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DESIGN OF SLAB CORE TEST FACILITY (SCTF) IN LARGE SCALE REFLOOD TEST PROGRAM, PART I: CORE-1

June 1983

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This report describes the design principle and the detailed features of the Slab Core Test Facility (SCTF) which is used to investigate the two-dimensional, thermohydraulic behavior in the reactor pressure vessel during the last part of blowdown, refill and reflood phases of a postulated loss-of-coolant accident for pressurized water reactor. The SCTF test program is one of the research activities based on the agreement on so called the 2D/3D test program among Japan Atomic Energy Research Institute, Bundesminister für Forschung und Technologie and United Stated Nuclear Regulatory Commission. Not only for good understanding of the SCTF test results but also for further analytical work, information of instruments, identification of the measurements and the description of the test procedure are introduced as well as the description of hardware of the facility.

Keywords: Safety, PWR, LOCA, Blowdown, Refill, Reflood, Core Cooling, SCTF, Thermo-Hydrodynamics

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The work was performed under contract with the Atomic Energy Bureau of Science and Technology Agency of Japan.

+ Department of Large Tokamak Development

大型再冠水平板炉心試験装置（SCTF）の設計
第Ⅰ部：第一次模擬炉心

日本原子力研究所東海研究所安全工学部

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（1983年5月11日受理）

本報告書は，平板炉心試験装置の設計指針および詳細を述べたものである。平板炉心試験計画は，加圧水型原子炉で想定される冷却材喪失事故時のブローダウン末期からリフィルおよび再冠水過程における二次元炉心熱水力挙動を明らかにしようとするものである。

平板炉心試験計画は，日本原子力研究所，ドイツ連邦共和国連邦研究技術省，米国原子力規制委員会の3国間協定，いわゆる2D/3D試験計画の研究事業の1つである。

本報告書には，平板炉心試験結果を十分理解し，解析作業の手助けになるよう，試験装置各部の詳細説明とともに，計測器に関する情報，計測チャンネルの識別法，試験手順についても述べている。

本報告書は，電源開発促進対策特別会計法に基づき，科学技術庁からの受託によって行った研究の成果である。

＋　東海研究所大型トカマク開発部

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1. Introduction

1.1 Background

Slab Core Test Facility (SCTF) Test Program is a part of Large Scale Reflood Test Program(1) of Japan Atomic Energy Research Institute (JAERI), together with Cylindrical Core Test Facility (CCTF) Test Program.

In the CCTF test program, primary concern is overall simulation of thermo-hydrodynamic system behavior during the last part of blowdown, refill and reflood phases of a postulated large break loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR). On the other hand, in the SCTF test program, major objectives are to clarify:

(1) two-dimensional core thermo-hydrodynamics,

(2) interaction in fluid behavior between core and upper plenum, and

(3) hot leg carryover characteristics.

The SCTF test program is one of the research activities based on "the Agreement on Research Participation and Technical Exchange among the Federal Minister for Research and Technology (BMFT) of the Federal Republic of Germany (FRG), the United States Nuclear Regulatory Commission (USNRC) and JAERI in a Coordinated Analytical and Experimental Study of the Thermohydraulic Behavior of Emergency Core Coolant (ECC) during the Refill and Reflood Phases of a LOCA in a PWR (the 2D/3D Agreement)". Responsibilities of each party based on the 2D/3D agreement are shown in Fig.1-1. JAERI performs the CCTF and SCTF test programs. The FRG performs a full scale upper plenum simulation test called the Upper Plenum Test Facility (UPTF) Test Program. The USNRC provides advanced two-phase instrumentation for these test programs and, in addition, it supports the experimental works analytically by using the three-dimensional LOCA analysis code, TRAC. Coupling tests between the SCTF and UPTF are planned in the later period of the SCTF test program.

1.2 Objectives of the SCTF Test Program

The three major research items of the SCTF test program introduced in the previous section can be broken down as follows.

—— Two-dimensional core thermo-hydrodynamics called chimney effect which is induced by radial core heating power distribution.

——— Fall-back water induced core thermo-hydrodynamic behavior called sputtering effect which is caused by violent steam generation occurred locally or in a wide space due to touching of the fall-back water with the high temperature heater rods.

——— Two-dimensional core thermo-hydrodynamics caused by local steam condensation which is induced by subcooled water fall-back.

——— Local enhancement or interference with core cooling called blockage effect which is caused by ballooning of the clads of fuel rods.

——— Water carryover out of core which is a function of droplet generation around the quench front and droplet capture at the downstream of quench front.

——— Water fall back from upper plenum which is a function of collapsed water level above the upper core support plate (UCSP) and steam and water flow rates out of the core. And it is considered to be strongly affected by the geometory of the interfacial structures between the core and the upper plenum (UCSP, end box tie plates, control rod spiders, etc.).

——— Droplet generation above UCSP which is induced by steam penetration through the water pool on the UCSP.

——— Droplet capture, i.e., de-entrainment on upper plenum structures (control rod guide tubes, support columns, etc.).

——— Steam-water separation in hot leg pipe and steam generator inlet plenum and water reverse flow in the hot leg pipe.

——— Other important phenomena related to core thermo-hydrodynamics which are occurred mainly in and around reactor pressure vessel, such as condensation induced oscillation and U-tube oscillation between core and downcomer.

These various phenomena are investigated in the SCTF test program both experimentally and analytically for the last part of blowdown, refill and reflood phases of PWR LOCA.

In order to meet these objectives, the SCTF is designed and fabricated to simulate the radial slab extracted from the 1,100 MWe class PWR core with a full height, full radius and one bundle width as shown in Fig.1-2. The simulated core consists of eight electrically heated rod bundles with 16×16 rod array which are arranged in a row. The nominal volume scaling ratio is 1/21, the maximum available core heating power is about 10 MW and the achievable system pressure is about 0.6 MPa.

In the SCTF test program, three simulated cores are planned to provide. The Core-I existing is for simulating the partly blocked core of a Westinghouse type PWR in which all the heater rods in the two rod bundles out of the eight have blockage sleeves. The Core-II under fabrication simulates the unblocked normal core of the Westinghouse type PWR. Simulation tests for a B&W type PWR with vent valves are also planned to perform with the Core-II under proper compromises. The Core-III is planned to simulate a KWU type PWR of the FRG. Simulation tests for the Westinghouse type PWR will also be performed with the Core-III under proper compromises.

In accordance with the 2D/3D Agreement, the USNRC provides various kinds of advanced type two-phase flow instruments for the SCTF tests; the liquid level detectors (LLDs), fluid distribution grids (FDGs), drag disks, turbine flow meters, γ-densitometers, spool pieces, flag probes, prong probes, film probes, string probes, reference probe and video optical probes. These advanced two-phase flow measurements are utilized not only for detailed analysis of thermo-hydrodynamic behavior in the SCTF tests but also for the coupling tests between the UPTF and the SCTF. In the tests, interfacial two-phase flow conditions between the core and the upper plenum are intended to be the same between the UPTF tests and the corresponding SCTF tests. The interfacial conditions are measured and evaluated by the use of the advanced two-phase flow measurements.

TRAC code analyses performed by the USNRC are expected to be effectively utilized not only for good understanding of the SCTF test data and generalizing the experimental information but also for evaluation and correction of the atypical facility characteristics of the SCTF such as the side wall effect of the core and no heat source effects of the downcomer and the steam-water separator (steam generator simulator). TRAC analyses are performed also for guiding the coupling tests between the UPTF and the SCTF as well as regular non-coupled tests.

1.3 Schedule of the SCTF Test Program

As shown in Fig.1-3, twenty SCTF Core-I tests are planned to perform from 1981 to 1983. Since CCTF is operated with some components shared with SCTF and, in addition, construction works for additional subsystems such as the combined injection system and the steam supply system are done, the available test period is actually very short.

Twenty SCTF Core-II tests and twenty Core-III tests are planned to perform from 1984 to 1985 and from 1986 to 1987, respectively. And this test program will be completed by the end of March, 1988.

1.4 Purposes of the Report

The purposes of this report are;

(1) to give the principal features of the SCTF required from the program objectives,

(2) to give the design criteria and major facility parameters of SCTF, and

(3) to give a description of the whole system, major components, instrumentation and test procedure.

These informations are necessary and very useful for better understanding and effective utilizing of the SCTF test data.

