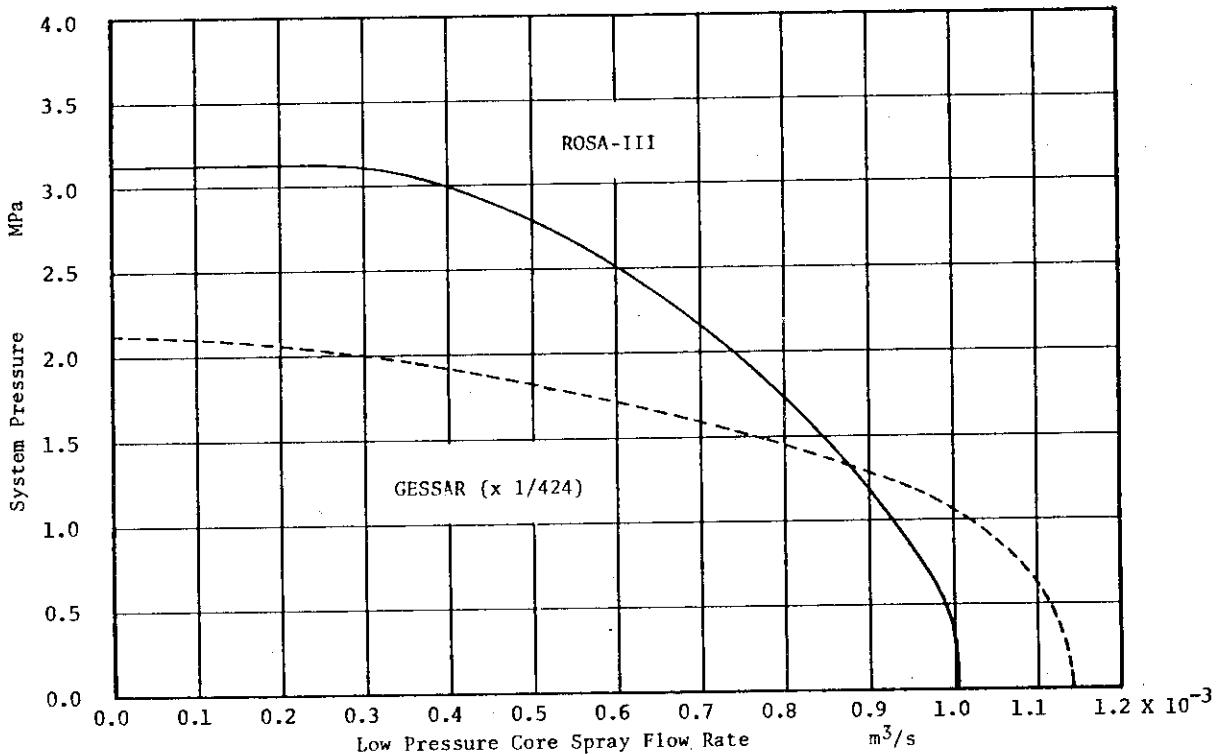


Fig. 2.45 LPCS Flow versus System Pressure

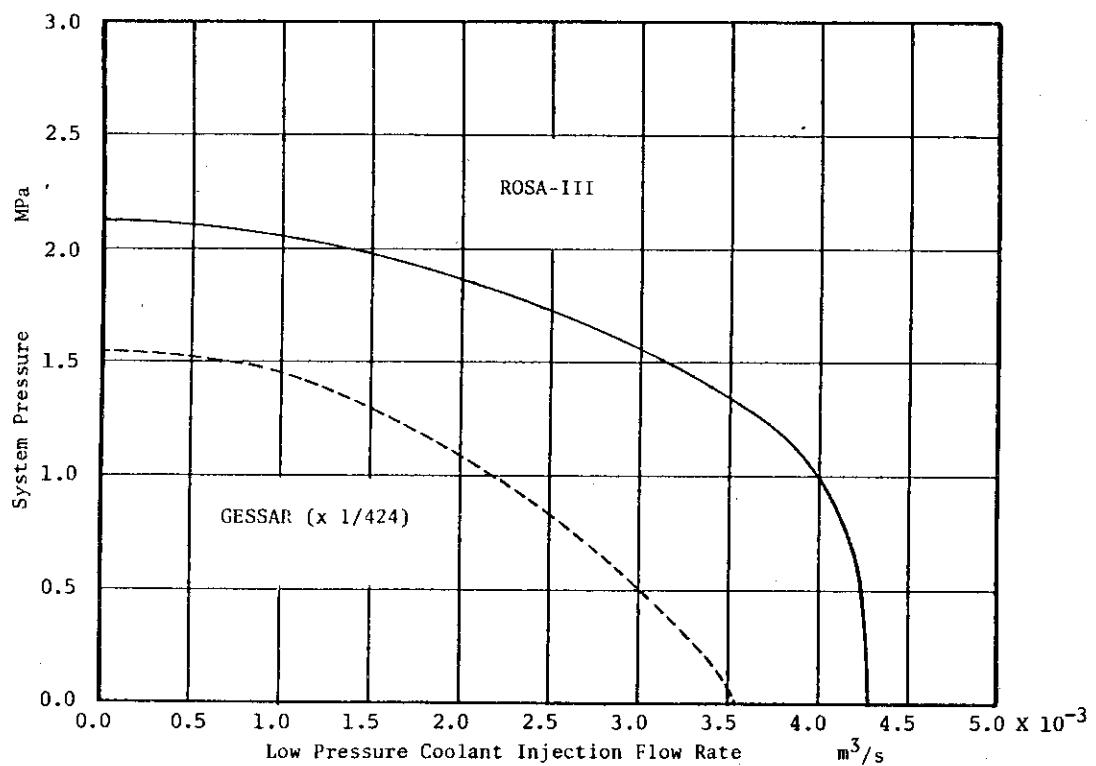


Fig. 2.46 LPCI Flow versus System Pressure

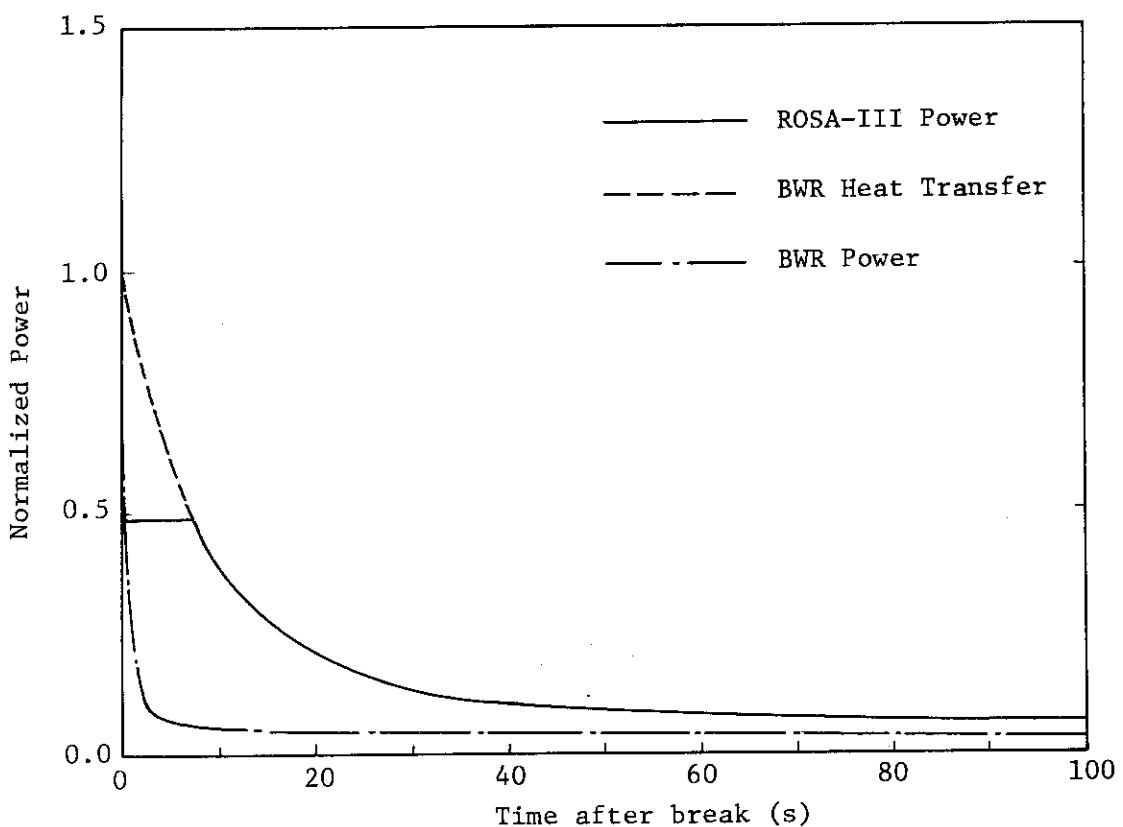


Fig. 2.47 Normalized Power Transient in BWR and ROSA-III

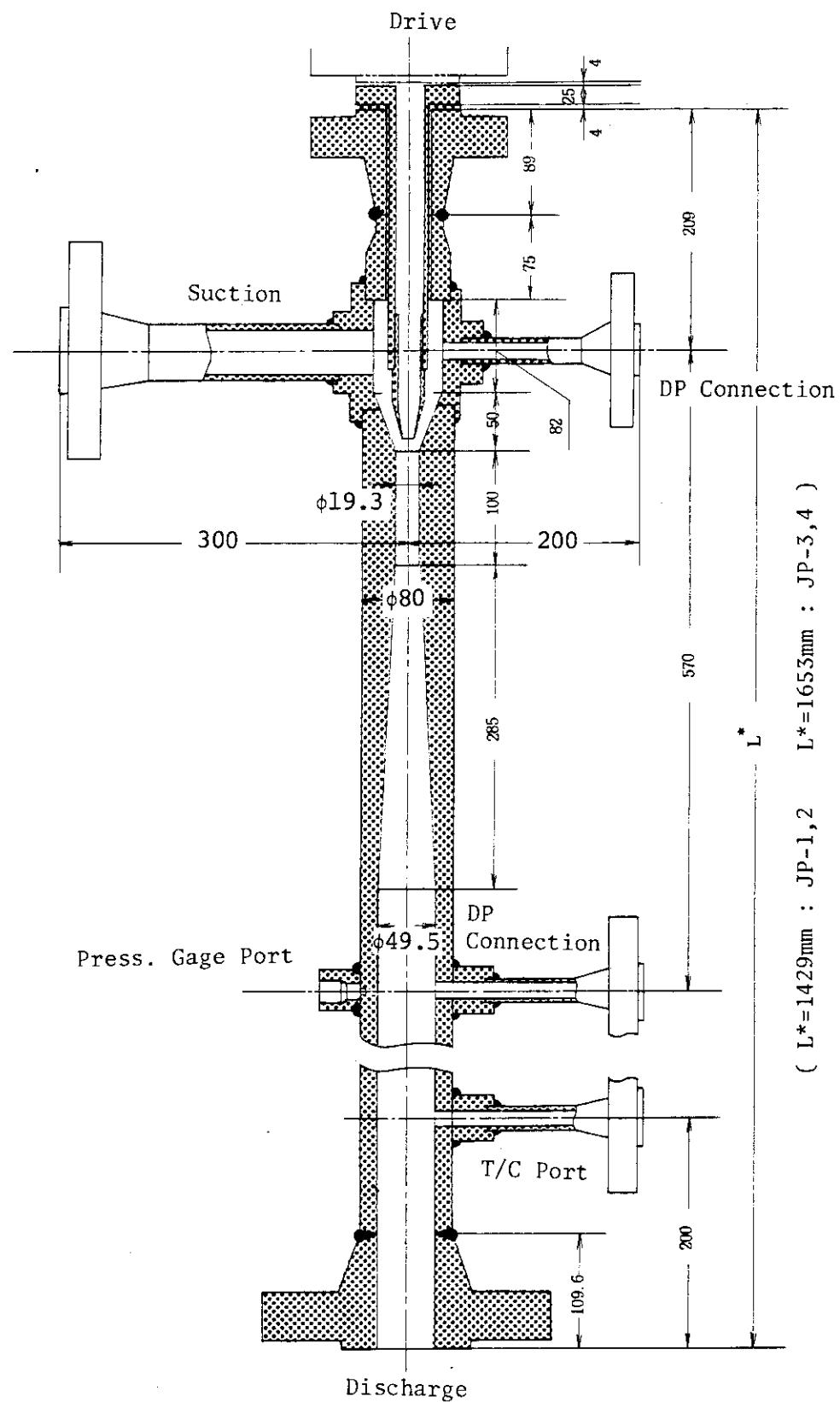