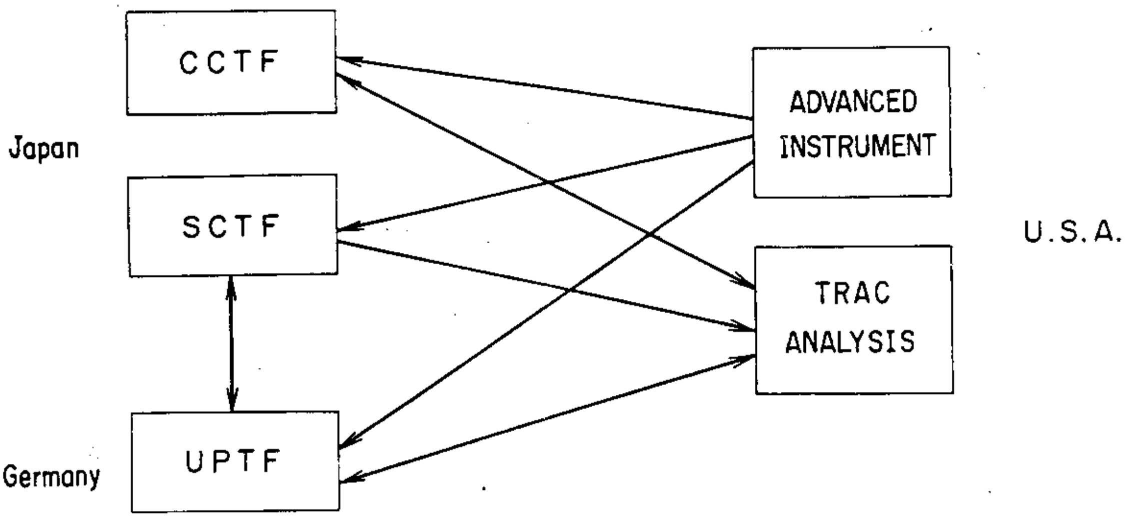


Fig.1-1 Coordinated Refill-Reflood Study among the Three Countries

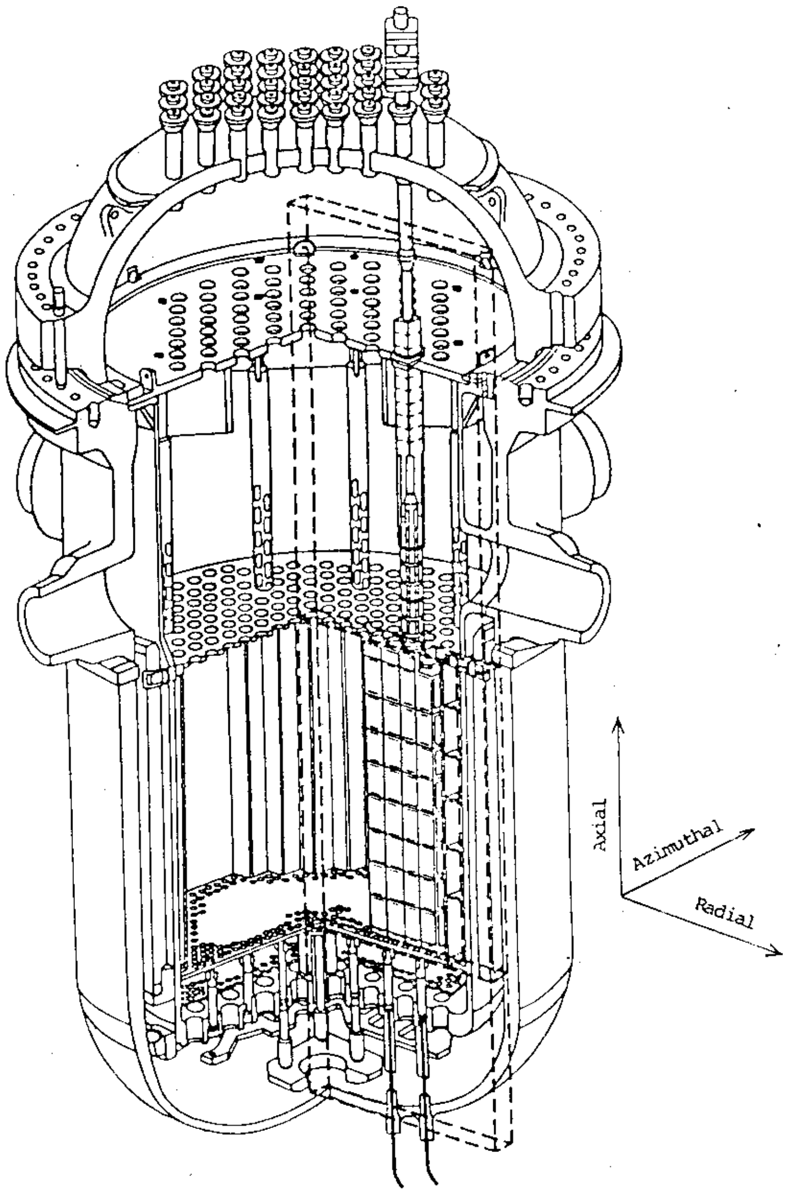


Fig.1-2 Comparison of SCTF and the Reference PWR

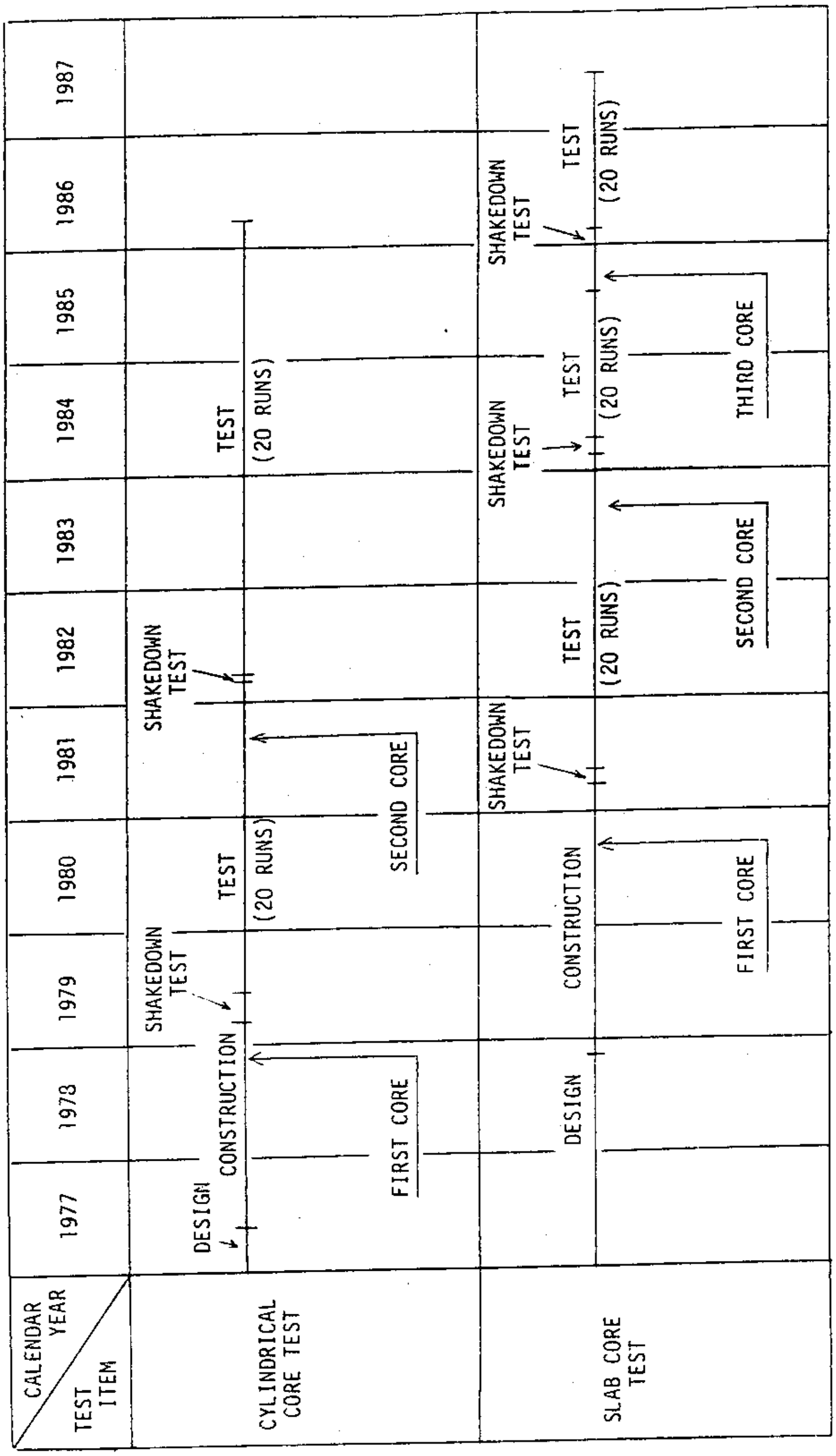


Fig.1-3 Time Schedule of JAERI Large Scale Reflood Test Program

2. Design Philosophy of the SCTF

2.1 Principal Features of the SCTF

Principal features of the SCTF required from the program objectives described in the previous chapter are as follows:

(1) The facility dimension should be at least of the full height, full radius and one fuel bundle width of the pressure vessel of the actual reactor.

(2) Simplified but proper vessel internal structures to simulate the effects on thermo-hydrodynamics in the pressure vessel should be connected to the pressure vessel.

(3) A simplified but proper primary coolant system to simulate the principal characteristics of large break LOCA transient should be attached to the pressure vessel.

(4) Independent controling for each bundle should be available on the bundle power, initial representative rod temperature and interfacial two-phase flow conditions between the core and the upper plenum.

(5) Simulation on the system pressure, bundle powers and other important plant conditions should be available from the time as early as practicable in the last part of blowdown phase of a large break LOCA.

The 1,178 MWe Trojan reactor of the USA was chosen as the reference reactor for the Cores-I and -II. Information on the Oh-i reactor of Japan was also used for the detailed design. Some compromises were made for the B&W reactor simulation tests with the Core-II.
The 1,300 MWe KWU reactor of the FRG was chosen as the reference reactor for the Core-III. Simulation tests for the Westinghouse type PWR will also be performed with the Core-III under some compromises.

In the design of the SCTF, the components and systems in the CCTF are considered to share to the maximum extent.

2.2 Design Criteria and Facility Parameters

The followings are the major design criteria and facility parameters of the SCTF.

(1) The SCTF pressure vessel has a slab geometry with the full height, full radius and one fuel bundle width.

(2) The SCTF pressure vessel is partitioned into the six regions, i.e., the core, core baffle region, upper plenum, upper head, lower plenum and downcomer.

(3) Volume and flow area of each region are reduced from those for the reference reactor based on the nominal core flow area scaling, 1/21.

(4) Height of major parts is maintained equal to the reference reactor.

(5) The SCTF core consists of eight electrically heated simulated fuel bundles arranged in a row with bundle pitch of 230 mm. The bundle 1 corresponds to the center bundle of actual PWR and the bundle 8 the peripheral bundle.

(6) Each rod bundle has 234 heater rods and 22 non-heated rods arranged in a 16 × 16 square arrangement with rod pitch of 14.3 mm.

(7) Design of each rod is based on that for the 15 × 15 Westinghouse type fuel bundle, i.e., diameter and heated length of the heater rods are 10.7 mm O.D. and 3,660 mm, respectively and diameter of the non-heated rods is 13.8 mm O.D..

(8) In the Core-I, the bundles 3 and 4 are so-called the blocked bundles and all the heater rods in these bundles have blockage sleeves with the maximum diameter of 14.2 mm O.D. at the midplane to simulate co-planer ballooning of fuel rods.

(9) Independent bundle power control is available. The total maximum core heating power is about 10 MW.

(10) Cross sections of the upper plenum structures and UCSP are half size (quarter cross sectional area) so as to get as correct the number ratio of each type of structure to the total as possible.

(11) Proper simulations are made for the local but important components such as the top grid spacers, end boxes with tie plates, plugging devices, cross-flow resistance simulator, baffle plates in the control rod guide tubes and vent valve simulator for B&W PWR.

(12) For better simulation of lower plenum flow resistance, the heater rods do not penetrate through the bottom plate of the lower plenum but terminate at the elevation below the bottom of the core.

(13) Side walls which accomodate the slab core, upper plenum and upper part of the lower plenum are designed so as to minimize the thermal and hydrodynamic effects of the walls on the reflood

phenomena. The honeycomb structure thermal insulator panels are attached on the inner surfaces of the walls for this purpose.

(14) Proper gaps should be between the rod bundles and the honeycomb panels and between the core barrels and the vessel walls for preventing from the interferences due to thermal deformation during tests but these gap is determined as small as possible so as to minimize the additional fluid volume of the core.
Any measures practicable should be taken to minimize the effect of the additional fluid volume.

(15) The primary coolant loops are simplified ones which consist of one hot leg simulating the four actual hot legs, one steam-water separator corresponding to the four actual steam generators but without heat source of the secondary sides, one intact cold leg and one pump simulator without driving force simulating the three actual intact cold legs and their recirculation pumps and two broken cold legs of the pressure vessel side and the steam-water separator side simulating two halves of the actual broken cold leg.

(16) Cross section of the hot leg is an elongated circle with the full size longer diameter for good simulation of two-phase flow pattern transition.

(17) Cross section of the broken cold leg nozzle of the pressure vessel is an elongated circle of which longer diameter is the same as the diameter of the intact cold leg nozzle because of small available space for the nozzles. The pressure vessel side broken cold leg pipe itself is circular cross-sectional.

(18) The two cold leg nozzles of the pressure vessel are provided at the same side of the downcomer for preventing from direct carry-over of water from the intact cold leg to the broken cold leg. In addition, these nozzles are shifted down from the hot leg for preventing from interference of flow by the hot leg.

(19) Loop resistances are adjustable by inserting orifice plates of various hole diameters into the intact cold leg piping, pump simulator and broken cold leg pipings of the both sides.
Simulation tests for various break locations can be performed by adjusting the loop resistances.

(20) The broken cold legs of the both sides are connected to the different two containment tanks through the respective break valve.

The containment tanks-I (connected to the downcomer of the pressure vessel) and -II (connected to the steam-water separator) are connected with each other through the pressure equalizing pipe so that pressures in the two containment tanks behave similarly during a test.

(21) Pressure in the containment tank-II is controlled by the blow valve.

(22) Slab geometry of the pressure vessel should be utilized to the maximum extent to attach various instruments for studying thermo-hydrodynamics in the pressure vessel.

(23) Three kinds of ECCSs are provided, i.e., the accumulator injection system (Acc), low pressure coolant injection system (LPCI) and combined injection system. Available injection locations for the former two are the intact and broken cold legs, the hot leg, the lower plenum and the downcomer. On the other hand, those for the last one are the top and bottom-side of the upper plenum and the intact and broken cold legs.

(24) Water extraction system from the bottom-side of the upper plenum is provided.

(25) Steam supply system to the steam-water separator, the pump simulator and the containment tank-II is provided.

(26) Various kinds of advanced two-phase flow instruments should be distributed as well as the conventional instruments in order to clarify the thermo-hydrodynamic behavior in the facility. View windows also should be provided for flow observation.

(27) Achievable system pressure of the facility is 0.6 MPa and the allowable temperatures for the primary system and the Core-I heater rods are 350 and 900°C, respectively.

Components of the SCTF, principal dimensions of the SCTF, comparison of dimensions between the SCTF and the reference PWR and achievable conditions of the SCTF are given in Tables 2-1 through 2-4, respectively.

Vertical cross sections of the SCTF pressure vessel is shown in Fig.3-1. Schematic diagram of the SCTF, comparison in dimensions between the SCTF and the reference PWR and artist's view of the SCTF are shown in Figs.2-1 through 2-3, respectively.

Table 2-1 List of Components of the SCTF

1. Pressure Vessel
   - Core
   - Baffle Region
   - Downcomer (including Upper Annulus)
   - Lower Plenum
   - Upper Plenum
   - Upper Head
   - Vent Valve Simulation

2. Primary Coolant Loops
   - Hot Leg
   - Steam Water Separator
   - Intact Cold Leg (including Pump Simulator)
   - Pressure Vessel Side Broken Cold Leg (from Pressure Vessel to Containment Tank-I)
   - Steam Water Separator Side Broken Cold Leg (from Steam Water Separator to Containment Tank-II)

3. ECC Water Supply System
   - Acc Tank (including Acc Line)
   - LPCI Tank (including LPCI Line, Header and Injection Lines)
   - UCSP Water Supply Tanks-I and -II (including Injection Lines)
   - UCSP Water Extraction System

4. Containment Tank System
   - Containemmt Tanks-I and -II

5. Auxiliary System
   - Saturated Water Tank
   - Pressurizer
   - Nitrogen Gas Supply System
   - Steam Supply System
   - Water Purification System

Table 2-2 Principal Dimensions of the SCTF

1. Core Dimension	
(1) Quantity of Bundle	8 Bundles
(2) Bundle Array	1 × 8
(3) Bundle Pitch	230 mm
(4) Rod Array in a Bundle	16 × 16
(5) Rod Pitch in a Bundle	14.3 mm
(6) Quantity of Heater Rod in a Bundle	234 rods
(7) Quantity of Non-Heated Rod in a Bundle	22 rods
(8) Total Quantity of Heater Rods	234×8=1872 rods
(9) Total Quantity of Non-Heated Rods	22×8=176 rods
(10) Effective Heated Length of Heater Rod	3660 mm
(11) Diameter of Heater Rod	10.7 mm
(12) Diameter of Non-Heated Rod	13.8 mm
2. Flow Area & Fluid Volume	
(1) Core Flow Area	0.259 m^2
(2) Core Fluid Volume	0.92 m^3
(3) Baffle Region Flow Area	0.10 m^2
(4) Baffle Region Fluid Volume (nominal)	0.36 m^3
(5) Effective Core Flow Area Based on the Measured Level-Volume Relationship Including Gap between Core Barrel and Pressure Vessel Wall and Various Penetration Holes	0.35 m^2 m^2
(6) Downcomer Flow Area	0.121 m^2
(7) Upper Annulus Flow Area	0.158 m^2
(8) Upper Plenum Horizontal Flow Area	0.525 m^2
(9) Upper Plenum Fluid Volume	1.16 m^3
(10) Upper Head Fluid Volume	0.86 m^3
(11) Lower Plenum Fluid Volume	1.305 m^3
(12) Steam Generator Inlet Plenum Simulator Flow Area	0.626 m^2
(13) Steam Generator Inlet Plenum Simulator Fluid Volume	0.931 m^3
(14) Steam Water Separator Fluid Volume	5.3 m^3
(15) Flow Area at the Top Plate of Steam Generator Inlet Plenum Simulator	0.195 m^2
(16) Hot Leg Flow Area	0.0826 m^2

Table 2-2 (Continued)

(17) Intact Cold Leg Flow Area (Diameter = 297.9 mm)	0.0697	m^2
(18) Broken Cold Leg Flow Area (Diameter = 151.0 mm)	0.0179	m^2
(19) Containment Tank-I Fluid Volume	30	m^3
(20) Containment Tank-II Fluid Volume	50	m^3
(21) Flow Area of Exhausted Steam Line from Containment Tank-II to the Atmosphere	see Fig.4-63	
3. Elevation & Height		
(1) Top Surface of Upper Core Support Plate (UCSP)	0	mm
(2) Bottom Surface of UCSP	− 76	mm
(3) Top of the Effective Heated Length of Heater Rod	− 393	mm
(4) Bottom of the Skirt in the Lower Plenum	−5270	mm
(5) Bottom of Intact Cold Leg	+ 724	mm
(6) Bottom of Hot Leg	+1050	mm
(7) Top of Upper Plenum	+2200	mm
(8) Bottom of Steam Generator Inlet Plenum Simulator	+1933	mm
(9) Centerline of Loop Seal Bottom	−2281	mm
(10) Bottom Surface of End Box	− 185.1	mm
(11) Top of Upper Annulus of Downcomer	+2234	mm
(12) Height of Steam Generator Inlet Plenum Simulator	1595	mm
(13) Height of Loop Seal	3140	mm
(14) Inner Height of Hot Leg Pipe	737	mm
(15) Bottom of Lower Plenum	−5770	mm
(16) Top of Upper Head	+2887	mm