Fig. 2.48 Jet Pump

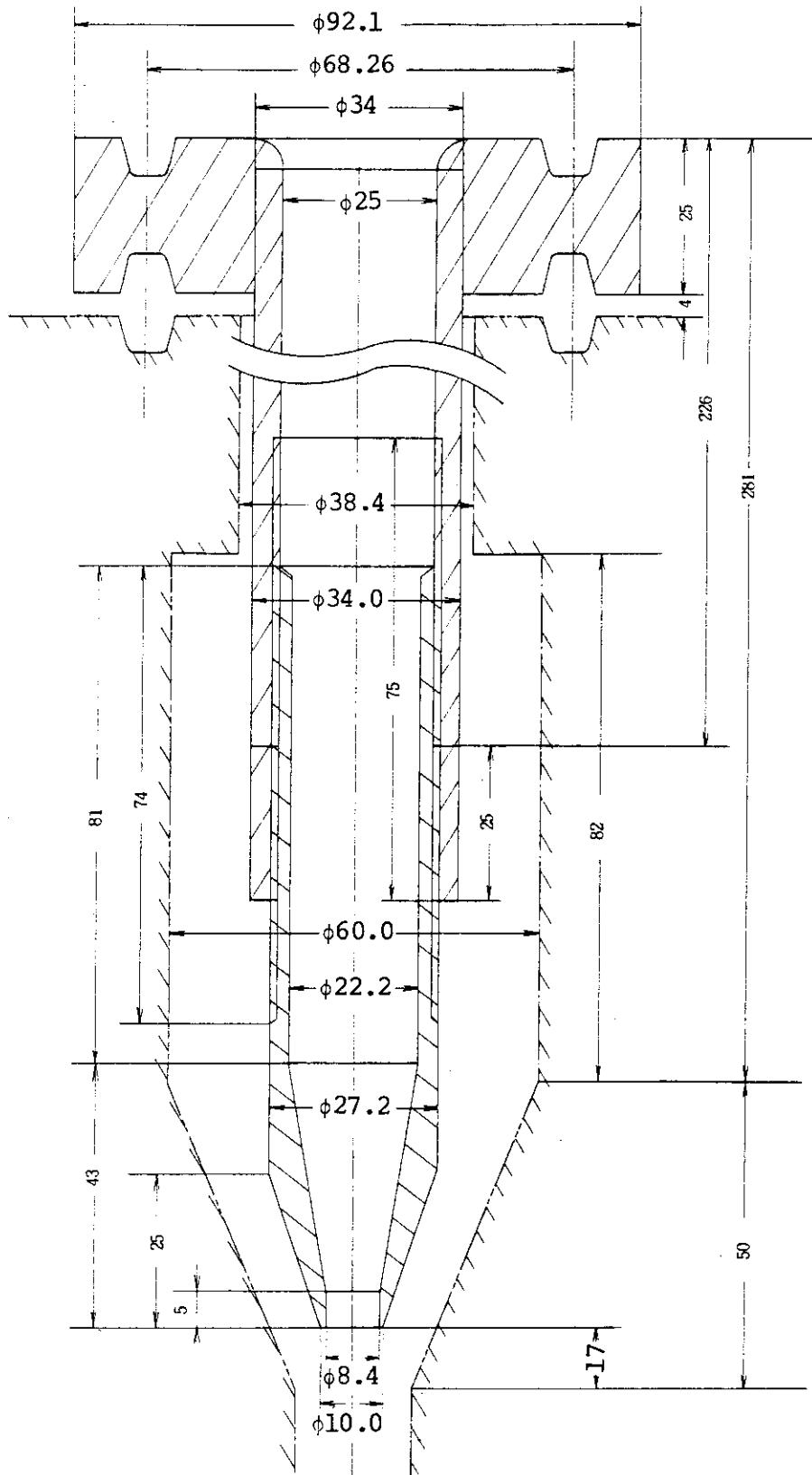


Fig. 2.49 Jet Pump Driving Flow Nozzle Details

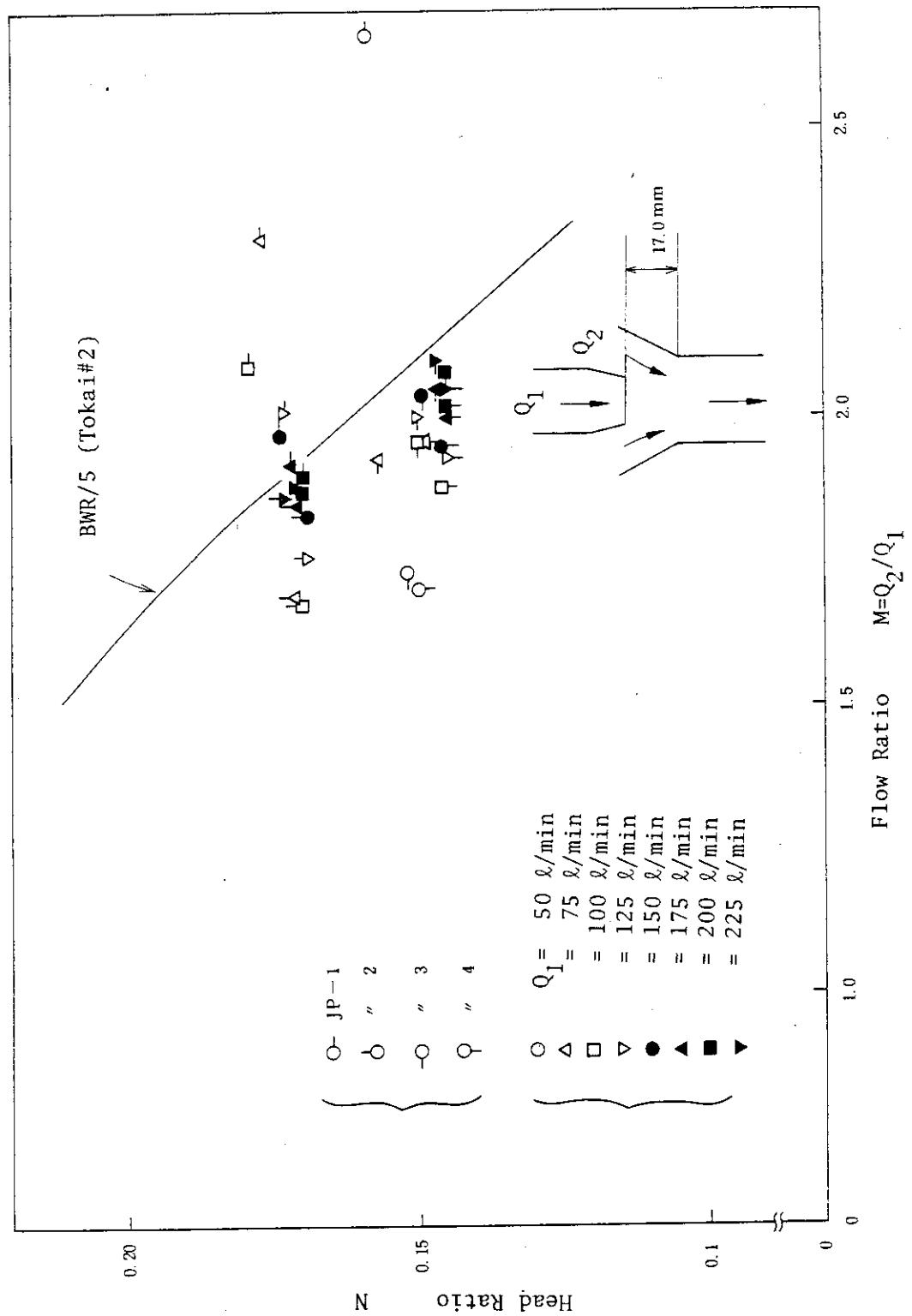


Fig. 2.50 Characteristic of Jet Pump in ROSA-III and BWR

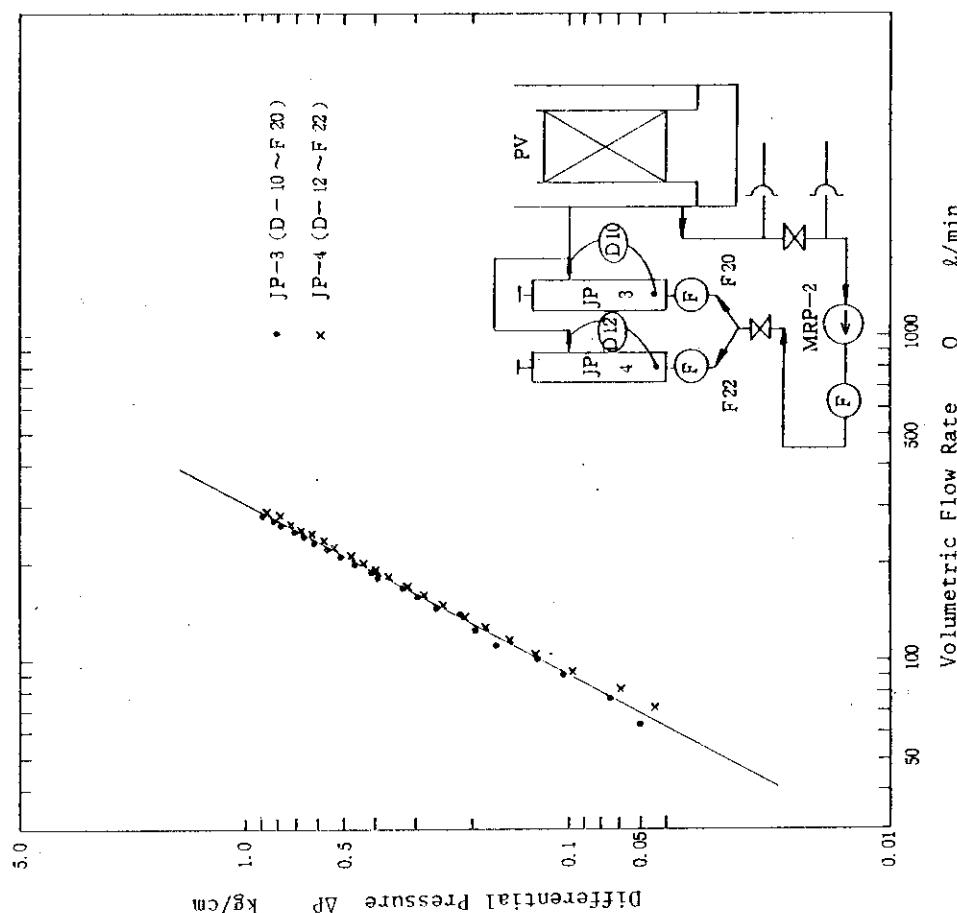
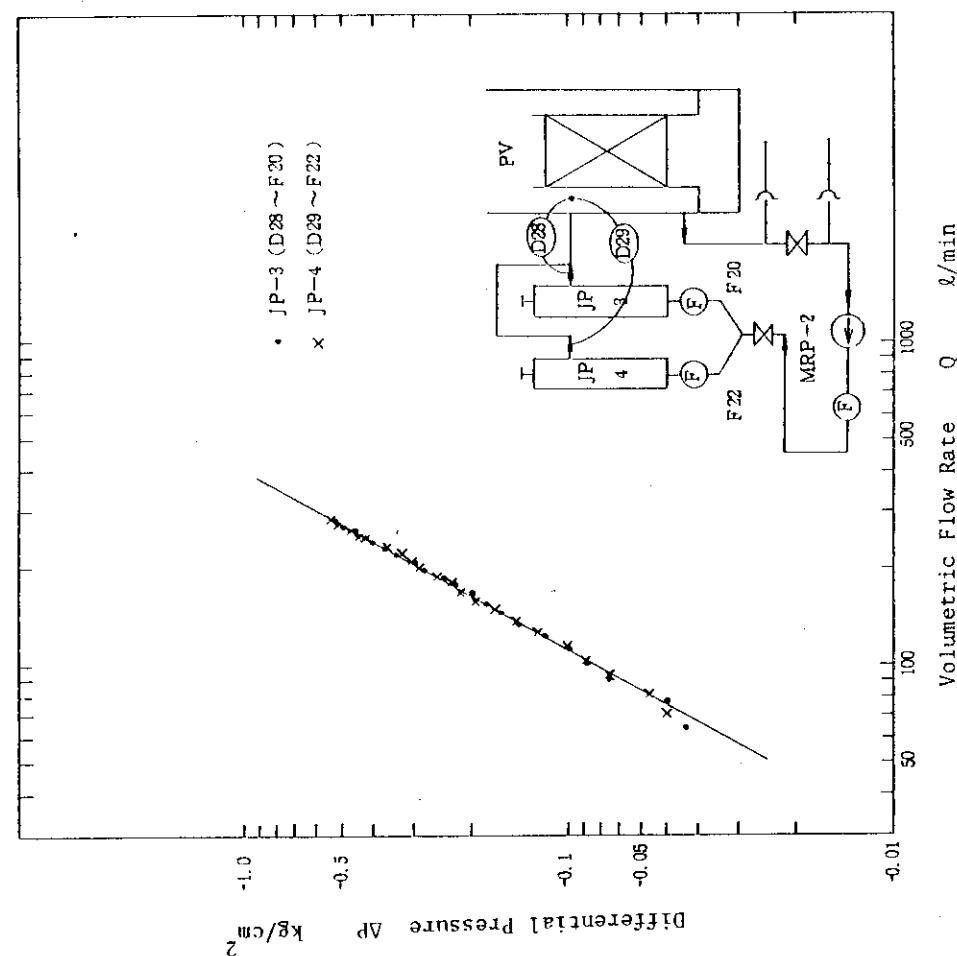