Table 2-3 Comparison of Dimensions between the SCTF and the Reference PWR

Item	SCTF	PWR	Ratio (SCTF/PWR)
Quantity of Bundle	8	193	1/24.1
Number of Heater Rod	1872	39372	1/21.0
Number of Rods	2048	43425	1/21.2
Effective Length of Heater Rod (mm)	3660	3660	1/1
Rod Pitch (mm)	14.30	14.30	1/1
Diameter of Heater Rod (mm)	10.70	10.72	1/1
Diameter of Unheated Rod (mm)	13.80	13.87	1/1
Flow Area of Core (m^2)	0.259	4.76	1/17.7
Effective Core Flow Area Based on the Measured Level-Volume Relationship (m^2)	0.35	4.76	1/13.6
Fluid Volume of Core Enveloped by Honeycomb Insulators*	0.92	17.95	1/19.5
Fluid Volume of Lower Plenum (m^3)	1.305	29.62	1/22.7
Fluid Volume of Upper Head (m^3)	0.86	19.8	1/23.0
Baffle Region Flow Area (m^2)	0.10	1.76	1/17.6
Upper Plenum Fluid Volume (m^3)	1.16	23.8	1/20.5
Downcomer Flow Area (m^2)	0.121	2.47	1/20.4
UCSP Thickness (m)	76	76	1/1
Steam Generator Inlet Plenum Simulator Volume (m^3)	0.931	4.25×4	1/18.3
Height of Steam Generator Inlet Plenum Simulator (m)	1.595	1.595	1/1
Flow Area at the Top Plate of Steam Generator Inlet Plenum Simulator (m^2)	0.19	4.0	1/21.2
Major Axis Length of Hot Leg Cross Section	737	736.6	1/1
Flow Area of Hot Leg (4 Loops)	0.0826	1.704	1/20.6
Flow Area of Intact Loop (3 Loops)	0.0696	1.149	1/16.5
Flow Area of Broken Cold Leg (m^2)	0.0179	0.383	1/21.4
* Fluid Volume of Core Including Gaps between Core Barrel and Pressure Vessel Wall	1.74		

Table 2-4 Achievable Condition of the SCTF

(1) System pressure	: up to 6 kg/cm^2 absolute
(2) Wall temperature	
○ Primary coolant loop (Hot leg, Cold leg and Steam-Water Separator)	: up to 300°C
○ Containment tanks-I and -II	: up to saturated temperature at 6 kg/cm^2 absolute
○ Pressure vessel thermal insulator	: ditto
(3) Clad temperature of heater rod	
○ Initial temperature (Hottest region)	: up to 800°C
○ Highest allowable temperature	: up to 900°C
(4) Heater rod power	
○ Total power	: up to about 10 MW
○ Highest heat flux rod	: 2.3 kW/m (peak power) 6.0 kW/Rod
(5) ECC water flow rate	
○ Acc	: 70 to 360 m^3/hr
○ LPCI	: 7 to 70 m^3/hr
○ UCSP water supply	: up to 360 m^3/hr
(6) ECC water temperature	
○ Acc	: up to near-saturated temperature at 6 kg/cm^2 absolute
○ LPCI	: 20 ~ 130°C
○ UCSP water supply	: 20 ~ 160°C (controllable during the test)
(7) Initial water inventory	
○ Location	: Containment tank-I and -II. Lower plenum
○ Water temperature	: up to saturated temperature at 6 kg/cm^2 absolute
(8) Nitrogen injection	
○ Injection rate	: 0.1 ~ 3 Nm^3/hr
○ Total amount	: 30 Nm^3
○ Duration time	: up to 20 sec

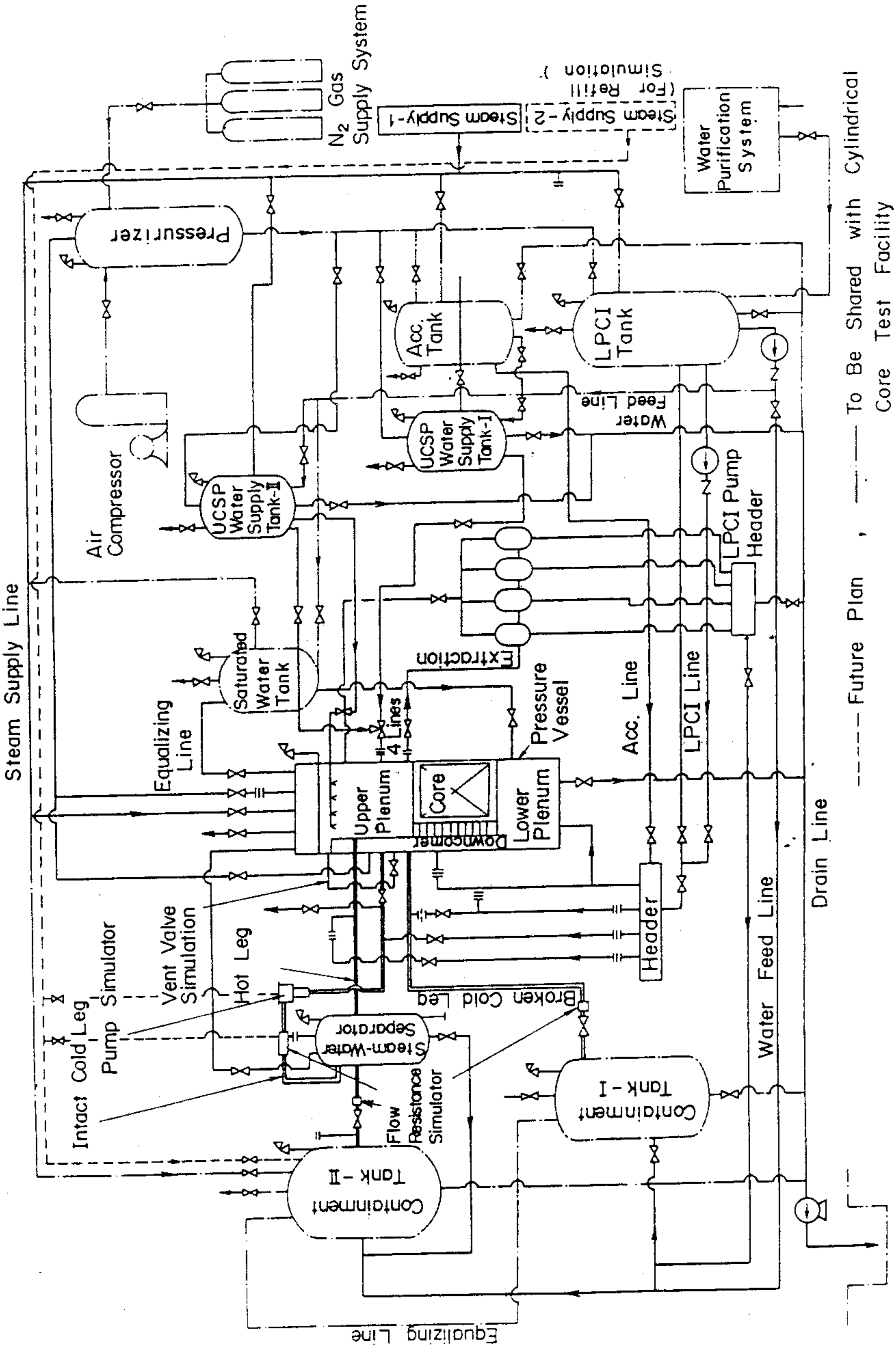


Fig.2-1 Schematic Diagram of the SCTF

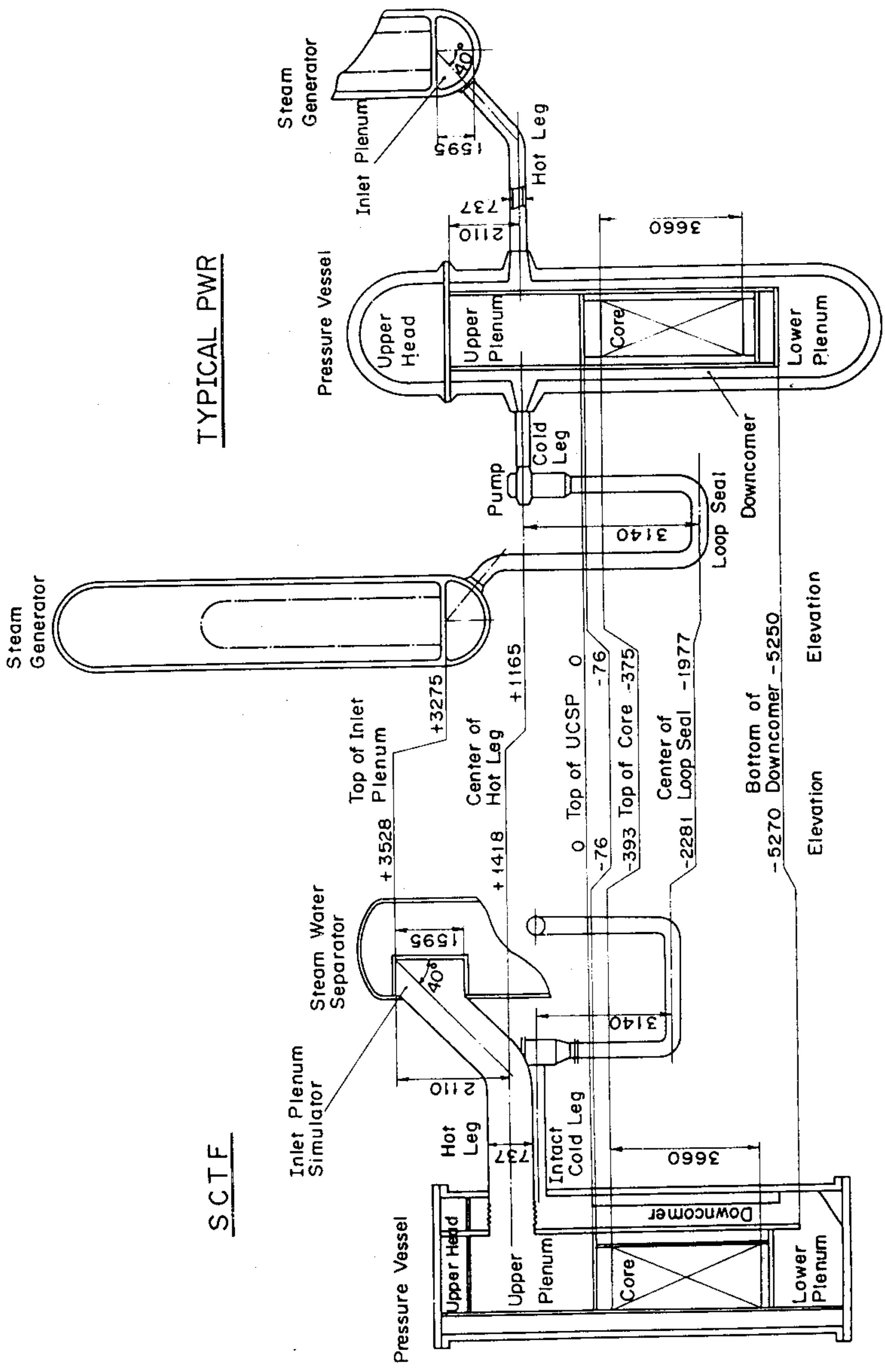


Fig.2-2 Comparison of Dimensions between SCTF and the Reference PWR

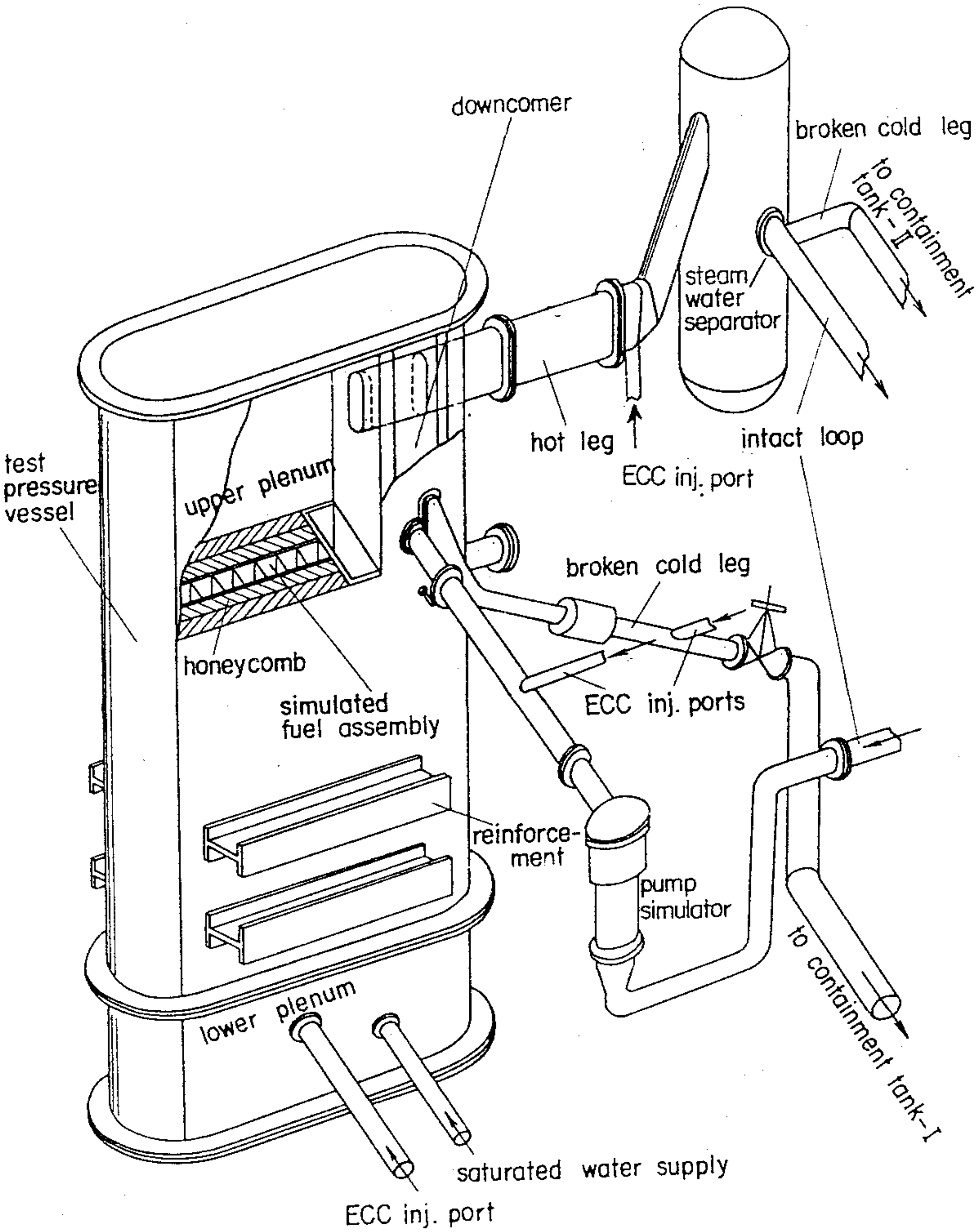


Fig.2-3 Artist's View of the SCTF

3. Detailed Design Features of the SCTF

In this chapter, detailed design features of the SCTF except instrumentation are given.

3.1 Pressure Vessel

The vertical cross section of the pressure vessel is shown in Fig.3-1. The downcomer, core baffle region and core are arranged in a line in the pressure vessel. The hot leg nozzle penetrates through the downcomer from the upper plenum at one end of the pressure vessel. Just below the hot leg nozzle in the downcomer are provided the intact cold leg nozzle of round shape and the pressure vessel side broken cold leg of an elongated circle. One end of the core adjacent to the core baffle region corresponds to the peripheral bundle of a PWR core, and the other end of the core corresponds to the center bundle of a PWR core. Fillers are inserted into the dead space at one end of the pressure vessel so as not to provide excess volume (on the left hand side of the pressure vessel shown in Fig.3-1).

The upper part of the downcomer simulates the proper flow area of upper annulus of actual downcomer based on the core flow area scaling.

The wall thickness of the pressure vessel is decided based on pressure rating and is 105 mm. Horizontal cross sections of the pressure vessel are shown in Figs.3-2 and 3-3. Fig.3-2 shows the cross sections at the upper head and the upper plenum elevations. Fig.3-3 shows those at the elevations of upper plenum (without internals), the core and the lower plenum.

The upper head is enveloped by the pressure vessel wall, and the upper plenum, the core and the upper part of lower plenum are enveloped by the honeycomb thermal insulator panels attached to the inside of the upper plenum barrel and the core barrel.

For insertion of the core barrel into the pressure vessel some excess clearance is needed, which is not favourable for the experimental requirement. Actual dimensions of the gap are shown in Fig.3-6 which are the average values for the top, middle and bottom elevations at the cold state. The dimensions without the parentheses are those in the direction of the depth of the pressure vessel and the dimensions with parentheses are those in the direction of the width.

The measured relation between the water level and the fluid volume in the pressure vessel excluded downcomer is shown in Fig.3-7.

In Figs.3-4 and 3-5 is shown the arrangement of the principal nozzles which are attached on the pressure vessel wall to meet the experimental requirements. There are three groups of nozzles. One is used for simulation of a PWR. These include nozzles for hot leg, intact cold leg, broken cold leg, vent valve simulation, ECC top injection, UCSP water injection-extraction. Another is used for inserting instruments. These include nozzles for wall film probes, γ-densitometers, turbine meters, drag disks, etc.. The third is used for view windows to observe the flow behavior in the pressure vessel. In these two figures only large nozzles are shown, and many small nozzles, for example, for thermocouples and pressure taps are not shown here.

3.2 Core

The core consists of eight bundles arranged in a straight line. The bundle number is denoted in order from the designated center bundle of the core to the peripheral. Each bundle has 16×16 rods array. In each bundle there are 234 heater rods and 22 non-heated rods. SCTF Core-I aimes to investigate the effect of channel flow blockage. Therefore, two bundles out of the eight are so called blocked ones. The blocked bundles are the bundles 3 and 4. Each blocked bundle consists of the 234 heater rods with coplaner blockage sleeves and 22 non-heated rods without sleeves. The arrangement of unblocked bundles and blocked bundles is shown in Fig.3-8.

Components to be simulated in the core are, (i) upper end boxes (ii) non-heated rods, (iii) heater rods, (iv) spacers and (v) lower end boxes. In order to realize the proper core thermo-hydrodynamic behavior the dimensions of these component should be preserved as much as possible. The principal dimension for the simulation is shown in Fig.3-9. In Fig.3-10, the relative elevation of the core baffle, spacers, heater rods, non-heated rods and blockage sleeves is shown. The elevation is presented as the distance from the bottom of the lower plenum.

The concept of the radial power distribution of which effect is to be investigated is shown in Fig.3-11. The three types of the radial power distribution are now under consideration, one is radially flat, another is steep and the third is the best estimate. The KWU core simulation shown in Fig.3-11 will be applied as the steep power distribution and either Westinghouse initial or burned core as the best estimate power distribution.

As for the electric power supplied to the core, the SCTF has eight power controllers corresponding to the 8 bundles. Four power controllers corresponding to the bundles 1 through 4 have the maximum capacity of 1.4 MW for each and the rest 4 controllers of 1.2 MW for each. The total available electric power of the core is 10 MW.

3.2.1 Heater Rods

The SCTF core has two kinds of heater rods of which number is 1872 in total. The difference in these two kinds is only whether or not the heater rod has a blockage sleeve at the midplane of the rod in order to simulate the ballooning of the fuel rods. There are no differences in configuration and characteristics of heater rod itself. The normal heater rods without sleeve are for the unblocked bundles 1, 2 and 5 through 8. On the other hand, heater rods with sleeve are for the blocked bundles 3 and 4.

In this section design of the heater rod itself is described, and the sleeve attached on the heater rod will be described in Section 3.2.3. In Fig.3-12 are shown the configuration and dimension of heater rods. The cross section of the heater rod is shown in Fig.3-13. The dimension and characteristics of heater rods are summarized in Table 3-1, and the material and the important properties of material are shown in Tables 3-2 through 3-4 and also in Figs.3-14 and 3-15. The heater rod is an indirectly heated rod and has a 17 step chopped cosine axial power profile to simulate the axial power distribution of the actual PWR fuel rod. The peaking factor of the heater rod is 1.4. Axial power distribution of the heater rod is shown in Fig.3-16.

Some heater rods and non-heated rods have thermocouples and the others no thermocouples. Arrangement of the rods with thermocouples in the core and location and elevation of the thermocouples are described in the chapter 4.

3.2.2 Non-heated Rods

The SCTF core has 176 non-heated rods in total. The non-heated rods are used as the instrumented rods and the tie rods. Number of the tie rods is different for each bundle due to the difference in number of the instrumented non-heated rods to meet the experimental requirements. The non-heated rods with instruments are rods with thermocouples for rod surface temperature measurement, fluid temperature measurement and steam temperature measurement, rods with film probes, rods with flag probes and rods with liquid level detectors (LLDs).

Number of the rods with and without instruments in each bundle are given in Table 3-5.

Configuration and dimension of the non-heated rods are shown in Fig.3-17. The tie rods are solid ones. The non-heated rods with thermocouples for steam temperature measurement are tubes without MgO in them and the non-heated rods with thermocouples for surface temperature and fluid temperature measurements are tubes with MgO in them. Principal dimension of the non-heated rods is 4448 mm in length and 13.8 mm in outer diameter.

3.2.3 Blockage Sleeves

As already described, the heater rods in the blocked bundles 3 and 4 have blockage sleeves to simulate the ballooning of the fuel rods. Location of the sleeve on the heater rod is shown in Fig.3-18.
The blockage sleeve is located just at the midplane of the heater rods where the heater rod has the maximum power rating in the axial direction. In Fig.3-19 the half of the blocked bundle facing the side wall is shown to illustrate that there are three kinds of blockage sleeves in the bundle. The corner rods "A" adjacent to the another blocked bundle, the periphery rods "B" except "A" adjacent to the another blocked bundle or the side walls and the rods "C" inside of the bundle or adjacent to the unblocked bundles have different shapes of blockage sleeve. This difference of configuration is shown in Fig.3-20. The largest outer diameter of the sleeve is 14.2 mm against the rod pitch of 14.3 mm. Therefore the nominal clearance between adjacent two sleeves is only 0.1 mm at the cold state. The local blockage fraction defined in a typical sub-channel sorrounded by four heater rods is,

$$1 - \frac{14.3^2 - \frac{\pi}{4}\,14.2^2}{14.3^2 - \frac{\pi}{4}\,10.7^2} = 0.597$$

at the cold state. The blockage fraction based on the whole bundle is,

$$\frac{\frac{\pi}{4} \times 234 \times \{14.2^2 - 10.7^2\}}{227 \times 230 - \frac{\pi}{4}\{10.7^2 \times 234 + 13.8^2 \times 22\}} = 0.574 \quad .$$

Flow area of the blocked bundles at the elevation of blockage sleeve is the minimum and thus the flow resistance should be very large. In order to avoid the bypass flow through the gap between the bundles and the side wall at the elevation of the blockage part, the closing plates and flow intercepters are attached between the 3rd and 4th spacers of the eight bundles as shown in Fig.3-21. Properties of the blockage sleeve material are given in Table 3-6.

3.2.4 End Boxs and Spacers

In the SCTF, end boxes and spacers are properly simulated as for the configuration and the dimension directly related to the characteristics of the flow dynamics in the core.

The heater rods and non-heated rods are fixed at the top by double nuts to the top grid spacers of which arrangement and principal dimensions are shown as grid spacer in Fig.3-22.

The configuration and dimension of the top grid spacer is shown in Fig.3-23. As already mentioned, all rods are fixed at the top grid spacer and therefore, weight of each bundle is held by each top grid spacer. The perforated fraction of each top grid spacer is 0.553. Above the top grid spacer, the end box is installed. The perforation rate and the thickness of the tie plate are the same as the actual ones of the reference PWR. Arrangement and principal dimensions of end boxes are also shown in Fig.3-22. The end box is shown in detail in Fig.3-24, and the dimension of the end box is given in Table 3-7.

All spacers except for the top grid spacers are of the same design and shown in Fig.3-25. Outer diameter of the spacers is 226.3 mm and two kinds of thickness, 0.8 mm and 0.4 mm, of the eggplate are used. The height of the spacer is 40 mm instead of 38 mm of the reference PWR.

The elevations of spacers are shown in Fig.3-10.

3.2.5 Plugging Devices in End Boxes and Cross Flow Simulators above Top Grid Spacers

To simulate as much as possible flow behavior in the end boxes of the reference PWR, the plugging devices shown in Fig.3-26 are installed just above each the end box tie plate. The configuration and dimension of the plugging device are shown in Fig.3-26. The top surface of the plugging device is located at the center of the end box and 3.5 mm above the top surface of the tie plate. The plugging device covers the area of 73 holes from the 225 holes of each the end box tie plate.

On the other hand, perforated plates called flow resistance simulators are equipped above the top grid spacers at between the adjacent each two bundles in order to properly simulate the horizontal flow resistance across bundles above the top spacers which is caused by the top part of the heater rods and non-heated rods. The concept of arrangement of the cross flow simulators is shown in Fig.3-27. The detailed dimension is shown in Fig.3-28.

3.2.6 Core Baffle Region

Flow path in the core baffle region is simulated properly. The detailed dimension of the core baffle region is shown in Fig.3-29. The core baffle region is separated into 9 subregions by the partition plates. Each subregion is connected to each other by a flow path of 36 mm in diameter. The core baffle is connected to the core by a flow path of 253 cm^2 at the bottom and by a flow path of 161 cm^2 at the top. There is provided a flow path connecting the core baffle region at the top to the downcomer for giving a flexibility of test mode but normally this flow path is plugged. As shown in Fig.3-29, the dimension of all the subregions of the core baffle region is the same except for the top subregion. The relative elevation of the core baffle region to the core is shown in Fig.3-10. Principal dimension is shown in Table 3-8.

3.2.7 Thermal Insulator Panels

Thermal insulator is provided on the inner surface of the core barrel and the upper plenum barrel to give the proper boundary condition to the core, the upper plenum and the upper part of the lower plenum.

The insulator is divided into a lot of small panels to make the thermal deformation as small as possible. The thermal insulator panels are made of honeycomb-shaped metalic plates. Material of the insulator panels is Inconel 600.

The concept of constitution of the insulator is shown in Fig.3-30. The detailed configuration of the honeycomb panels is shown in Fig.3-31 and the characteristics of the thermal insulator is listed in Table 3-9.

3.3 Interface between Core and Upper Plenum

Special attention has been paid to the deisgn of interface between the core and the upper plenum so as to provide proper flow behavior. Principal dimensions are presserved to be the same as the reference PWR as much as practicable. Between the core and the upper plenum there are provided the UCSP, the end boxes with plugging devices, top grid spacers with cross flow simulators. The thickness of the plates and the perforation ratio for flow paths are kept the same as a reference PWR.

The arrangement and the dimension of interface between the core and the upper plenum are shown in Fig.3-32. As seen in Fig.3-32, there are no honeycomb thermal insulator panels in the region of UCSP, end boxes and top grid spacers. Just above the UCSP as shown in Fig.3-33, there are provided the two sets of nozzles on both sides of the side walls. Each set of nozzles consists of eight nozzles. One set of nozzles are used to supply water above the UCSP at arbitrary flow rates and temperatures and the others to extract water from above the UCSP. These nozzles are mainly used to carry out the coupling tests between the UPTF and the SCTF tests in the SCTF Core-III, but these are also used in the SCTF Core-I and Core-II to investigate the effect of water accumulated on the UCSP. The arrangement and the dimension of the UCSP water injection and extraction nozzles are shown in Fig.3-33. As seen in Fig.3-33, the nozzles attached on the pressure vessel wall are of round shape but are of rectangular shape at inside of the pressure vessel wall to make the water velocity as low as possible and to prevent from the excess disturbance of flow above the UCSP.