Fig. 2.51 Pressure Drop across the Jet Pump under the Reverse Flow Condition

Fig. 2.52 Pressure Drop across the Jet Pump Suction Line under the Reverse Flow Condition

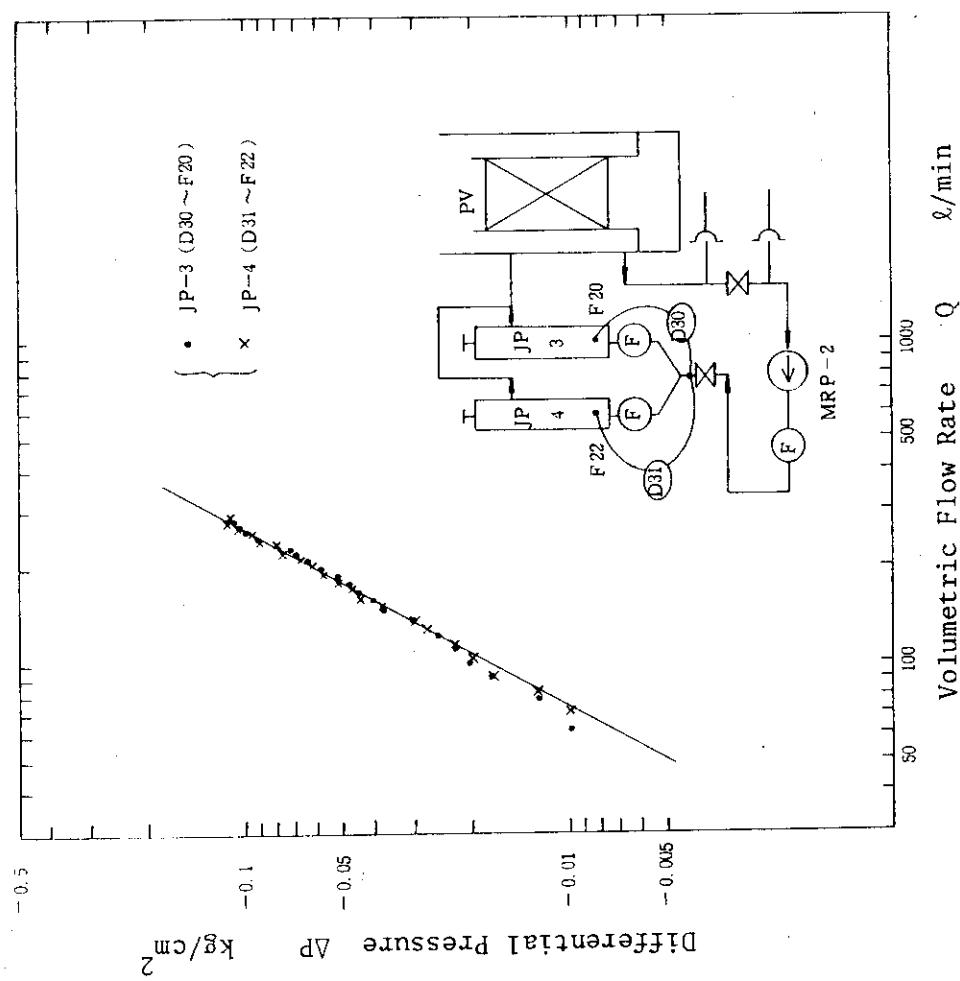


Fig. 2.53 Pressure Drop across the Y Branch under the Reverse Flow Condition

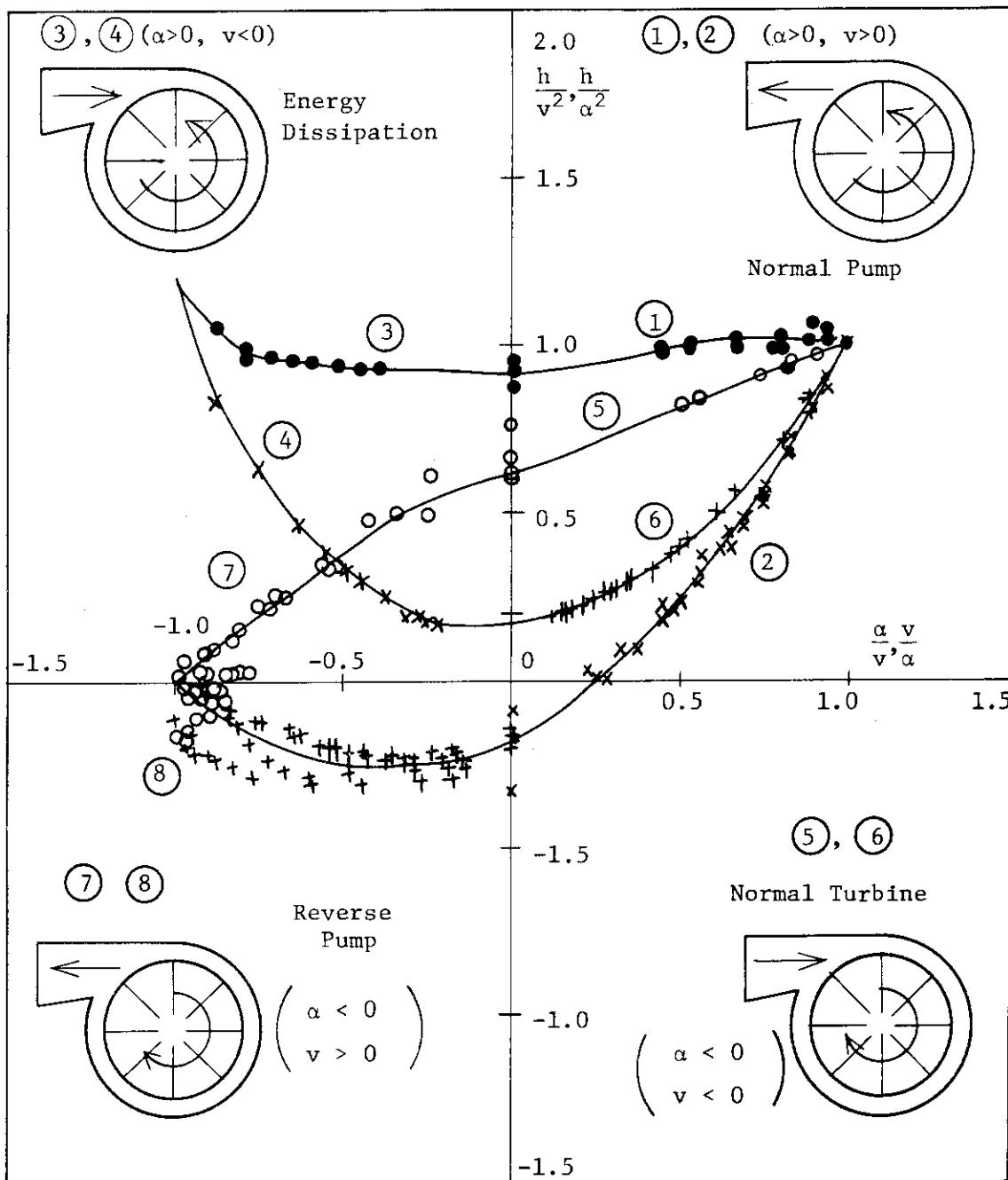


Fig. 2.54 Single-phase Homologous Head Curve for the ROSA-III Recirculation Pump

$$Q_r = 450 \text{ l/min}, \quad v = Q/Q_r$$

$$\omega_r = 3600 \text{ rpm}, \quad \omega = \omega/\omega_r$$

$$H_r = 262 \text{ m}, \quad h = H/H_r$$

Table 3.1 ROSA-III Measurement List for the Fuel Assembly No.4

ROSA-III MEASUREMENT LIST 4

CH. 1 ~ CH. 100

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
1	Press.	P- 1	Lower Plenum	0.1 ~ 10.0 MPa	51	Diff.P.	D-31	JP-4 Disch. - Below Y	-100 ~ 100 kPa
2		P- 2	Upper Plenum	"	52		D-32	Below Y - Lower Plenum	- 50 ~ 50 kPa
3		P- 3	Steam Dome	"	53		D-33	Lower Pl.- DC Middle	-250 ~ 250 kPa
4		P- 4	Downcomer Bottom	"	54		D-34	Lower Pl.- DC Bottom	"
5		P- 5	JP-3 Drive	"	55		D-35	DC Bottom - DC Middle	- 50 ~ 50 kPa
6		P- 6	JP-4 Drive	"	56		D-36	DC Middle - Steam Dome	"
7		P- 7	JP-3 Suction	"	57		D-37	Lower Pl.Mid-Upper Pl.	0 ~ 250 kPa
8		P- 8	JP-4 Suction	"	58		D-38	Lower Pl.Bottom-Middle	0 ~ 50 kPa
9		P- 9	MRP-1 Suction	"	59		D-39	Upper Plenum Head	0 ~ 20 kPa
10		P-10	MRP-2 Suction	"	60		D-40	Channel Orifice A	0 ~ 100 kPa
11		P-11	MRP-2 Delivery	"	61		D-41	Channel Orifice B	"
12		P-12	Break A Upstream	"	62		D-42	Channel Orifice C	"
13		P-13	Break A Downstream	"	63		D-43	Channel Orifice D	"
14		P-14	Break B Upstream	"	64		D-44	Bypass Hole	0 ~ 200 kPa
15		P-15	Break B Downstream	"	65	Level	WL-1	HPCS Tank	0 ~ 1.73 m
16		P-16	Steam Line	"	66		WL-2	LPCS Tank	"
17		P-17	JP-1,2 Outlet Spool	"	67		WL-3	LPCI Tank	0 ~ 3.56 m
18		P-18	JP-3,4 Outlet Spool	"	68		EL-4	Pressure Vessel	3.9 ~ 6.0 m
19		P-19	Break A Spool Piece	"	69	Flow	F- 1	Main Steam Line	0 ~ 15 kg/s
20		P-30	Break B Spool Piece	"	70		F- 2	ADS Line	0 ~ 3.0 kg/s
21	Diff.P.	D- 1	Lower Pl.-Upper Pl.	- 50 ~ 350 kPa	71		F- 7	HPCS	0 ~ 2.5x10 ⁻² m ³ /s
22		D- 2	Upper Pl.-Steam Dome	- 10 ~ 90 kPa	72		F- 9	LPCS	"
23		D- 3	Lower Plenum Head	0 ~ 150 kPa	73		F-11	LPCI	0 ~ 8.3x10 ⁻³ m ³ /s
24		D- 4	Downcomer Head	0 ~ 100 kPa	74		F-15	Feed Water	0 ~ 1.0x10 ⁻² m ³ /s
25		D- 5	PV Bottom - Top	-100 ~ 900 kPa	75		F-17	JP-1	0 ~ 1.7x10 ⁻² m ³ /s
26		D- 6	JP-1 Disch.-Suction	-100 ~ 300 kPa	76		F-18	JP-2	"
27		D- 7	JP-1 Drive -Suction	0 ~ 2.5 MPa	77		F-19	JP-3 Disch. Positive	"
28		D- 8	JP-2 Disch.-Suction	-100 ~ 300 kPa	78		F-20	JP-3 Disch. Negative	0 ~ 5x10 ⁻³ m ³ /s
29		D- 9	JP-2 Drive -Suction	- 0 ~ 2.5 MPa	79		F-21	JP-4 Disch. Positive	0 ~ 1.7x10 ⁻² m ³ /s
30		D-10	JP-3 Disch.-Suction	-100 ~ 300 kPa	80		F-22	JP-4 Disch. Negative	0 ~ 5x10 ⁻³ m ³ /s
31		D-11	JP-3 Drive -Suction	-1.0 ~ 2.0 MPa	81		F-23	JP1,2 Outlet	0 ~ 30 kg/s
32		D-12	JP-4 Disch.-Suction	-100 ~ 300 kPa	82		F-24	JP3,4 Outlet	"
33		D-13	JP-4 Drive -Suction	-0.5 ~ 2.5 MPa	83		F-25	Break A	"
34		D-14	MRP-1 Deliv.-Suction	-0.1 ~ 2.5 MPa	84		F-26	Break B	"
35		D-15	MRP-2 Deliv.-Suction	-0.1 ~ 2.5 MPa	85		F-27	MRP1	0 ~ 1.2x10 ⁻² m ³ /s
36		D-16	DC Bottom -MRP-1 Suc.	- 50 ~ 50 MPa	86		F-28	MRP2	"
37		D-17	MRP1 Deliv.-JP1 Drive	0 ~ 250 kPa	87	Diff. P.	D-F1	F1 Orifice	0 ~ 0.9 MPa
38		D-18	MRP1 Deliv.-JP2 Drive	"	88		D-F2	F2 Orifice	0 ~ 5.0 kPa
39		D-19	DC Middle - JP1 Suc.	"	89		D-F17	F17 Venturi	0 ~ 100 kPa
40		D-20	DC Middle - JP2 Suc.	"	90		D-F18	F18 Venturi	"
41		D-21	JP1 Disch.-Lower Pl.	-100 ~ 100 kPa	91		D-F19	F19 Orifice	0 ~ 150 kPa
42		D-22	JP2 Disch.-Lower Pl.	"	92		D-F20	F20 Orifice	"
43		D-23	DC Bottom - Break B	0 ~ 2.0 MPa	93		D-F21	F21 Orifice	"
44		D-24	Break B - Break A	0 ~ 100 kPa	94		D-F22	F22 Orifice	"
45		D-25	Break A-MRP2 Suction	-500 ~ 500 kPa	95		D-F27	F27 Venturi	0 ~ 200 kPa
46		D-26	MRP2 Deliv.-JP3 Drive	-500 ~ 500 kPa	96		D-F28	F28 Venturi	"
47		D-27	MRP2 Deliv.-JP4 Drive	"	97				
48		D-28	DC Middle-JP3 Suc.	-250 ~ 250 kPa	98				
49		D-29	DC Middle-JP4 Suc.	"	99				
50		D-30	JP3 Disch.-Below Y	-100 ~ 100 kPa	100				

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CH. 101 ~ CH. 200

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
101	Power	W- 1	S50 kW Power Supplier	0 ~ 550 kW	151	Fluid Temp.	T-14	MRP-1 Suction	273 ~ 673 K
102		W- 2	1800kW Power Supplier	0 ~ 1700 kW	152		T-15	MRP-1 Delivery	"
103		W- 3	2100kW Power Supplier	0 ~ 2100 kW	153		T-16	MRP-2 Suction	"
104	Rev.	N- 1	MRP-1	0 ~ 5000 rpm	154		T-17	MRP-2 Delivery	"
105		N- 2	MRP-2	"	155		T-18	Break A Upstream	"
106	Signal	S- 1	Break Signal A	close-open	156		T-19	Break B Upstream	"
107		S- 2	Break Signal B	"	157		T-20	RCN A Condensed Water	"
108		S- 3	QSV Signal	"	158		T-21	RCN B Condensed Water	"
109		S- 6	HPCS Valve	"	159		T-22	Discharged Steam	"
110		S- 7	LPCS Valve	"	160		T-24	JP-1,2 Outlet Spool	"
111		S- 8	LPCI Valve	"	161		T-25	JP-3,4 Outlet Spool	"
112		S- 9	Feed W. Control Limit	"	162		T-26	Break A Spool Piece	"
113		S-10	MSIV Signal	"	163		T-37	Break B Spool Piece	"
114		S-11	Steam Line Valve	"	164	Slab Temp.	TS- 1	Core Barrel C Pos. 1	"
115		S-12	AOS Valve	"	165		TS- 2		"
116		S-13	MRP-1 Power Off	ON-OFF	166		TS- 3		"
117		S-14	MRP-2 Power Off	"	167		TS- 4		"
118		RD- 1	MRP-1	Pos.-Neg.	168		TS- 5		"
119		RD- 2	MRP-2	"	169		TS- 6		"
120	Density	DF- 1	JP-1,2 Outlet Beam 1	0 ~ 1000kg/m ³	170		TS- 7	Core Barrel A Pos. 1	"
121		DF- 2	Beam 2	"	171		TS- 8		"
122		DF- 3	Beam 3	"	172		TS- 9		"
123		DF- 4	JP-3,4 Outlet Beam 1	"	173		TS-10		"
124		DF- 5	Beam 2	"	174		TS-11		"
125		DF- 6	Beam 3	"	175		TS-12		"
126		DF- 7	Break A	Beam 1	176		TS-13	Filler Block C Pos.1	
127		DF- 8	Beam 2	"	177		TS-14		"
128		DF- 9	Break B	Beam 1	178		TS-15		"
129		DF-10	Beam 2	"	179		TS-16		"
130	Moment. Flux	M- 1	JP-1,2 Outlet Spool	0~1.5x10 ⁻⁵ kg/ms	180		TS-17		"
131		M- 2	JP-3,4 Outlet Spool	"	181		TS-18		"
132		M- 3	Break A Spool Piece	"	182		TS-19	Filler Block A Pos.1	"
133		M- 4	Break B Spool Piece	"	183		TS-20		"
134					184		TS-21		"
135					185		TS-22		"
136					186		TS-23		"
137					187		TS-24		"
138	Fluid Temp.	T- 1	Lower Plenum	273 ~ 673 K	188		TS-25	JP-1 Diffuser Wall	"
139		T- 2	Upper Plenum	"	189		TS-26	JP-2 Diffuser Wall	"
140		T- 3	Steam Dome	"	190		TS-27	JP-3 Diffuser Wall	"
141		T- 4	Upper Downcomer	"	191		TS-28	JP-4 Diffuser Wall	"
142		T- 5	Lower Downcomer	"	192		TS-29	PV Wall Inside 1-1	"
143		T- 6	JP-1 Drive		193		TS-30	PV Inner Surface 1-2	"
144		T- 7	JP-2 Drive	"	194		TS-31		1-3
145		T- 8	JP-3 Drive	"	195		TS-32	PV Wall Inside 2	"
146		T- 9	JP-4 Drive	"	196		TS-33		3
147		T-10	JP-1 Discharge	"	197		TS-34		4
148		T-11	JP-2 Discharge	"	198		TS-35	L.P. Inner Surface	"
149		T-12	JP-3 Discharge	"	199		TS-36	L.P. Wall Inside	"
150		T-13	JP-4 Discharge	"	200				

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CH. 201 ~ CH. 300

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
201	Surface Temp.	TF4- 1	A11 Fuel Rod Pos.1	273 ~ 1273 K	251	Surface Temp.	TF4-51	A31 Fuel Rod Pos.1	273 ~ 1273 K
202		2		2	252		52		4
203		3		3	253		53	A33 Fuel Rod Pos.1	
204		4		4	254		54		2
205		5		5	255		55		3
206		6		6	256		56		4
207		7		7	257		57		5
208		8	A12 Fuel Rod Pos.1		258		58		6
209		9		2	259		59		7
210		10		3	260		60	A34 Fuel Rod Pos.1	
211		11		4	261		61		2
212		12		5	262		62		3
213		13		6	263		63		4
214		14		7	264		64		5
215		15	A13 Fuel Rod Pos.1		265		65		6
216		16		2	266		66		7
217		17		3	267		67	A37 Fuel Rod Pos.1	
218		18		4	268		68		4
219		19		5	269		69	A42 Fuel Rod Pos.1	
220		20		6	270		70		4
221		21		7	271		71	A44 Fuel Rod Pos.1	
222		22	A14 Fuel Rod Pos.1		272		72		2
223		23		2	273		73		3
224		24		3	274		74		4
225		25		4	275		75		5
226		26		5	276		76		6
227		27		6	277		77		7
228		28		7	278		78	A48 Fuel Rod Pos.1	
229		29	A15 Fuel Rod Pos.1		279		79		4
230		30		4	280		80	A51 Fuel Rod Pos.1	
231		31	A17 Fuel Rod Pos.1		281		81		4
232		32		4	282		82	A53 Fuel Rod Pos.1	
233		33	A22 Fuel Rod Pos.1		283		83		4
234		34		2	284		84	A57 Fuel Rod Pos.1	
235		35		3	285		85		4
236		36		4	286		86	A62 Fuel Rod Pos.1	
237		37		5	287		87		4
238		38		6	288		88	A66 Fuel Rod Pos.1	
239		39		7	289		89		4
240		40	A24 Fuel Rod Pos.1		290		90	A68 Fuel Rod Pos.1	
241		41		2	291		91		4
242		42		3	292		92	A71 Fuel Rod Pos.1	
243		43		4	293		93		4
244		44		5	294		94	A73 Fuel Rod Pos.1	
245		45		6	295		95		4
246		46		7	296		96	A75 Fuel Rod Pos.1	
247		47	A26 Fuel Rod Pos.1		297		97		4
248		48		4	298		98	A77 Fuel Rod Pos.1	
249		49	A28 Fuel Rod Pos.1		299		99		2
250		50		4	300		100		3