3.4 Upper Plenum and Upper Head

A schematic of the upper plenum is shown in Fig.3-34. The dimension of the upper plenum is given in Table 3-10. A hot leg nozzle is attached to the one end of the upper plenum corresponding to the periphery of PWR upper plenum. The bottom of the hot leg is located at 1050 mm above the top surface of the UCSP. In the upper plenum there are provided the upper plenum internals such as control rod guide tubes, support columns and orifices. The concept of the guide tubes and the support columns is shown in Fig.3-35. To provide the proper characteristics of flow behavior in the upper plenum of a full size PWR, the upper plenum internals are scaled down at one half of the full size. Therefore, four UCSP holes are corresponding to one bundle as shown in Figs.3-36 and 3-37. The ratios of number of guide tubes, support columns, orifices and open holes to the total are close to those for the Westinghouse 17 × 17 PWR. The arrangement of the upper plenum internals is shown in Fig.3-36. There are 10 guide tubes, 9 support columns, 2 orifices and 11 open holes. In Fig.3-37 is shown the size and arrangement of the each hole in the UCSP. There are three kinds of holes with different diameter, 78 mm, 84 mm and 90 mm. The 90 mm holes are for the guide tubes and orifices, the 84 mm holes for the support columns and the 78 mm holes for the open holes. In Fig.3-38 is shown the upper support plate which separates the upper plenum from the upper head. Guide tubes penetrate through the upper support plate into the upper head region. In Figs.3-39 and 3-40 is shown dimension of the guide tubes. Especially in Fig.3-40 are shown the internals in each guide tube which are provided to give proper flow resistance in the guide tubes. The dimension of the support column is shown in Fig.3-41.

A schematic of upper head is shown in Fig.3-42. The upper head has no thermal insulator but provides the proper fluid volume for simulation. The fluid volume of the upper head is 0.86 m^3 and the area of flow path between the upper head and the upper plenum is 0.016 m^2. Four top injection nozzles for ECC water are provided into the upper head, but in the SCTF Core-I these nozzles are not used.

3.5 Lower Plenum

A schematic and the principal dimension of the lower plenum is shown in Fig.3-43. The upper half of the lower plenum has the thermal insulator panels but the lower half does not. The bottom of the heater rods terminates in the lower plenum as shown in Fig.3-10 so as not to give excess flow disturbance and flow resistance in the lower plenum. The principal dimension of the lower plenum is shown in Table 3-11. At the elevation of 719 mm above the bottom plate of the lower plenum there are horizontally arranged copper electrodes for heater rods. The detail of the electrodes is shown in Fig.3-44. The electrodes block the flow area in the lower plenum but the blocked ratio is only 25.2% and is rather small as shown in Fig.3-44.

3.6 Downcomer (Including Upper Annulus)

The configuration and the dimension of the downcomer including the upper annulus are shown in Fig.3-45. The principal dimension is also listed in Table 3-12. The filler is provided to give the proper flow area of the downcomer to simulate the flow area of the reference PWR by reducing the longer width of the flow area from 632 mm to 484 mm. In order to carry out the tests under the forced-feed reflooding condition, a closing plate can be attached at the bottom of the downcomer for separation of the downcomer from the lower plenum. Another filler of wedge shape is provided at the bottom of downcomer in order to give the smooth flow from the downcomer to the lower plenum that is expected in the actual PWR. A broken cold leg of pressure vessel side and an intact cold leg are attached at the elevation of 6637 mm above the bottom of lower plenum. The bottom of these cold legs are offset down by 317 mm from the bottom of the hot leg to avoid to be interfered the flow through these nozzles by the hot leg. Besides, a downcomer ECC water injection nozzle and a downcomer nitrogen gas injection nozzle are provided for simulation of a B&W PWR and for investigating the effect of nitrogen gas injection into the downcomer following the Acc water injection, respectively. The cross sections of downcomer at the two different elevations are shown in Figs.3-46 and 3-47, respectively and the filler for smooth flow from the downcomer to the lower plenum is shown in Fig.3-48.

3.7 Hot Leg

The arrangement of the hot leg is shown in Fig.3-49. The hot leg connects the upper plenum with the steam-water separator. The configuration of cross section of the hot leg is an elongated circle. The flow area is equivalent to that of the four loops of the reference PWR and is scaled down in proportion to the nominal core flow area scaling, 1/21. The principal dimension is also listed in Table 3-13. There are a spool piece to measure mass flow rate, two view windows to observe flow pattern and many pressure taps to measure pressure drop and water level in the hot leg. .

The dimension of the piping for the spool piece is shown in Fig.3-50.

3.8 Steam-Water Separator and Inlet Plenum Simulator

In Fig.3-51 is shown the upper half of the steam-water separator. The riser part of the hot leg is connected to the inlet plenum simulator which is equipped in the steam-water separator. To the steam-water separator are connected an intact cold leg equivalent to the three intact loops of the reference PWR and a broken cold leg. That is, the intact loop connects the steam-water separator with the downcomer of the pressure vessel, and the broken cold leg connects the steam-water separator with the containment tank-II.

The role of the inlet plenum simulator is to provide the proper characteristics of water entrainment coming into the U-tubes of the steam generator of a PWR. Therefore, the inlet plenum simulator has the arrangement of holes at the top plate which are equivalent to the actual steam generator inlet plenum. The arrangement and the dimension of holes at the top plate of the inlet plenum simulator are shown in Fig.3-52 and principal dimension in Table 3-14. The role of the steam water separator is to separate the water entrainment out of the two-phase flow coming from the inlet plenum and to measure the flow rate of the water entrainment. To meet this, the steam-water separator has the devices in the tank for separating the water from steam. The overall feature of the steam-water separator is shown in Fig.3-53. The flow rate of water collected in the steam-water separator is measured by using the differential pressure detector and the orifice flow meter.

The latter is used when the water is introduced into the containment tank-II after the water level in the steam-water separator reached a preset value during a test.

3.9 Intact Cold Leg and Pump Simulator

The intact cold leg connects the steam-water separator with the downcomer of the pressure vessel. The flow area of the intact cold leg is equivalent to that of the three loops of the reference PWR and is scaled down approximately in proportion to the nominal core flow area scaling, 1/21. The intact loop has a loop seal part before the pump simulator, an ECC water injection port between the pump simulator and the pressure vessel and a Venturi flow meter to measure the flow rate between the pump simulator and the steam-water separator. There are also two view windows at both sides of the ECC water injection port for observation of flow regime. The arrangement of the intact cold leg is shown in Fig.3-54. The configuration and the principal dimension of the pump simulator are shown in Fig.3-55.

3.10 Broken Cold Legs

There are two broken cold legs. One is on the pressure vessel side, which is connecting the downcomer with the containment tank-I and the other is on the steam-water separator side, which is connecting the steam-water separator with the containment tank-II. The flow areas of the two broken cold legs are equivalent to that of one loop of the reference PWR and is scaled down approximately in proportion to the nominal core flow area scaling, 1/21.

3.10.1 Pressure Vessel Side

The arrangement of the pressure vessel side broken cold leg is shown in Fig.3-56. The configuration of the cross section of the piping connected to the pressure vessel is not circular but of an elongated circle because of the restricted area for attaching both of the broken cold leg nozzle and the intact cold leg nozzle on the downcomer wall. The broken cold leg has a view window for flow observation, a spool piece for two-phase mass flow measurement and a break valve for simulating the refill period.

3.10.2 Steam-Water Separator Side

The arrangement of the steam-water separator side broken cold leg is shown in Fig.3-57. The broken cold leg has a Venturi flow meter to measure flow rate, an orifice to give the proper flow resistance and a break valve for simulating the refill period.

3.11 Vent Valve Simulator for B&W PWRs

The B&W PWRs have the vent valves connecting the upper plenum directly with the downcomer. To study the effect of vent valves, the SCTF has a vent valve simulator of an external piping connecting the upper plenum with the downcomer, which has a check valve in it.
The arrangement and the dimension of the external piping for vent valve simulation are shown in Fig.3-58.

3.12 ECC Water Injection System

The schematic of the ECC water injection system is shown with the solid line in Fig.3-59. The SCTF has a variety of ECC water injection ports to meet the experimental requirements. As the source of ECC water there are an Acc tank, a LPCI tank and UCSP water supply tanks-I and -II. Three kinds of ECC water supply are done from these tanks.
One is Acc water supply and another is LPCI water supply, the third is UCSP water supply for combined injection.

3.12.1 Acc and LPCI Water Injection Systems

The Acc line from Acc tank and LPCI line from LPCI tank are connected to a header from which ECC water is distributed to each injection port.

The available injection locations are:

(1) lower plenum,

(2) downcomer,

(3) broken cold legs,

(4) intact cold leg between the pump simulator and the pressure vessel, and

(5) hot leg.

The injection ports are selected to meet the experimental requirements.

The Acc water is supplied by the pressure of nitrogen gas from the pressurizer and the LPCI water by the LPCI pump. The waters in the Acc tank and the LPCI tank are heated up to the specified temperatures but the temperatures can not be changed during a test.

3.12.2 UCSP Water Injection and Extraction Systems

3.12.2.1 UCSP Water Injection System

The UCSP water injection system which consists of UCSP water supply tanks-I and -II and the piping system is used for the combined injection tests. The UCSP water supply tank-I contains hot water and the UCSP water supply tank-II cold water. This system is designed so as to provide the specified transient of water flow rate and water temperature to the eight UCSP injection nozzles just above the UCSP. As each adjacent two nozzles are connected into one at the outside of the pressure vessel, four lines in total are provided for giving the specified flow and fluid temperature transients independently. The schematic of the system is shown in Fig.3-60. To give a flexibility for the experiment, the system is connected to the four top nozzles of the pressure vessel (cold tank system only) and to the header to which Acc and LPCI lines are connected for ECC water injection into the primary system.

3.12.2.2 UCSP Water Extraction System

The schematic diagram of the UCSP water extraction system is shown in Fig.3-61. The configuration and the dimension of the eight UCSP water extraction nozzles attached on the pressure vessel wall just above UCSP are shown in Fig.3-33. As shown in Fig.3-61, each two nozzles are connected into one water extraction line to make up four extraction lines in total. Each extraction line has a flow rate regulation valve, a steam-water separator and an electro-magnetic flow meter. These four extraction lines meet to each other at the header which is connected to the containment tank-I. The water in the two-phase flow extracted from just above the UCSP is separated in the steam-water separator, and the steam is fed back to the upper plenum through the orifice for measuring the flow rate of the steam. The water flow rate is measured by using both of the electro-magnetic flow meter and the detector for water level change in U-tube downstream of the steam-water separator.

3.12.3 Saturated Water Supply Tank System

A saturated water tank system is used to provide the moderate initial condition for tests. In some tests, subcooled Acc water is introduced to the pressure vessel or the primary system. In such cases, saturated water is first introduced to the lower plenum just before the tests in order to avoid violent flow disturbance by condensation due to subcooled water.

The saturated water supply system can also be used in some tests to provide proper initial water inventry in the lower plenum.

3.13 Containment Tanks-I and -II

The SCTF has two containment tanks. The containment tank-I is connected to the downcomer of the pressure vessel through the broken cold leg of the pressure vessel side and on the other hand, the containment tank-II is connected to the steam-water separator with the other broken cold leg of steam-water separator side. These two containment tanks are connected to each other with a pressure equalizing line. As the volume of these two tanks are not big enough (30 m^3 for the containment tank-I and 50 m^3 for the containment tank-II) to simulate the containment of a PWR, a pressure regulation system is provided to the containment tank-II. The pressure regulation system can provide not only the almost constant pressure in the containment tank-II during a test but also a specified pressure transient to meet the experimental requirement. The containment tank-I has a special role to measure the water carried over from the downcomer through the broken cold leg and then has a mechanism in the tank for steam-water separation.
The relation between the water level and the water volume in the containment tank-I is shown in Fig.3-62. Besides, the initial water inventory can be set both in the containment tank-I and -II for simulation of the refill phase.

3.14 Auxiliary Systems

In the SCTF a pressurizer system, a saturated water tank system, a steam supply system, and a water purification system are provided as auxiliary systems. These are all shared with the CCTF. In addition, the another steam supply system is provided so as to meet the experimental requirements for Core-II and -III. The steam supply system has the ability to provide steam into the containment tank-II, the pump simulator and the steam-water separator with the total maximum flow rate of 15 kg/s and with the total steam mass of more than 300 kg.

3.15 Additional Important Information

Here is given the additional important information for analysis of the test data. The characteristics of valves are listed in Table 3-15 as for the times for full close. The flow area of nozzles and pipings for convinience of the analysis are listed in Table 3-16.
The characteristics of the orifices used for flow resistance simulators is listed in Table 3-17. K-factor for each loop, valve and Venturi are listed in Table 3-18. The dimension of the Venturi flow meters equipped in the primary loops is listed in Table 3-19. The pipe arrangement from containment tank-II to the atmosphere is shown in Fig.3-63.