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CH. 301 ~ CH. 400

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
301	Surface Temp.	TF4-101	A77 Fuel Rod Pos.4	273 ~ 1273 K	351	Surface Temp.	TF4-151	B77 Fuel Rod Pos.2	273 ~ 1273 K
302		102		5	352		152		3
303		103		6	353		153		4
304		104		7	354		154		5
305		105	A82 Fuel Rod Pos.1		355		155		6
306		106		4	356		156		7
307		107	A84 Fuel Rod Pos.1		357		157	B86 Fuel Rod Pos.4	
308		108		4	358		158	C11 Fuel Rod Pos.1	
309		109	A85 Fuel Rod Pos.1		359		159		2
310		110		2	360		160		3
311		111		3	361		161		4
312		112		4	362		162		5
313		113		5	363		163		6
314		114		6	364		164		7
315		115		7	365		165	C13 Fuel Rod Pos.1	
316		116	A87 Fuel Rod Pos.1		366		166		2
317		117		2	367		167		3
318		118		3	368		168		4
319		119		4	369		169		5
320		120		5	370		170		6
321		121		6	371		171		7
322		122		7	372		172	C15 Fuel Rod Pos.4	
323		123	A88 Fuel Rod Pos.1		373		173	C22 Fuel Rod Pos.1	
324		124		2	374		174		2
325		125		3	375		175		5
326		126		4	376		176		4
327		127		5	377		177		5
328		128		6	378		178		6
329		129		7	379		179		7
330		130	B11 Fuel Rod Pos.1		380		180	C31 Fuel Rod Pos.4	
331		131		2	381		181	C33 Fuel Rod Pos.1	
332		132		3	382		182		2
333		133		4	383		183		3
334		134		5	384		184		4
335		135		6	385		185		5
336		136		7	386		186		6
337		137	B13 Fuel Rod Pos.4		387		187		7
338		138	B22 Fuel Rod Pos.1		388		188	C35 Fuel Rod Pos.4	
339		139		2	389		189	C66 Fuel Rod Pos.4	
340		140		3	390		190	C68 Fuel Rod Pos.4	
341		141		4	391		191	C77 Fuel Rod Pos.1	
342		142		5	392		192		2
343		143		6	393		193		3
344		144		7	394		194		4
345		145	B31 Fuel Rod Pos.4		395		195		5
346		146	B33 Fuel Rod Pos.4		396		196		6
347		147	B51 Fuel Rod Pos.4		397		197		7
348		148	B53 Fuel Rod Pos.4		398		198	D11 Fuel Rod Pos.4	
349		149	B66 Fuel Rod Pos.4		399		199	D13 Fuel Rod Pos.4	
350		150	B77 Fuel Rod Pos.1		400		200	D22 Fuel Rod Pos.1	

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CH. 401 ~ CH. 500

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
401	Surface Temp.	TF4-201 202	D22 Fuel Rod Pos.2 3	273 ~ 1273 K	451	Fluid Temp.	TC-10 11	Ch. Box Outlet C-1 C-2	273 ~ 1273 K
402		203	4		452		12	C-3	
403		204	5		453		13	C-4	
404		205	6		454		14	C-6	
405		206	7		455		TG- 1	Upper Tieplate A UP.1	
406		207	D31 Fuel Rod Pos.4		456		2		2
408		208	D33 Fuel Rod Pos.4		457		3		3
409		209	D51 Fuel Rod Pos.4		458		4		4
410		210	D53 Fuel Rod Pos.4		459		5		5
411		211	D66 Fuel Rod Pos.4		460		6		6
412		212	D77 Fuel Rod Pos.4		461		7		7
413		213	D86 Fuel Rod Pos.4		462		8		8
414	Fluid Temp.	TW- 1 2	A45 Tie Rod Pos.1 2	273 ~ 773 K	463		9		9
415		3	3		464		10		10
416		4	4		465		11	Upper Tieplate A Low.1	
417		5	5		466		12		2
418		6	6		467		13		3
419		7	7		468		14		4
420		8	B45 Tie Rod Pos.1		469		15		5
421		9	2		470		16		6
422		10	3		471		17		7
423		11	4		472		18		8
424		12	5		473		19		9
425		13	6		474		20		10
426		14	7		475		21	Upper Tieplate C Up.1	
427		15	C45 Tie Rod Pos.1		476		22		2
428		16	2		477		23		3
429		17	3		478		24		4
430		18	4		479		25		5
431		19	5		480		26		6
432		20	6		481		27		7
433		21	7		482		28		8
434		22	D45 Tie Rod Pos.1		483		29		9
435		23	2		484		30		10
436		24	3		485		31	Upper Tieplate C Low.1	
437		25	4		486		32		2
438		26	5		487		33		3
439		27	6		488		34		4
440		28	7		489		35		5
441		TC- 1	Channel Box A Inlet		490		36		6
442		2	B Inlet		491		37		7
443		3	C Inlet		492		38		8
444		4	D Inlet		493		39		9
445		5	Ch. Box Outlet A-1		494		40		10
446		6	A-2		495		2		2
447		7	A-3		496	Surface Temp.	2		
448		8	A-4		497	TB- 1	3		
449		9	A-6		498		4		
450					499		5		
					500				

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CH. 501 ~ CH. 600

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
501	Surface Temp.	TB- 6 7	C.B.A1 Inner, Pos.6 7	273 ~ 773 K	551	Surface Temp.	TP- 7 8	Lower Pl. North 1 2	273 ~ 773 K
502			C.B.A2 Inner, Pos.1		552				
503		8			553		9		4
504		9		2	554		10		6
505		10		3	555		11	Lower Pl. South 1	
506		11		4	556		12		2
507		12		5	557		13		4
508		13		6	558		14		6
509		14		7	559	Liquid Level	LB- 1 2	C.B. Liquid Level A1-1	ON-OFF
510		15	C.B.B Inner, Pos.1		560				2
511		16		2	561		3		3
512		17		3	562		4		4
513		18		4	563		5		5
514		19		5	564		6		6
515		20		6	565		7		7
516		21		7	566		8	C.B. Liquid Level A2-1	
517		22	C.B.C Inner, Pos.1		567		9		2
518		23		2	568		10		3
519		24		3	569		11		4
520		25		4	570		12		5
521		26		5	571		13		6
522		27		6	572		14		7
523		28		7	573		15	C.B. Liquid Level B-1	
524		29	C.B.D Inner, Pos.1		574		16		2
525		30		2	575		17		3
526		31		3	576		18		4
527		32		4	577		19		5
528		33		5	578		20		6
529		34		6	579		21		7
530		35		7	580		22	C.B. Liquid Level C-1	
531	Fluid Temp.	TB-36 37	C.B.A Outer, Pos.1 2		581		23		2
532					582		24		3
533		38		3	583		25		4
534		39		4	584		26		5
535		40		5	585		27		6
536		41		6	586		28		7
537		42		7	587		29	C.B. Liquid Level D-1	
538		43	C.B.C Outer, Pos.1		588		30		2
539		44		2	589		31		3
540		45		3	590		32		4
541		46		4	591		33		5
542		47		5	592		34		6
543		48		6	593		35		7
544		49		7	594	LL- 1	Ch.Box Outlet A1-5		
545		TP- 1	Lower Pl. Center. 1		595		2		6
546		2		2	596		3		7
547		3		3	597		4	Ch.Box Outlet A2-5	
548		4		4	598		5		6
549		5		5	599		6		7
550		6		7	600		7	Ch.Box Outlet A-1	

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CH. 601 ~ CH. 700

CH. NO.	Item	Symbol	Location	Range	CH. NO.	Item	Symbol	Location	Range
601	Liquid Level	LL- 8	Ch.Box Outlet A-2	ON-OFF	651	Liquid Level	L- 9	Downcomer B4	ON-OFF
602		9	3		652		10	B5	
603		10	4		653	Void	VF- 1	A54 Tie Rod Pos.1	0 ~ 1
604		11	6		654		2	2	
605		12	Ch.Box Outlet C1-5		655		3	3	
606		13	6		656		4	4	
607		14	7		657		5	5	
608		15	Ch.Box Outelt C2-5		658		6	6	
609		16	6		659		7	7	
610		17	7		660		8	B54 Tie Rod Pos.1	
611		18	Ch.Box Outlet C-1		661		9	2	
612		19	2		662		10	3	
613		20	3		663		11	4	
614		21	4		664		12	5	
615		22	6		665		13	6	
616		23	Ch.Box Inlet A-1		666		14	7	
617		24	2		667		15	C54 Tie Rod Pos.1	
618		25	Ch.Box Inlet B-1		668		16	2	
619		26	2		669		17	3	
620		27	Ch.Box Inlet C-1		670		18	4	
621		28	2		671		19	5	
622		29	Ch.Box Inlet D-1		672		20	6	
623		30	2		673		21	7	
624		31	Lower Pl.North 1		674		22	D54 Tie Rod Pos.1	
625		32	2		675		23	2	
626		33	3		676		24	3	
627		34	4		677		25	4	
628		35	5		678		26	5	
629		36	6		679		27	6	
630		37	Lower Pl.South 1		680		28	7	
631		38	2		681	VE- 1	Ch.Box Outlet A-1		
632		39	3		682		2	2	
633		40	4		683		3	3	
634		41	5		684		4	Ch.Box Outlet B-1	
635		42	6		685		5	2	
636		43	Guide Tube North -0		686		6	3	
637		44	1		687		7	Ch.Box Outlet C-1	
638		45	3		688		8	2	
639		46	6		689		9	3	
640		47	Guide Tube South -0		690		10	Ch.Box Outlet D-1	
641		48	1		691		11	2	
642		49	3		692		12	3	
643		50	6		693		13	Lower Pl. Bottom 1	
644	L- 1	Downcomer D1			694		14	2	
645	2	D2			695		15	3	
646	3	D3			696	VP-1	Lower Pl. Inlet 1		
647	4	D4			697	VP-2		2	
648	5	D5			698				
649	7	Downcomer B2			699				
650	8	B3			700				

Table 3.2 Core Instrumentation List

Item	Pos. Rod NO.	Pos.1	Pos.2	Pos.3	Pos.4	Pos.5	Pos.6	Pos.7	Core Inlet
		DL							
	3417	3114.5	2879.5	2527	2174.5	1939.5	1637	1479	
Surface Temp.	A11	TF 1	TF 2	TF 3	TF 4	TF 5	TF 6	TF 7	
	A12	TF 8	TF 9	TF 10	TF 11	TF 12	TF 13	TF 14	
	A13	TF 15	TF 16	TF 17	TF 18	TF 19	TF 20	TF 21	
	A14	TF 22	TF 23	TF 24	TF 25	TF 26	TF 27	TF 28	
	A15	TF 29			TF 30				
	A17	TF 31			TF 32				
	A22	TF 33	TF 34	TF 35	TF 36	TF 37	TF 38	TF 39	
	A24	TF 40	TF 41	TF 42	TF 43	TF 44	TF 45	TF 46	
	A26	TF 47			TF 48				
	A28	TF 49			TF 50				
	A31	TF 51			TF 52				
	A33	TF 53	TF 54	TF 55	TF 56	TF 57	TF 58	TF 59	
	A34	TF 60	TF 61	TF 62	TF 63	TF 64	TF 65	TF 66	
	A37	TF 67			TF 68				
	A42	TF 69			TF 70				
	A44	TF 71	TF 72	TF 73	TF 74	TF 75	TF 76	TF 77	
	A48	TF 78			TF 79				
	A51	TF 80			TF 81				
	A53	TF 82			TF 83				
	A57	TF 84			TF 85				
	A62	TF 86			TF 87				
	A66	TF 88			TF 89				
	A68	TF 90			TF 91				
	A71	TF 92			TF 93				
	A73	TF 94			TF 95				
	A75	TF 96			TF 97				
	A77	TF 98	TF 99	TF100	TF101	TF102	TF103	TF104	
	A82	TF105			TF106				
	A84	TF107			TF108				
	A85	TF109	TF110	TF111	TF112	TF113	TF114	TF115	
	A87	TF116	TF117	TF118	TF119	TF120	TF121	TF122	
	A88	TF123	TF124	TF125	TF126	TF127	TF128	TF129	

Table 3.2 (Continued)

Item	Pos. Rod NO.	Pos.1	Pos.2	Pos.3	Pos.4	Pos.5	Pos.6	Pos.7	Core Inlet
		3417	3114.5	2879.5	2527	2174.5	1939.5	1637	1479
Surface Temp.	B11	TF130	TF131	TF132	TF133	TF134	TF135	TF136	
	B13				TF137				
	B22	TF138	TF139	TF140	TF141	TF142	TF143	TF144	
	B31				TF145				
	B33				TF146				
	B51				TF147				
	B53				TF148				
	B66				TF149				
	B77	TF150	TF151	TF152	TF153	TF154	TF155	TF156	
	B86				TF157				
	C11	TF158	TF159	TF160	TF161	TF162	TF163	TF164	
	C13	TF165	TF166	TF167	TF168	TF169	TF170	TF171	
	C15				TF172				
	C22	TF173	TF174	TF175	TF176	TF177	TF178	TF179	
	C31				TF180				
	C33	TF181	TF182	TF183	TF184	TF185	TF186	TF187	
	C35				TF188				
	C66				TF189				
	C68				TF190				
	C77	TF191	TF192	TF193	TF194	TF195	TF196	TF197	
	D11				TF198				
	D13				TF199				
	D22	TF200	TF201	TF202	TF203	TF204	TF205	TF206	
	D31				TF207				
	D33				TF208				
	D51				TF209				
	D53				TF210				
	D66				TF211				
	D77				TF212				
	D86				TF213				