Table 3-1 Dimension and Characteristics of Heater Rods

Total length of Heater Rod	4448 mm
Effective Heated Length of Heater Rod	3660 mm
Diameter of Effective Heated Part of Rod	10.7 ± 0.05 mm
Axial Peaking Factor	1.4 mm
Thickness of Cladding	0.96 mm
Outer Diameter of Coil of Heater Element	6.3 mm
Thickness of Heater Element	0.5 mm
Maximum Allowable Temperature	900 °C
Step Number of Chopped Cosine Power Distribution	17

Table 3-2 Material and Thermal Properties of Heater Rod

Item	Material
Heater Sheeth	Nichrofer 7216
Heater Element	Nichrome 5
Insulator	MgO

Thermal Properties

	Density (g/cm^3)	Specific Heat (cal/g·°C)	Thermal Conductivity (cal/cm·s·°C)
Nichrofer 7216	8.5	0.11	See Table 3-4
Nichrome 5	8.41	0.104	0.027
MgO	2.5	See Table 3-4	0.0015

Table 3-3 Electric Resistivity of Nichrome 5

Temperature (°C)	20	100	200	300	400	500	600
factor	1	1.005	1.015	1.028	1.045	1.065	1.068
Temperature	700	800	900	1000	1100	1200	
factor	1.057	1.051	1.052	1.062	1.071	1.080	

Resistivity is 103 μΩ-cm at 20°C

Table 3-4 Specific Heat of MgO and Thermal Conductivity and Coefficient of Linear Expansion of Nichrofer 7216

Specific Heat of MgO (cal/g·°C)

	IHI Data	JAERI Data
25°C		0.22_3 ± 3%
100	0.248	0.24_9
200		0.27_1
300	0.278	
400		0.28_8
500	0.294	
600		0.29_5
800	0.302	0.30_0

Nichrofer 7216

	Thermal Conductivity (cal/cm·s·°C)		Coefficient of Linear Expansion (m/m·°C)
20°C	0.036	20 ~ 100°C	13.8×10^{-6}
100	0.037	20 ~ 200	14.2
200	0.042	20 ~ 400	14.8
400	0.049	20 ~ 600	15.4
600	0.057	20 ~ 800	15.9
800	0.067	20 ~ 1000	16.7

Table 3-5 Number of Rods with and without Instruments

			1	2	3	4	5	6	7	8
	Bundle No.		1	2	3	4	5	6	7	8
Heater Rod	Heater Rod with TC		16	14	21	21	14	14	14	14
	Heater Rod Without Instrument		218	220	213	213	220	220	220	220
Non-heated Rod	Non-heated Rod with Instrument	Surface Temperature	2	2	3	3	2	2	2	2
		Fluid Temp.	2	2	2	2	2	2	2	2
		Steam Temperature	2	2	2	2	—	2	—	2
		Film Probe	0	2	0	2	0	0	0	2
		Flag Probe	0	1	0	1	1	0	0	1
		LLD	0	1	0	1	0	1	0	1
	Non-heated Rod Without Instrument (Tie Rod)		16	12	15	11	17	15	18	12

Table 3-6 Properties of Blockage Sleeves

Material	INCONEL 600 (NCF1-B)
Density	8.43 g/cm^3
Specific Heat	0.106 kcal/kg·°C
Thermal Conductivity	0.0355 cal/cm·s·°C
Thermal Expansion Modulus	13.3×10^{-6}/°C

Table 3-7 Principal Dimension of End Boxes

Number of Hole	225
Diameter of Hole	12.5 mm
Thickness of Tie Plate	15.1 mm
Height between bottom of UCSP and bottom of Tie Plate	109.1 mm
Perforated Area Fraction of Tie Plate	52.2 %
Height of the End Box	89.1 mm

Table 3-8 Principal Dimension of Core Baffle Region

Total Fluid Volume	0.3829 m^3
Flow Area of Each Segment	0.1 m^2
Flow Area of Hole in Partition Plate	0.0010 m^2
Flow Area of Flow Path from the Core Baffle Region to the Core at the Top of the Core	0.0161 m^2
Flow Area of Flow Path from the Core to the Core Baffle Region at the Bottom of the Core	0.0253 m^2
Diameter of Hole from Core Baffle Region to the Downcomer (Normally plugged)	36 mm

Table 3-9-1 Characteristics of Thermal Insulator (Honeycomb Structure)

Height	52.4 mm
Surface Plates Thickness	0.8 mm
Pitch of Honeycomb Cell	10mm $\times$ 12.7mm
Thickness of Honeycomb Cell Plate	0.102 mm
Volume of a Honeycomb Cell	$12.7 \times 10 \times (52.4-0.8 \times 2)$ $= 6.452 \times 10^3$ mm^3
Material	Inconel 625
Density of Material	8443 kg/m^3
Young's Modulus	2.9×10^7 psi

Table 3-9-2 Specific Heat of Thermal Insulator Panel per Unit Area

Temperature (°C)	C panel ($kcal/°C \cdot m^2$)
21	2.45
204	2.75
427	3.09
649	3.48
871	3.78

Table 3-9-3 Equivalent Thermal Conductivity of Thermal Insulator Panel

Temperature(°C)	λ(kcal/m·hr·°C)	$\lambda_{INCO\ 625}$*
180	0.4762	10.497
230	0.6830	11.167
405	1.082	13.46
480	1.518	14.41

* Value of Inconel 625

Table 3-10 Principal Dimension of Upper Plenum

Height	2200 mm
Width	2117 mm
Depth	248 mm
Fluid Volume	1.155 m^3
Area of Horizontal Cross Section	0.525 m^2
Elevation of Hot Leg Bottom above UCSP	1050 mm
Number of Guide Tube	10
Number of Support Column	9
Number of Orifice	2
Thickness of UCSP	76 mm
Thickness of UCSP	60 mm

Table 3-11 Principal Dimension of Lower Plenum

Height of Lower Plenum	1615 mm
Width	2117 mm 2307 mm
Depth	250 mm
Fluid Volume	1.305 m^3
Flow Area at the Skirt of Lower Plenum	0.529 m^2
Flow Area of Path from Downcomer to Lower Plenum	0.23 m^2
Blocked Area by Electrode in the Lower Plenum	0.227 m^2
Blocked Area Ratio by Electrode	25.2 %

Table 3-12 Principal Dimension of Downcomer Including Upper Annulus

Overall Height of Downcomer Including Upper Annulus	8004 mm
Width of Upper Annulus	632 mm
Width of Downcomer	484 mm
Depth of Downcomer Including Upper Annulus	250 mm
Fluid Volume of Downcomer Including Upper Annulus	0.903 m^3
Flow Area at the Elevation except for 872 mm to 5772 mm	0.158 m^2
Flow Area at the Elevation from 872 mm to 5772 mm	0.121 m^2
Elevation of the Centerline of Hot Leg Nozzle	7190.5mm
Elevation of the Centerline of Cold Leg Nozzles	6637 mm
Elevation of the Downcomer Injection Nozzle	6507 mm
Elevation of the Downcomer N_2 Injection Nozzle	7777 mm

Table 3-13 Dimension of Hot Leg

Wall Thickness	40 mm
Inner Diameter	737mm(Height) × 116mm(Width)
Flow Area	0.0826 m^2
Length of Center Line of the Hot Leg (from Upper Prenum to Steam Generator Inlet Plenum Simulator)	4.30 m
Angle of Riser Part of Hot Leg to Center Line of Hot Leg	60 °
Elevation of Bottom of Hot Leg above the Top Surface of UCSP	1050 mm

Table 3-14 Principal Dimension of Steam Generátor Inlet Plenum Simulator

Height	1488 mm
Flow Area	$\frac{\pi}{4} \times 1200^2 \times \frac{(9.6\times2+180)}{360}$ $= 6.258 \times 10^5$ mm^2
Diameter of Holes in the Top Plate	19.7 mm
Number of Holes in the Top Plate	640
Flow Area of Holes in the Top Plate	$\frac{\pi}{4} \times 19.7^2 \times 640$ $= 1.951 \times 10^5$ mm^2
Fluid Volume	$6.258 \times 10^5 \times 1488$ $= 9.312 \times 10^8$ mm^3
Elevation of Top Plate of Simulator above Center Line of Hot Leg	2110 mm

Table 3-15 Characteristics of Valves

(1) Break Valve in Pressure Vessel Side Broken Cold Leg (VL-01S)

Opening time (Close → Open) = 1.7 seconds

Closing time (Open → Close) = 1.6 seconds

(2) Break Valve in S-W Separator Side Broken Cold Leg (VL-02S)

Opening time (Close → Open) = 1.8 seconds

Closing time (Open → Close) = 1.9 seconds

(3) Injection Valve in Lower Plenum ECC Line (VA-03S)

Opening time = 2.8 seconds

Closing time = 2.8 seconds

(4) Injection Valve in Downcomer ECC Line (VA-11S)

Opening time = 2.9 seconds

Closing time = 3.0 seconds

(5) Injection Valve in Intact Cold Leg ECC Line (VA-04S)

Opening time = 2.6 seconds

Closing time = 2.6 seconds

(6) Injection Valve in Pressure Vessel Side Broken Cold Leg (VA-05S)

Opening time = 2.6 seconds

Closing time = 2.6 seconds

(7) Injection Valve in Hot Leg (VA-10S)

Opening time = 2.5 seconds

Closing time = 2.9 seconds

(8) Valve in LPCI Line (VT-02S)

Opening time = 2.8 seconds

Closing time = 2.8 seconds

(9) Valve in LPCI Circulation Line (VT-03S)

Opening time = 2.9 seconds

Closing time = 2.9 seconds

(10) Valves in UCSP Extraction Line

Opening time = 1.9 ~ 2.0 seconds

Closing time = 1.8 ~ 2.0 seconds

(11) Regulating Valve in Exhaust Line from Containment Tank-II (VV-11)

Opening time = 9.2 seconds

Closing time = 8.7 seconds

Table 3-16 Flow Area of Nozzles and Pipings

(1) Broken Cold Leg Nozzle Attached to Downcomer

$$S = 191 \times (37\times2) + \frac{\pi}{4}(37\times2)^2 = 14134 + 4301$$
$$= 1.8435 \times 10^4 \text{ mm}^2$$

(2) Intact Cold Leg Nozzle Attached to Downcomer

$$S = \frac{\pi}{4} \times (265)^2 = 5.5155 \times 10^4 \text{ mm}^2$$

(3) Hot Leg Nozzle and Piping

$$S = 8.26 \times 10^4 \text{ mm}^2$$

(4) Lower Plenum Injection Nozzle

$$S = \frac{\pi}{4} \times 131^2 = 1.3478 \times 10^4 \text{ mm}^2$$

(5) Downcomer Injection Nozzle

$$S = \frac{\pi}{4} \times 85^2 = 5.6745 \times 10^3 \text{ mm}^2$$

(6) Downcomer Nitrogen Injection Nozzle

$$S = \frac{\pi}{4} \times 143.2^2 = 1.6106 \times 10^4 \text{ mm}^2$$

(7) UCSP Water Supply Nozzle

$$S = \frac{\pi}{4} \times 73.9^2 = 4.289 \times 10^3 \text{ mm}^2$$

(8) UCSP Water Extraction Nozzle

$$S = \frac{\pi}{4} \times 73.9^2 = 4.289 \times 10^3 \text{ mm}^2$$

(9) Vent Valve Simulation Nozzle

$$S = \frac{\pi}{4} \times 143.2^2 = 1.6106 \times 10^4 \text{ mm}^2$$

Table 3-17 Characteristics of Orifices for Flow Resistance Simulators

Flow Area of Piping:

$A_{Hot\ Leg} = 0.0826\ m^2$

$A_{Intact\ Cold\ Leg} = 0.0697\ m^2$

$A_{Broken\ Leg} = 0.0179\ m^2$

$A_{Steam\ Water\ Separator} = 0.437\ m^2$

Definition of Friction Factor: K

$$K = K_i \left(\frac{\bar{A}_{Hot\ Leg}}{\bar{A}_{Component}}\right)^2$$

K_i : Local friction factor

$\bar{A}$: Flow Area Equivalent to One Loop

(1) Intact Cold Leg $(\bar{A}_{Hot\ Leg} / \bar{A}_C)^2 = 0.789$

Diameter of Piping = 298.0 mm

Diameter of Orifice = 211.2 mm (K_i=3.80, K=3.0)
191.1 mm (=7.56, =5.97)
179.9 mm (=11.3, =8.95)
178.7 mm (=11.39, =9.0)

(2) Steam-Water Separator Side Broken Cold Leg

$$(\bar{A}_{Hot\ Leg} / \bar{A}_C)^2 = 1.33$$

Diameter of Piping = 151.0 mm

Diameter of Orifice = 91.3 mm (K_i=10.84, K=14.42)
89.6 mm (=12.14, =16.16)
87.7 mm (=13.68, =18.21)
86.4 mm (=15.30, =20.40)
85.8 mm (=15.49, =20.62)
83.8 mm (=17.66, =23.50)

Table 3-17 (Continued)

(3) Pressure Vessel Side Broken Cold Leg

$$(\bar{A}_{Hot\ Leg} / \bar{A}_C)^2 = 1.33$$

Diameter of Piping = 151.0 mm

Diameter of Orifice = 90.7 mm (K_i=11.27, K=15.0)

86.3 mm (=15.03, =20.0)

82.8 mm (=18.78, =25.0)

(4) Pump Simulator $(\bar{A}_{Hot\ Leg} / \bar{A}_C)^2 = 0.1097$

Diameter of Piping = 488.0 mm

Diameter of Orifice = 184.3 mm (K_i=114.05, K=12.53)

179.0 mm (=129.89, =14.27)

173.7 mm (=148.54, =16.32)

168.3 mm (=170.48, =18.73)

162.9 mm (=196.69, =21.61)

(5) Steam-Water Separator $(\bar{A}_{Hot\ Leg} / \bar{A}_C)^2 = 0.03573$

Diameter of Flow = 746 mm (Equivalent Diameter)

(K_i=11.96, K=0.427)

Table 3-18 List of Friction Factor

1. Hot Leg

Flow Area = $0.0826\ m^2$

Equivalent Diameter = 0.206 m

$\varepsilon/d = 6\times10^{-5}$

$U_g = 18.64$ m/s

$R_e = 8.33\times10^5$

$f = 0.013$

$(\ell/d)_{straight} = 4.557/0.206 = 22.12$

$(\ell/d)_{40°\ elbow} = 11.4$

$K_p = 0.013\times(22.12+11.4)+0.5+1.0 = \underline{\underline{1.94}}$

$K = 1.94$

2. Intact Cold Leg (except pump simulator)

Flow Area = $0.0697\ m^2$

Diameter = 0.298 m

$\varepsilon/d = 4\times10^{-5}$

$U_g = 16.57$ m/s

$R_e = 1.07\times10^6$

$f = 0.0125$

$(\ell/d)_{straight} = 15.1/0.298 = 50.6$

$4\times(\ell/d)_{90°\ elbow} = 80$

$K_{venturi} = 0.496$

$K_{valve} = 0.322$

$K_p = 0.0125\ (50.6+80)+0.5+1.60+0.322+0.496$

$= \underline{\underline{4.55}}$

$K = 3.59$

3. Steam-Water Separator Side Broken Cold Leg (See Fig.3-57)

(1) Section between S-W Separator and Break Valve (VL-02S)

Flow Area = $0.0697\ m^2$

Diameter = 0.298

$\varepsilon/d = 4\times10^{-5}$

$U_g = 5.524$ m/s

$R_e = 3.75\times10^5$

$f = 0.0145$

$(\ell/d)_{straight} = 9.9104/0.298 = 33.26$

Table 3-18 (Continued)