Table 3.2 (Continued)

Item	Pos. Rod No.	Pos.1	Pos.2	Pos.3	Pos.4	Pos.5	Pos.6	Pos.7	Core Inlet
		DL							
In-Core Fluid Temp.	A45	TW 1	TW 2	TW 3	TW 4	TW 5	TW 6	TW 7	TC 1
	B45	TW 8	TW 9	TW 10	TW 11	TW 12	TW 13	TW 14	TC 2
	C45	TW 15	TW 16	TW 17	TW 18	TW 19	TW 20	TW 21	TC 3
	D45	TW 22	TW 23	TW 24	TW 25	TW 26	TW 27	TW 28	TC 4
In-Core Void	A54	VF 1	VF 2	VF 3	VF 4	VF 5	VF 6	VF 7	
	B54	VF 8	VF 9	VF 10	VF 11	VF 12	VF 13	VF 14	
	C54	VF 15	VF 16	VF 17	VF 18	VF 19	VF 20	VF 21	
	D54	VF 22	VF 23	VF 24	VF 25	VF 26	VF 27	VF 28	
Channel Box Inner Surface Temp.	A1*	TB 1	TB 2	TB 3	TB 4	TB 5	TB 6	TB 7	
	A2*	TB 8	TB 9	TB 10	TB 11	TB 12	TB 13	TB 14	
	B*	TB 15	TB 16	TB 17	TB 18	TB 19	TB 20	TB 21	
	C*	TB 22	TB 23	TB 24	TB 25	TB 26	TB 27	TB 28	
	D*	TB 29	TB 30	TB 31	TB 32	TB 33	TB 34	TB 35	
Bypass Fluid Temp.	E*	TB 36	TB 37	TB 38	TB 39	TB 40	TB 41	TB 42	
	F*	TB 43	TB 44	TB 45	TB 46	TB 47	TB 48	TB 49	
Channel Liquid Level	A1*	LB 1	LB 2	LB 3	LB 4	LB 5	LB 6	LB 7	
	A2*	LB 8	LB 9	LB 10	LB 11	LB 12	LB 13	LB 14	
	B*	LB 15	LB 16	LB 17	LB 18	LB 19	LB 20	LB 21	
	C*	LB 22	LB 23	LB 24	LB 25	LB 26	LB 27	LB 28	
	D*	LB 29	LB 30	LB 31	LB 32	LB 33	LB 34	LB 35	