$3 \times (\ell/d)_{90° \text{ elbow}} = 60$

$K_p = 0.0145 \times (3.26+60) + 1.0 = 2.352$

$K = 1.856$

(2) Section between Break Valve (VL-02S) and Containment Tank-II

Flow Area $= 0.0179\ m^2$

Diameter $= 0.151\ m$

$\varepsilon/d = 8 \times 10^{-5}$

$R_e = 7.05 \times 10^5$

$f = 0.0135$

$(\ell/d)_{\text{straight}} = 3.66/0.151 = 24.25$

$(\ell/d)_{90° \text{ elbow}} = 20$

$(K)_{\text{venturi}} = 0.37$

$(K)_{\text{valve}} = 0.89$

$K_p = 0.0135 \times (24.25+20) + 0.5 + 0.55 + 0.89 + 0.37$

$= 2.91$

$K = 3.87$

4. Pressure Vessel Side Broken Cold Leg (See Fig.3-56)

(1) Section of Pipe Diameter D = 0.151 m, including the Pressure Vessel Nozzle

Flow Area $= 0.0179\ m^2$

Diameter(Equivalent) $= 0.151\ m$

$\varepsilon/d = 8 \times 10^{-5}$

$U_g = 21.5\ m/s$

$R_e = 7.05 \times 10^5$

$f = 0.0135$

$(\ell/d)_{\text{straight}} = \frac{3.46}{0.151}$

$(\ell/d)_{45° \text{ elbow}} = 11$

$(K)_{\text{valve}} = 0.89$

$K_p = 0.0125 \times (22.9+22) + 0.5 + 0.55 + 0.89 = 2.50$

$K = 3.325$

Table 3-18 (Continued)

(2) Section of Pipe Diameter $D = 0.298$ m to Containment Tank-I

Flow Area	$= 0.0697\ m^2$
Diameter	$= 0.298$ m
ε/d	$= 4 \times 10^{-5}$
R_e	$= 1.07 \times 10^6$
f	$= 0.0125$
$(\ell/d)_{straight}$	$= \frac{15.654}{0.298} = 52.5$
$(\ell/d)_{90^\circ\ elbow}$	$= 20 \times 5 = 100$
$(\ell/d)_{45^\circ\ elbow}$	$= 11 \times 2 = 22$

$K_p = 0.0125 \times (52.5+100+22) + 1.0 = 3.18$

$K = 2.51$

5. Valve* in Intact Cold Leg

Inner Diameter	= 298 mm
K-factor	= 0.322

6. Valve* in Pressure Vessel Side Broken Cold Leg (Break Valve)

Inner Diameter	= 151 mm
K-factor	= 0.89

7. Valve* in Steam-Water Separator Side Broken Cold Leg (Break Valve)

Inner Diameter	= 151 mm
K-factor	= 0.89

8. Venturi Tube* in Steam-Water Separator Side Broken Cold Leg

Minimum Diameter (Throat)	= 112.3 mm
K factor	= 0.37

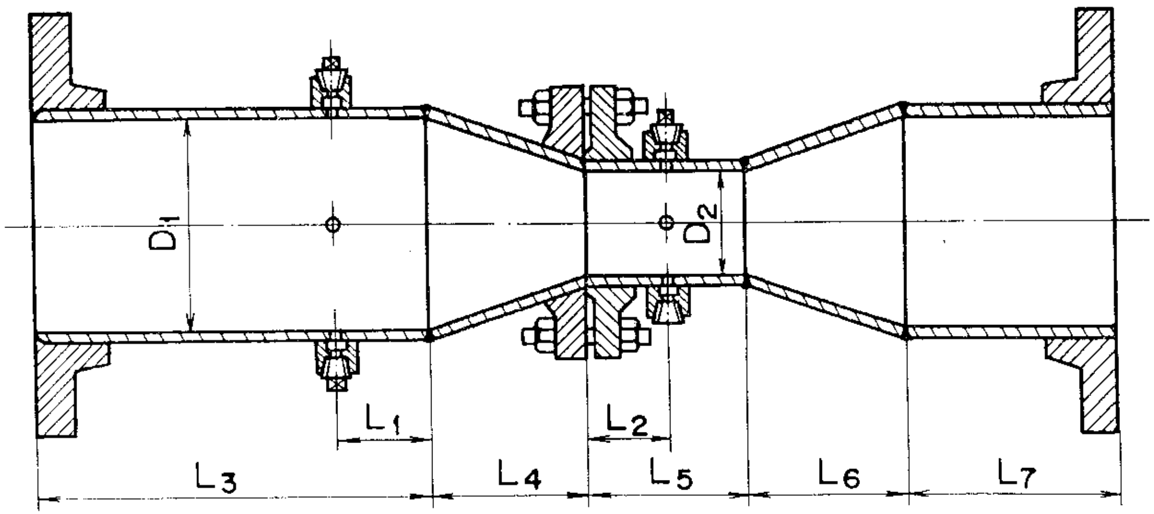
9. Venturi Tube* in Intact Cold Leg

Minimum Diameter (Throat)	= 199.6 mm
K-factor	= 0.496

*) $\Delta P_{valve} = K \cdot \frac{\gamma (U_g)^2_{valve\ or\ venturi}}{2g}$

Table 3-19 Principal Dimension of Venturis

Location	Nominal Pipe Diameter	D_1	D_2	L_1	L_2 (in mm)	L_3	L_4	L_5	L_6	L_7
Steam Water Separator Side -Broken Cold Leg	6 inches	151.6	112.3	75.5	56.2	500	104.3	112	146.8	181.9
Pressure Vessel Side -Broken Cold Leg	10	248.8	178.9	124.4	89.4	700	188.6	179	265.5	466.9
Intact Cold Leg	12	297.6	199.6	148.9	99.8	700	265.2	200	373.3	386.5



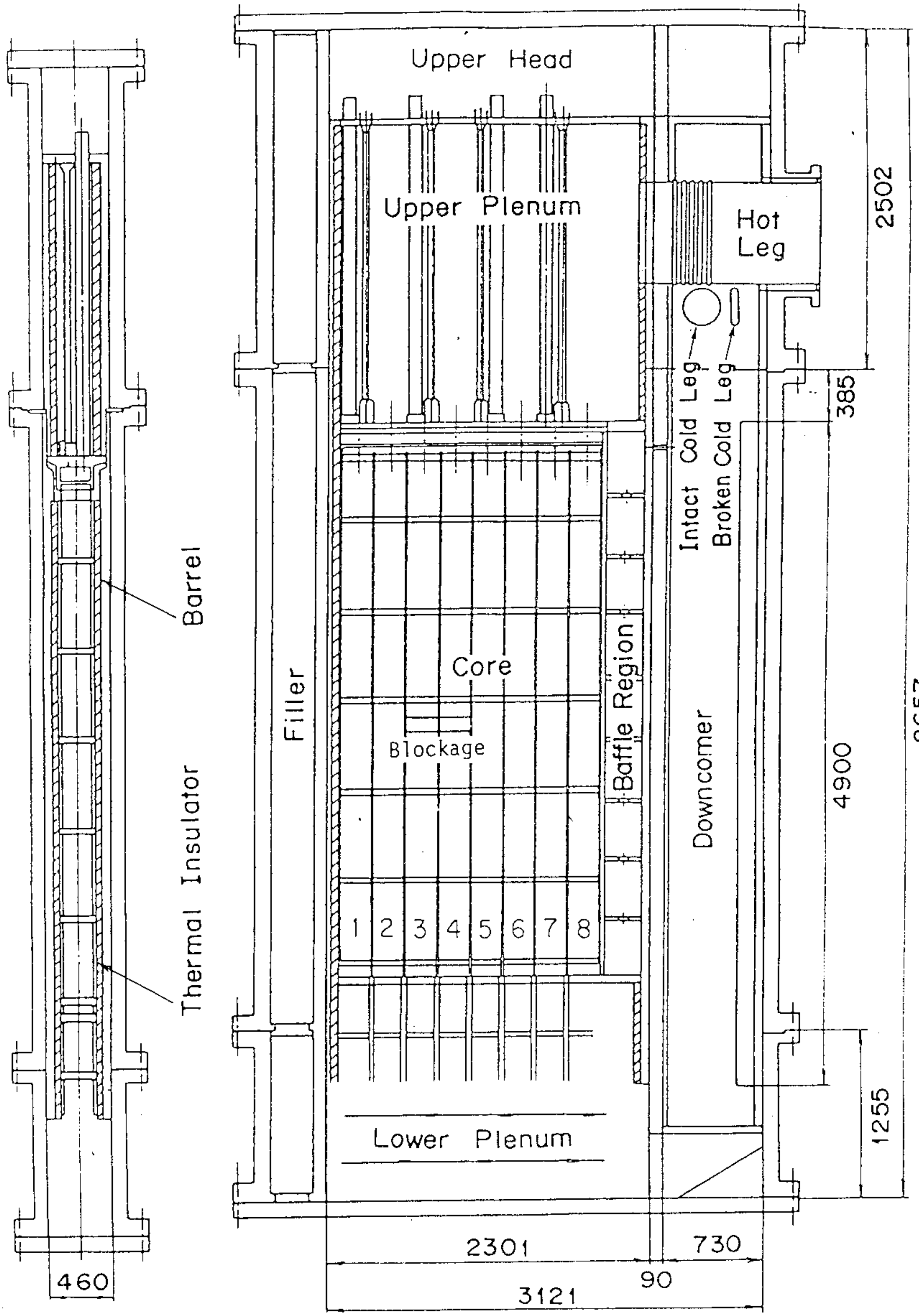


Fig.3-1 Vertical Cross Sections of the Pressure Vessel

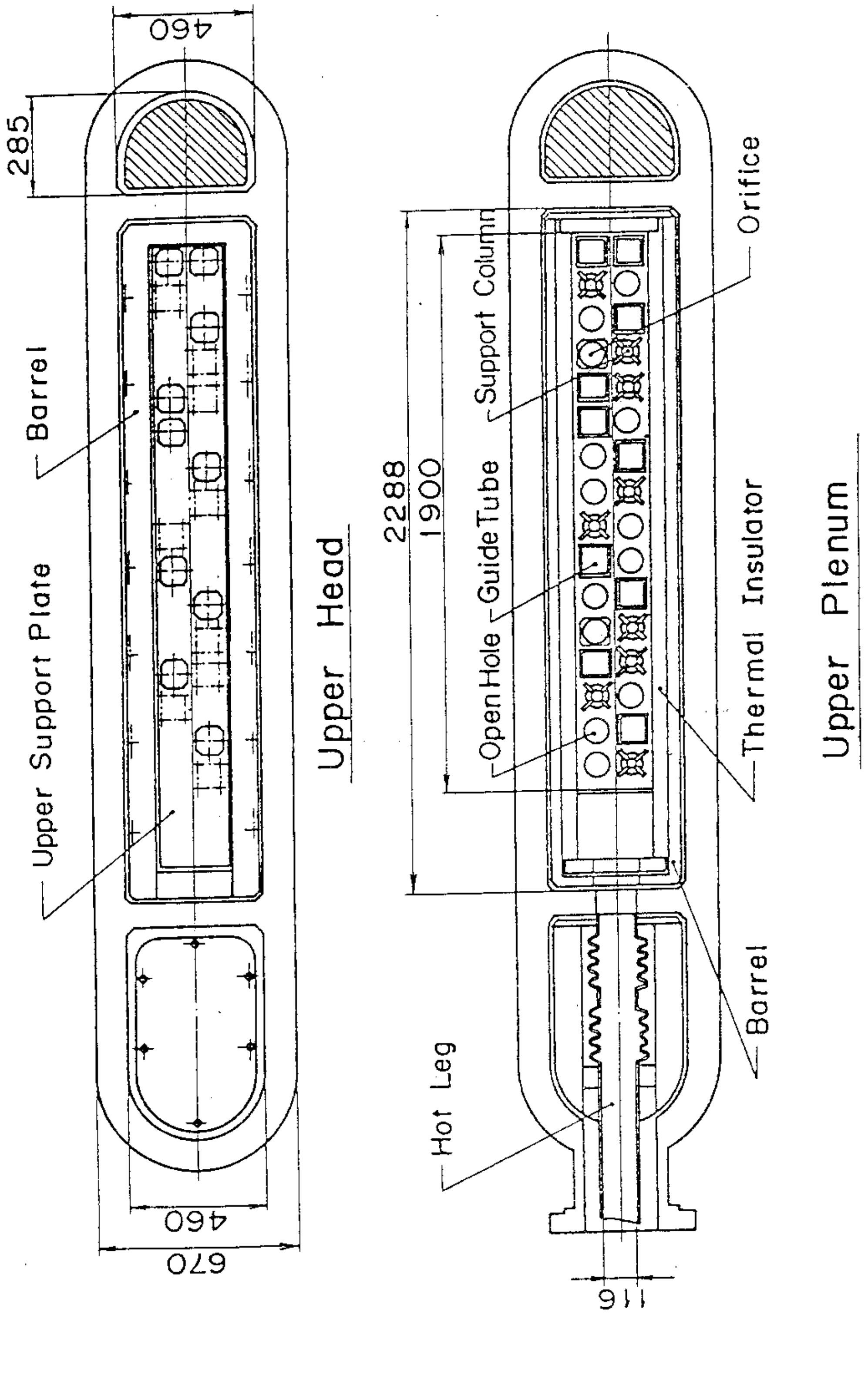


Fig.3-2 Horizontal Cross Sections of the Pressure Vessel (1)