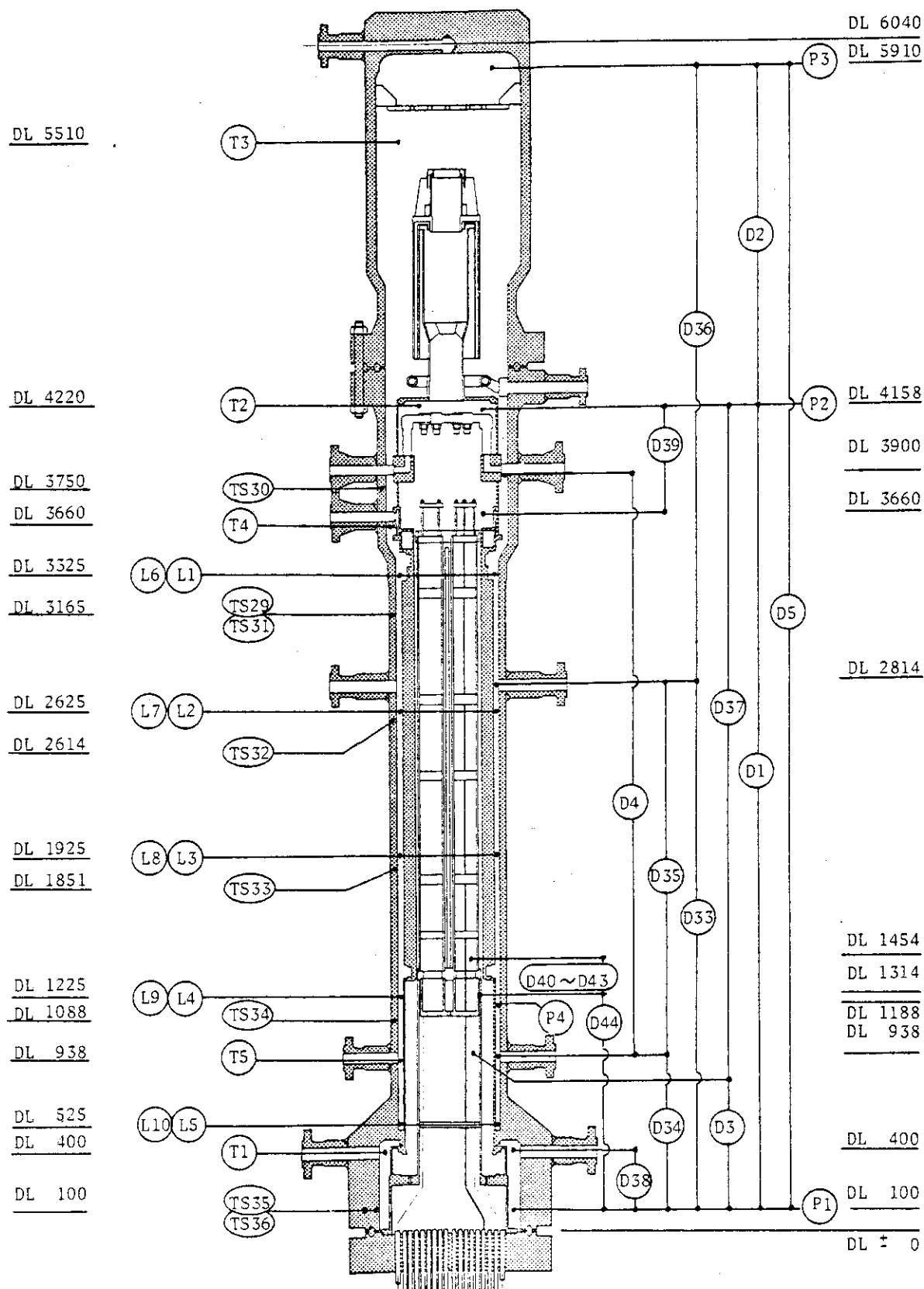


Fig. 3.1 Instrumentation in the Pressure Vessel

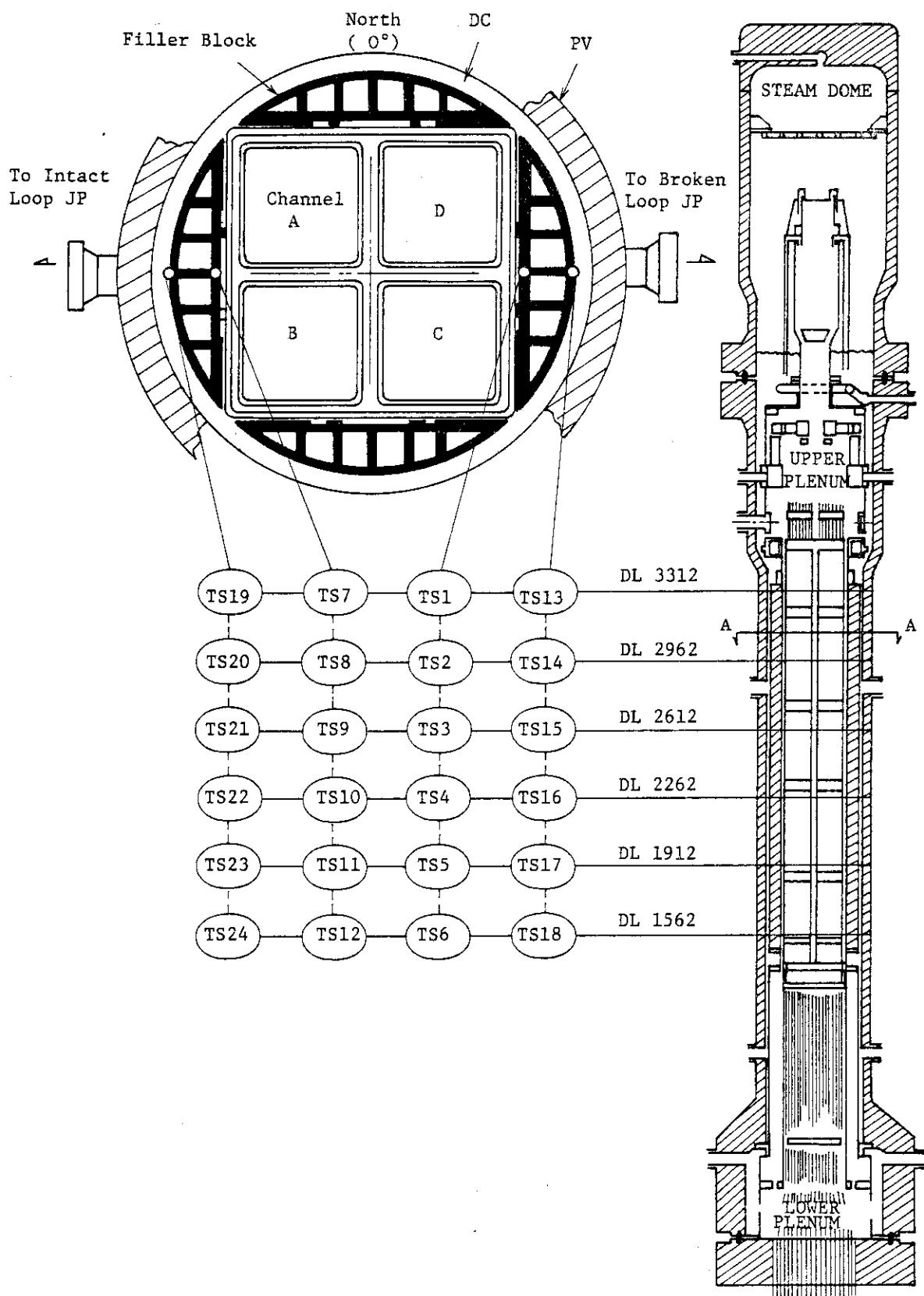


Fig. 3.2 Location of Thermocouples in Filler Block

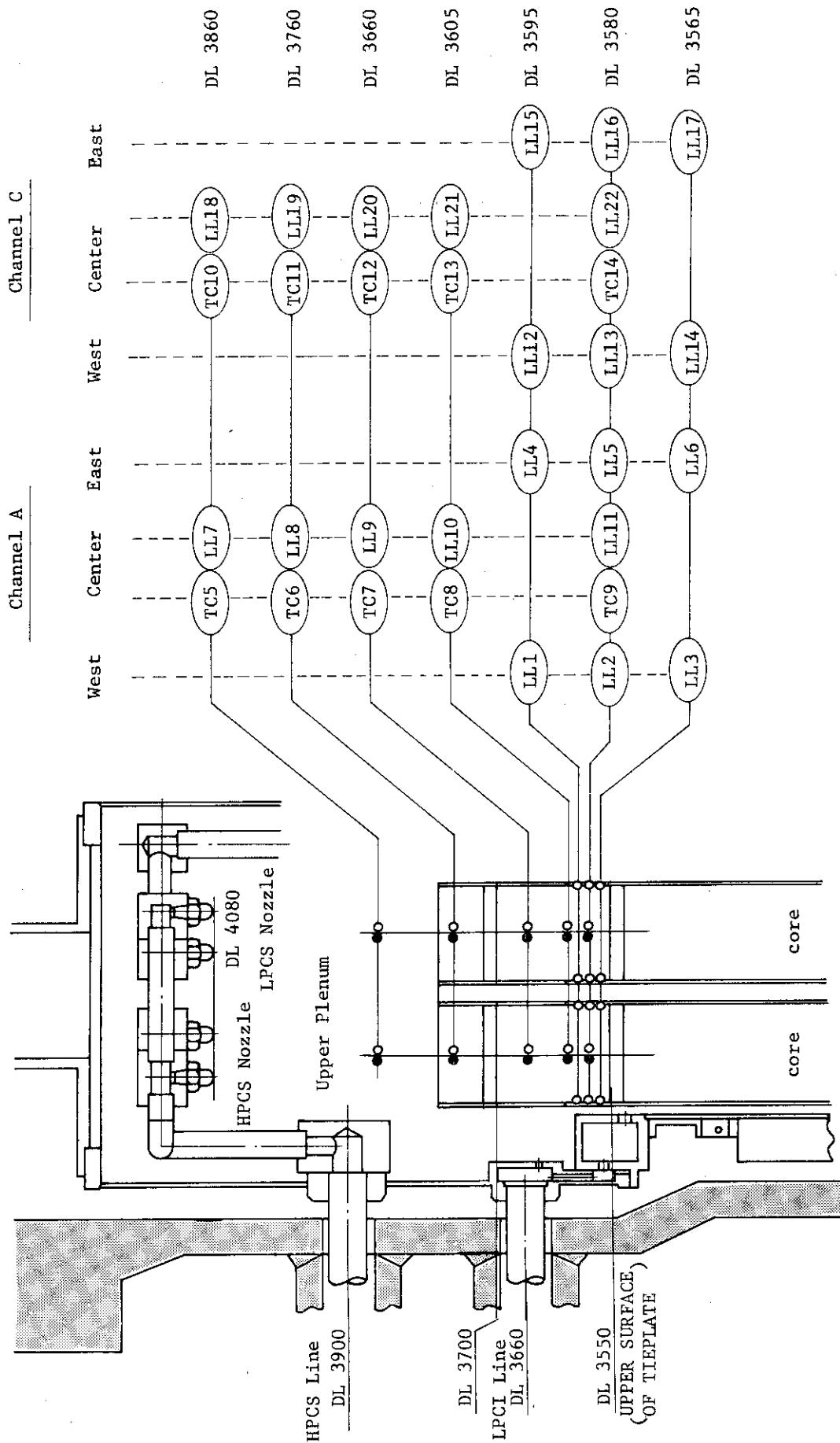


Fig. 3.3 Upper Plenum Instrumentation

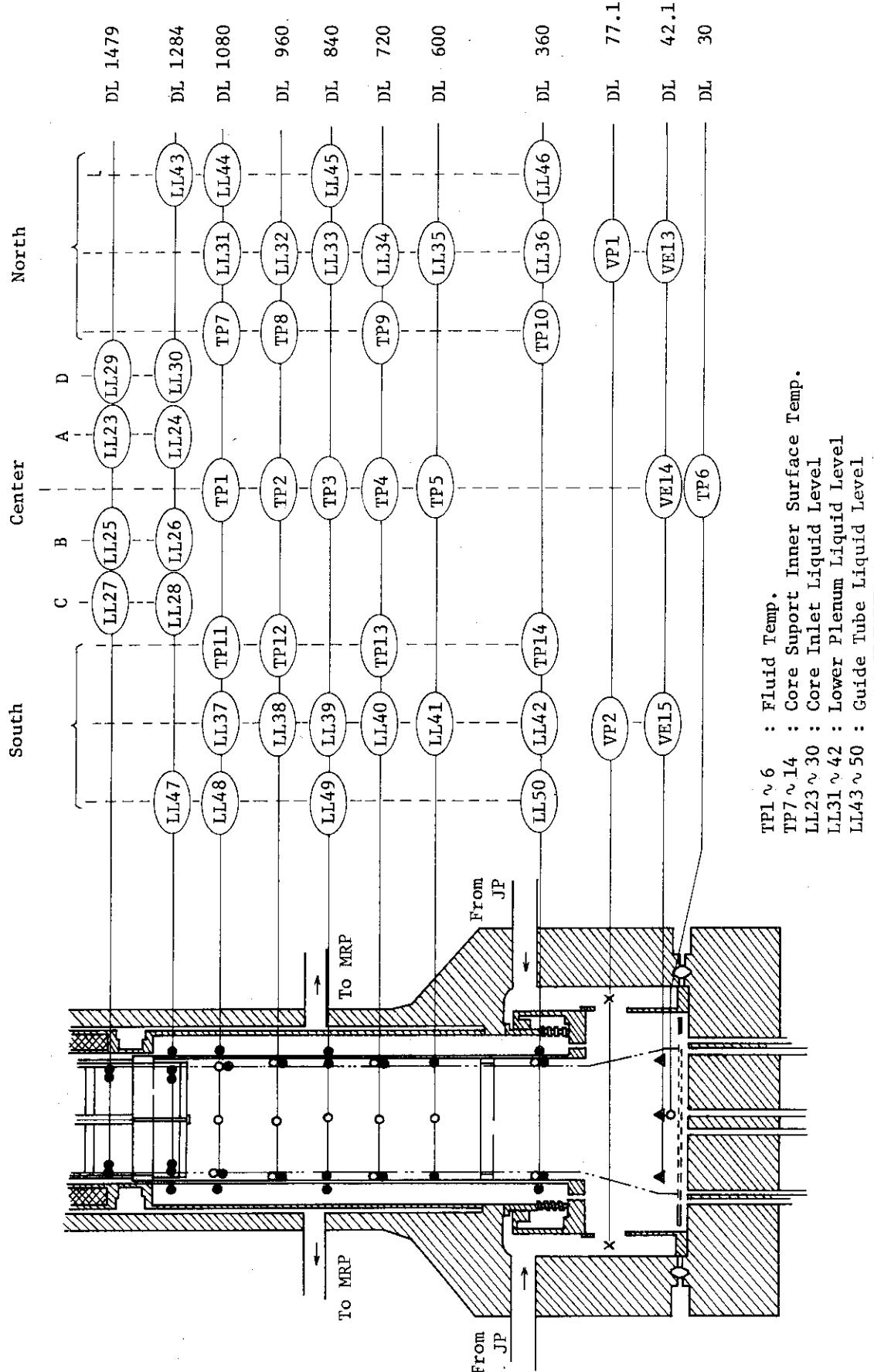


Fig. 3.4 Lower Plenum Instrumentations

TP1 ~ 6 : Fluid Temp.
 TP7 ~ 14 : Core Support Inner Surface Temp.
 LL23 ~ 30 : Core Inlet Liquid Level
 LL31 ~ 42 : Lower Plenum Liquid Level
 LL43 ~ 50 : Guide Tube Liquid Level

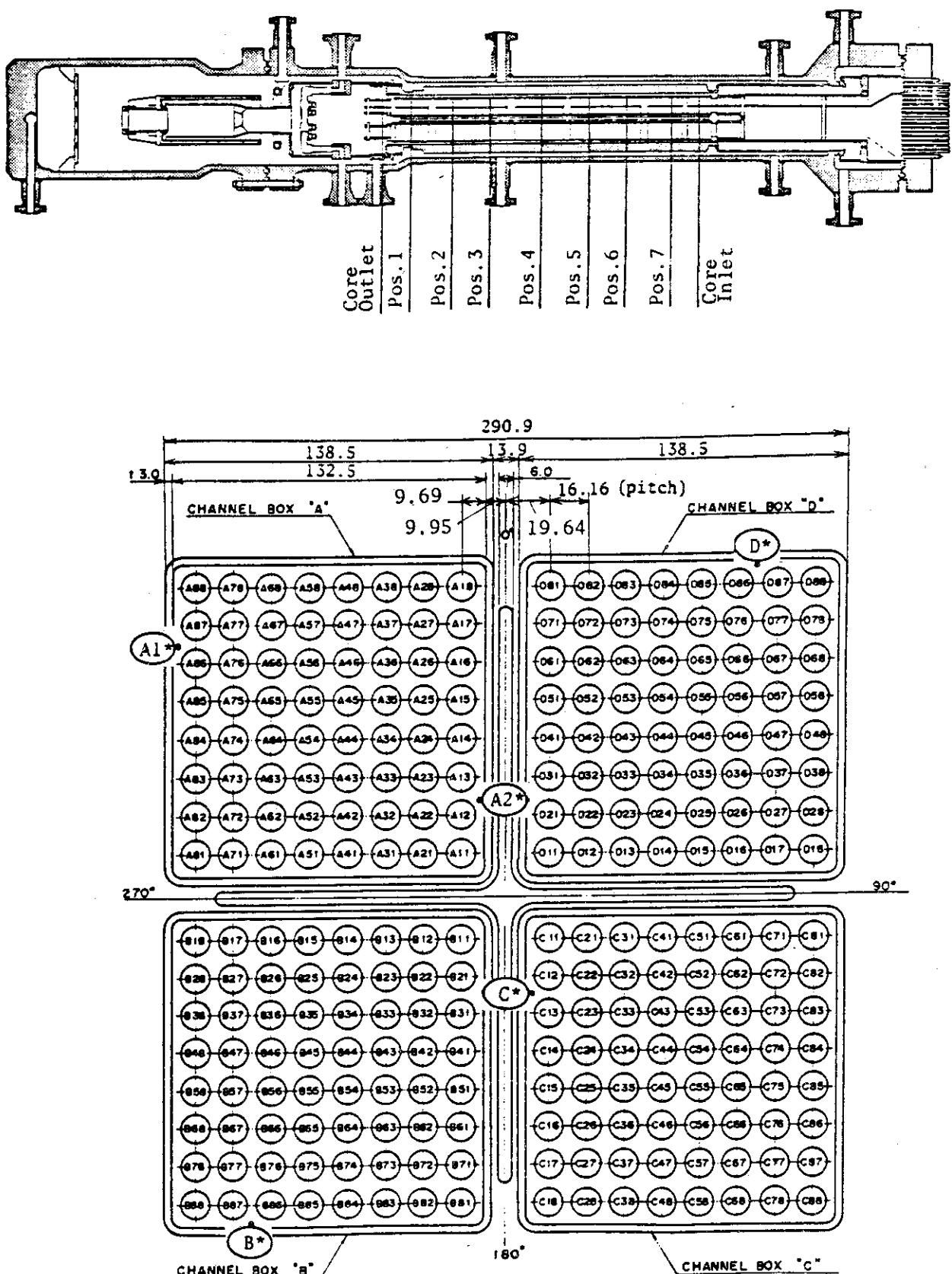


Fig.3.5 Heater rod O.D. is 12.27mm

A54, B54, C54 and D54 are water rod simulators with void probes,
O.D. = 15.01mm

A45, B45, C45 and D45 are water rod simulators with thermocouples,
O.D. = 15.01mm

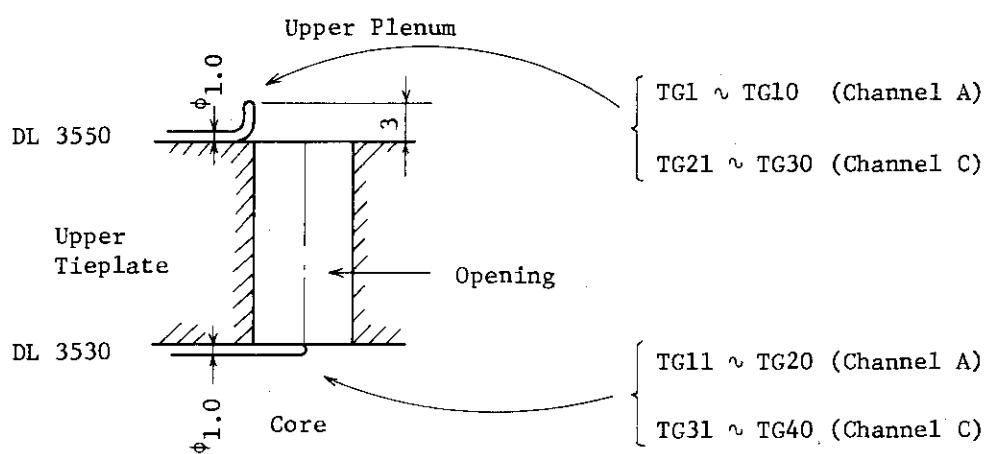
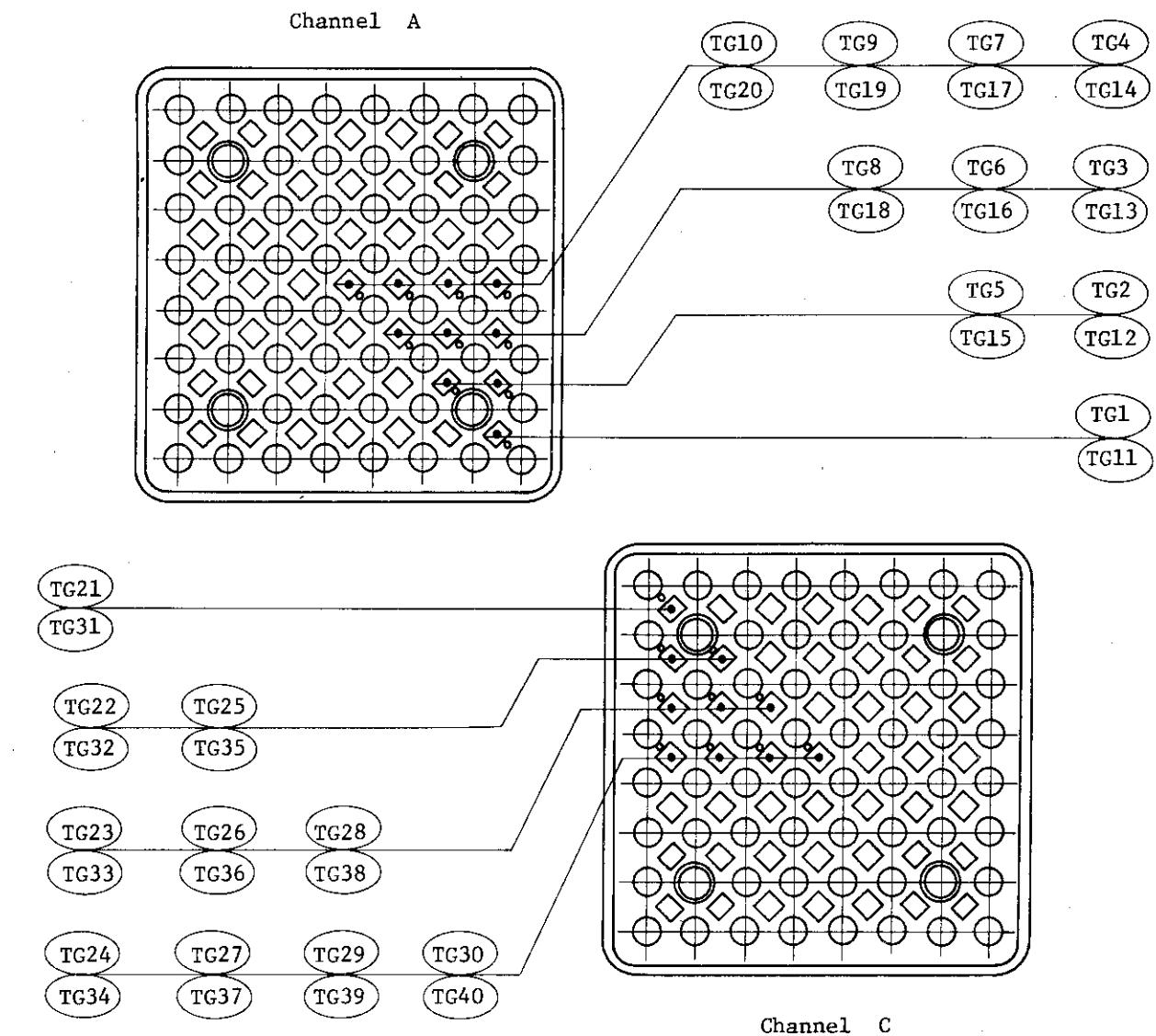


Fig. 3.6 Upper Tie Plate Instrumentations

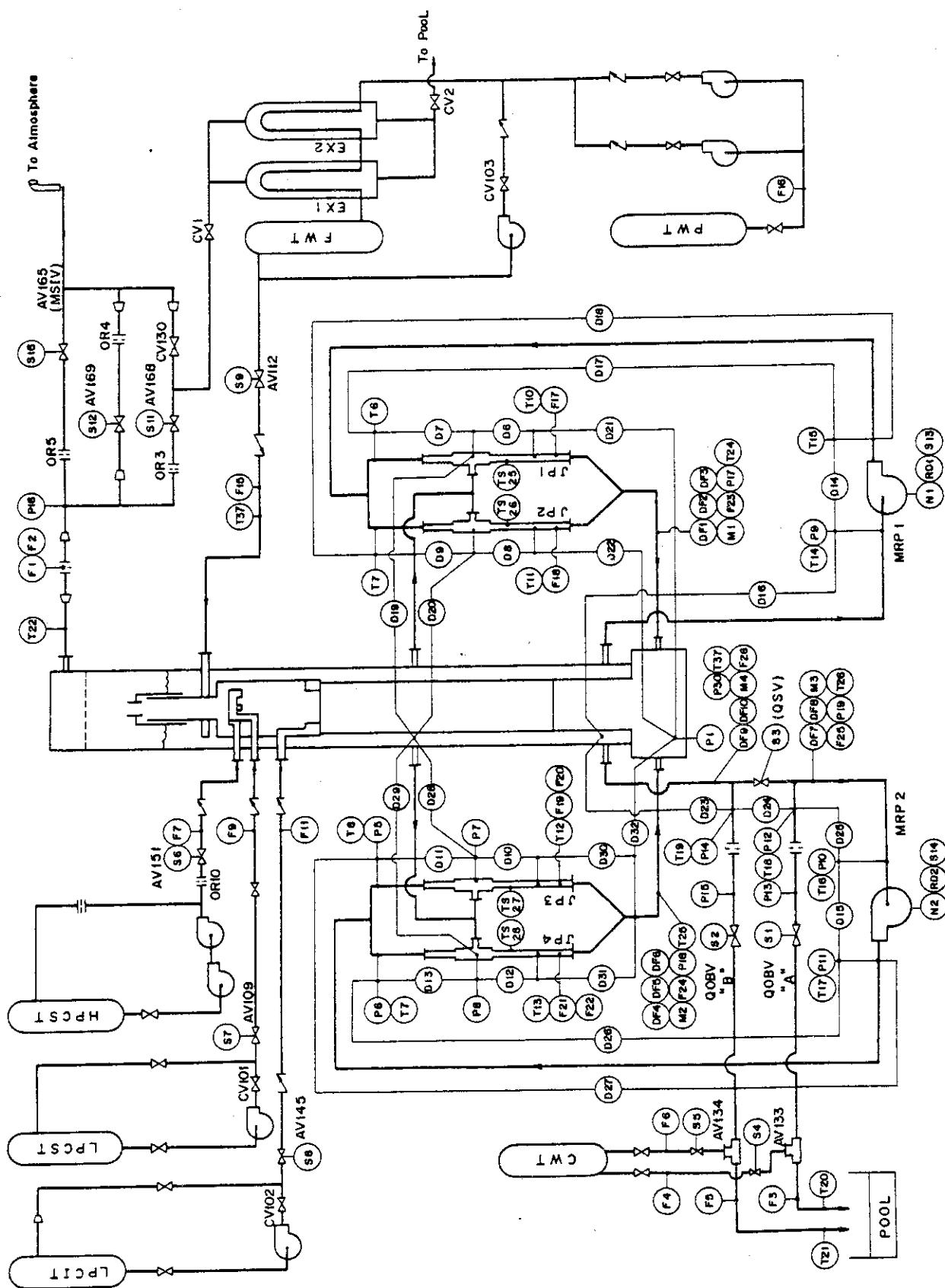


Fig. 3.7 Instrumentations of Recirculation Loops

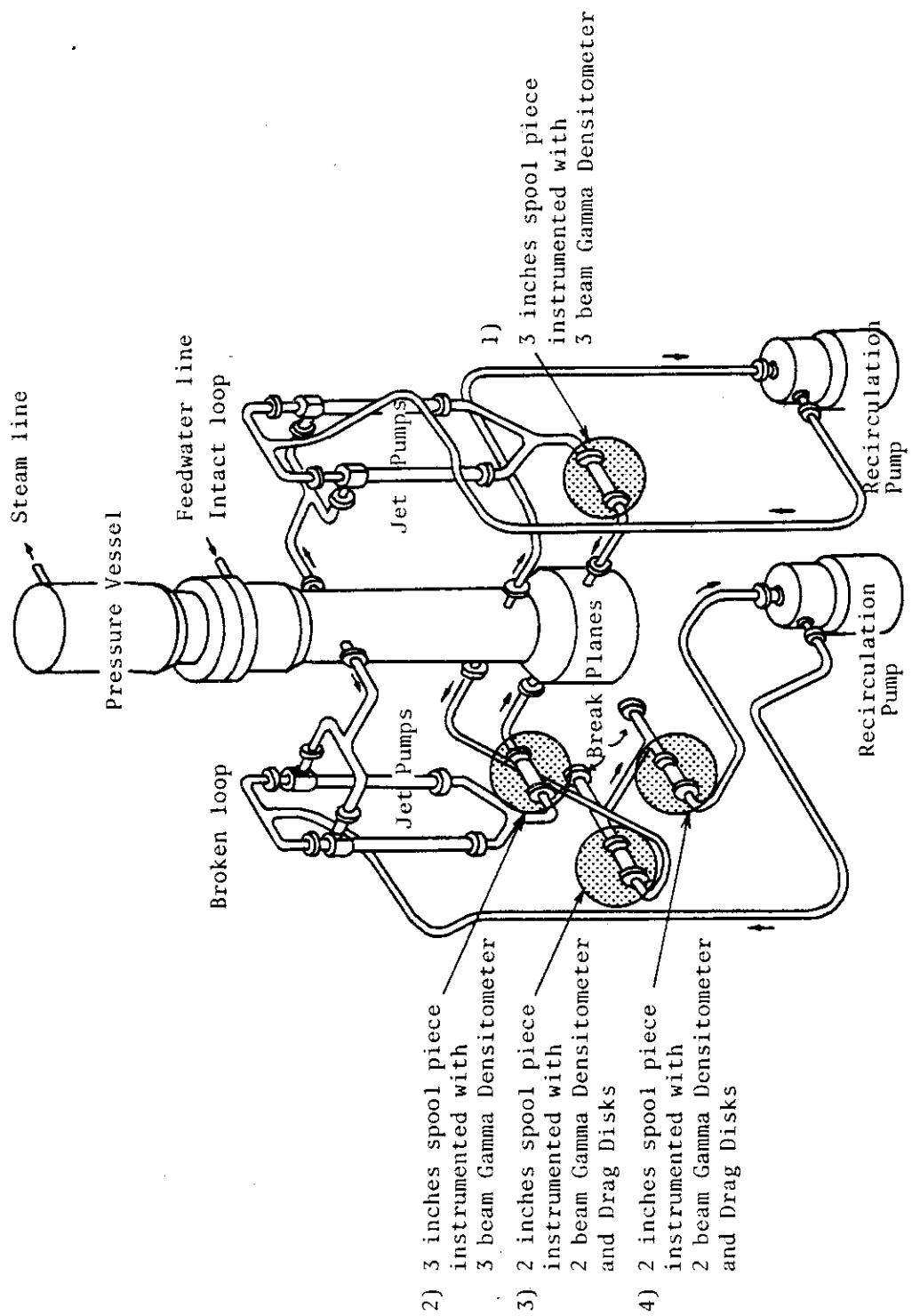


Fig. 3.8 Location of Two-phase Flow Measurement Spool Pieces