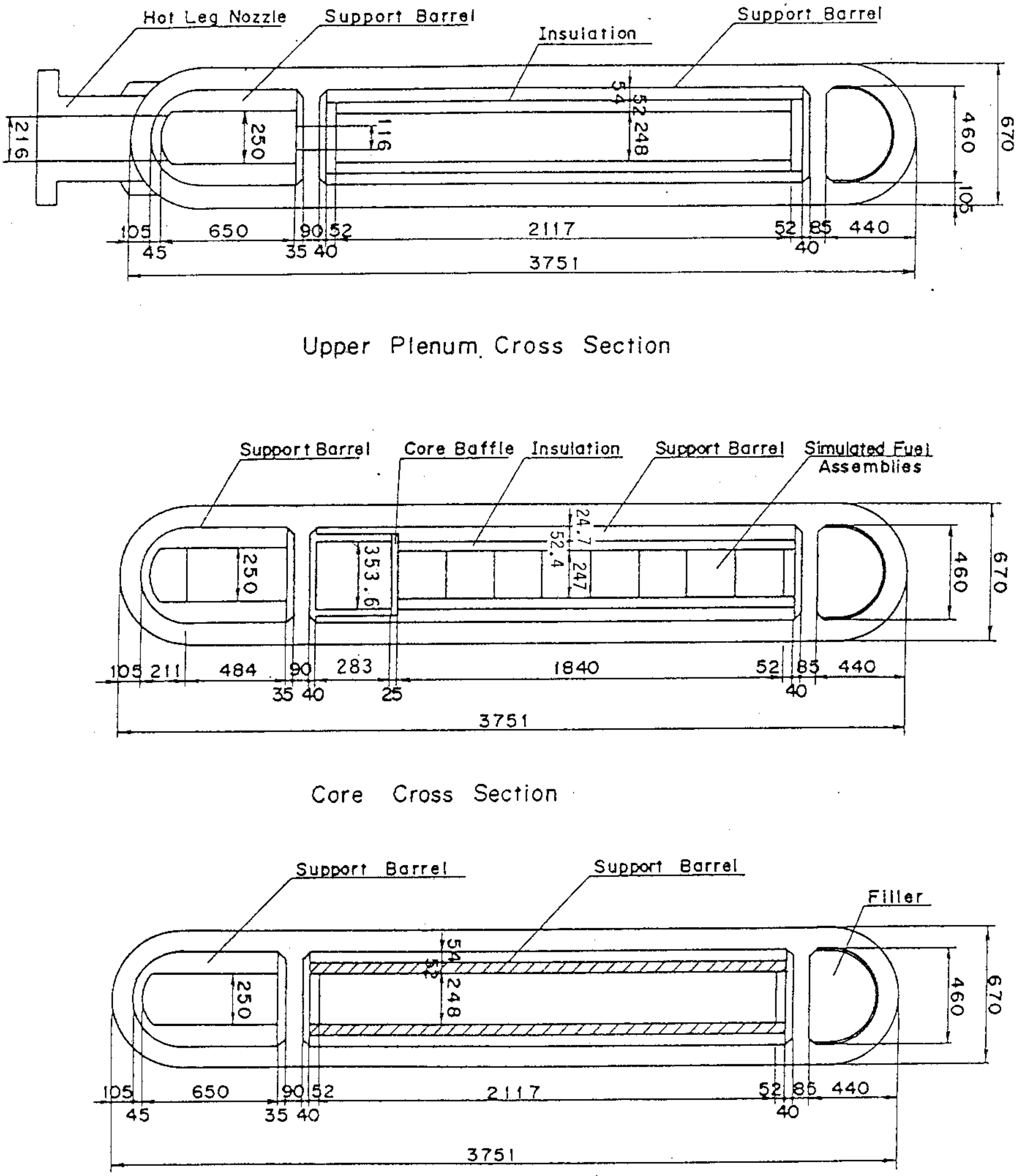


Fig.3-3 Horizontal Cross Sections of the Pressure Vessel (2)

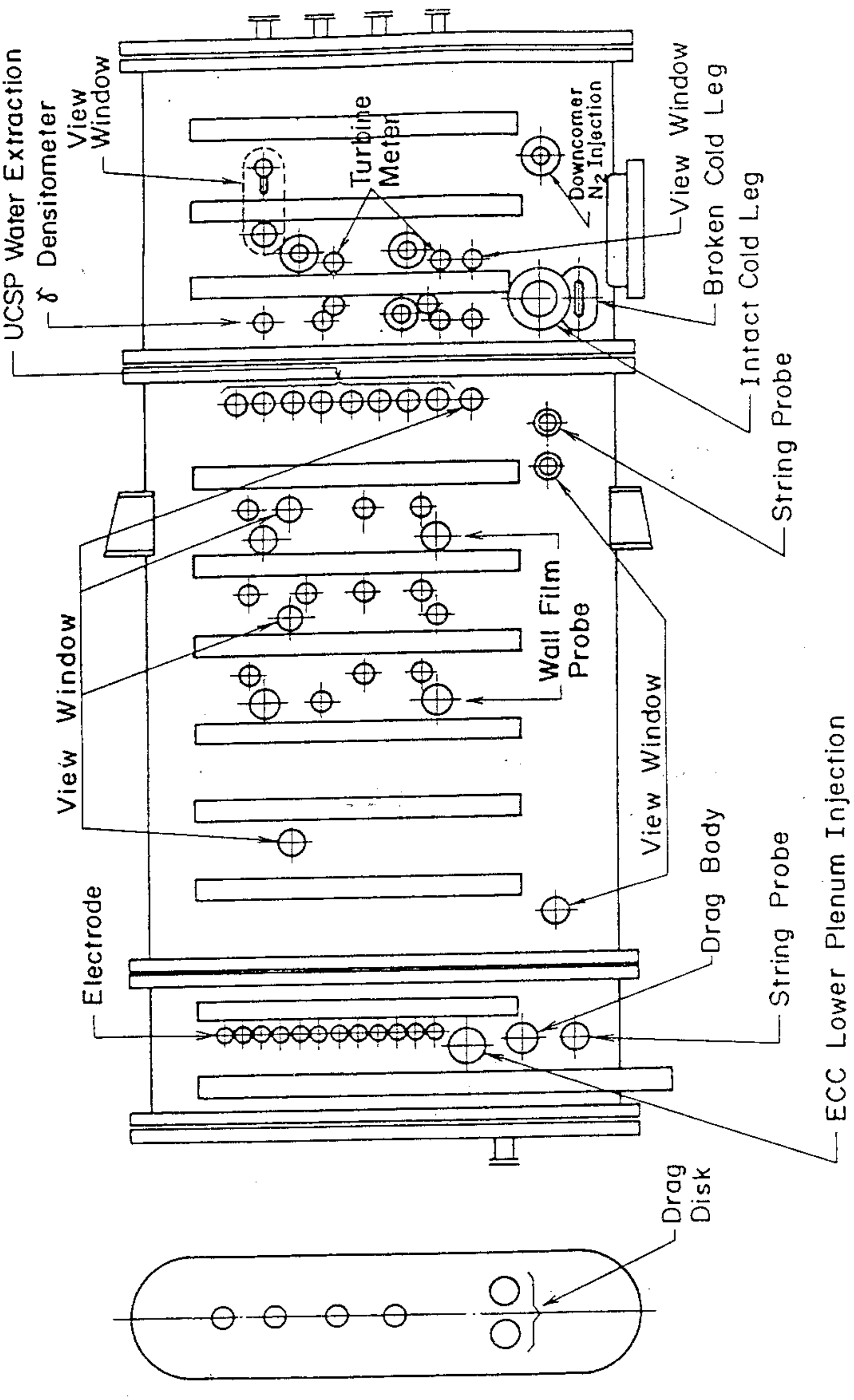


Fig.3-4 Nozzle Arrangement on the Pressure Vessel Wall (1)

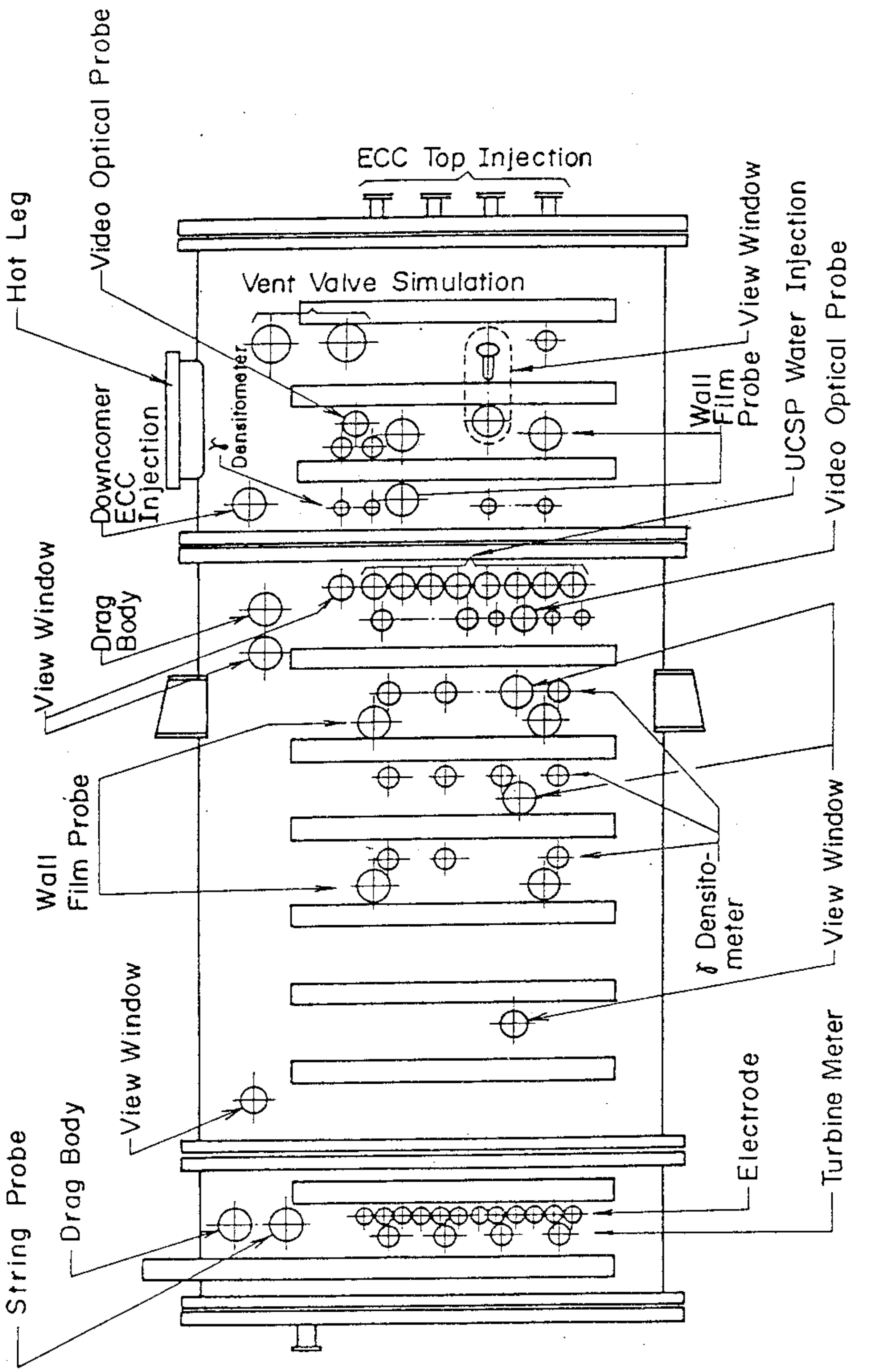


Fig.3-5 Nozzle Arrangement on the Pressure Vessel Wall (2)

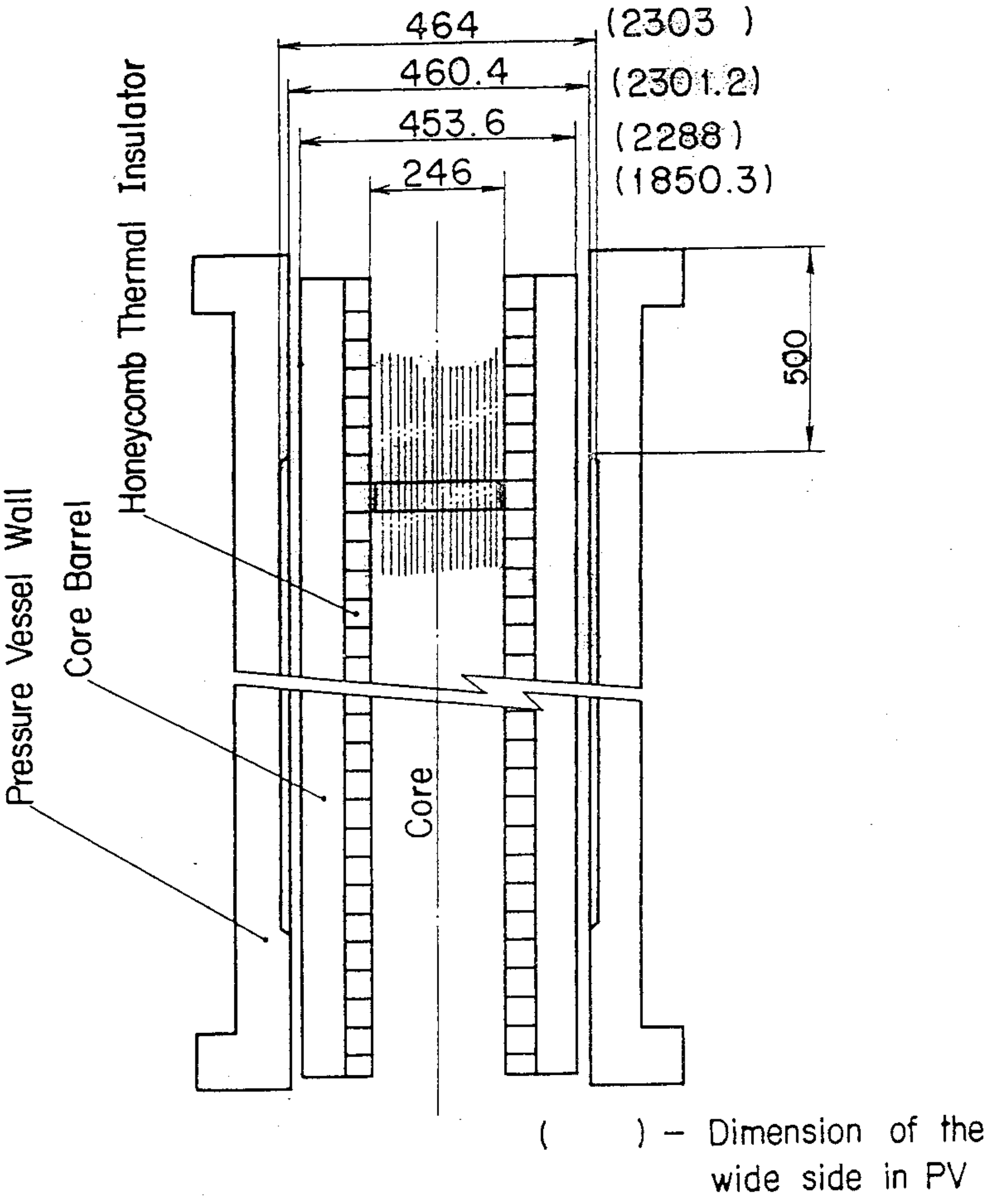


Fig.3-6 Dimension of the Gap Related to the Core Fluid Volume

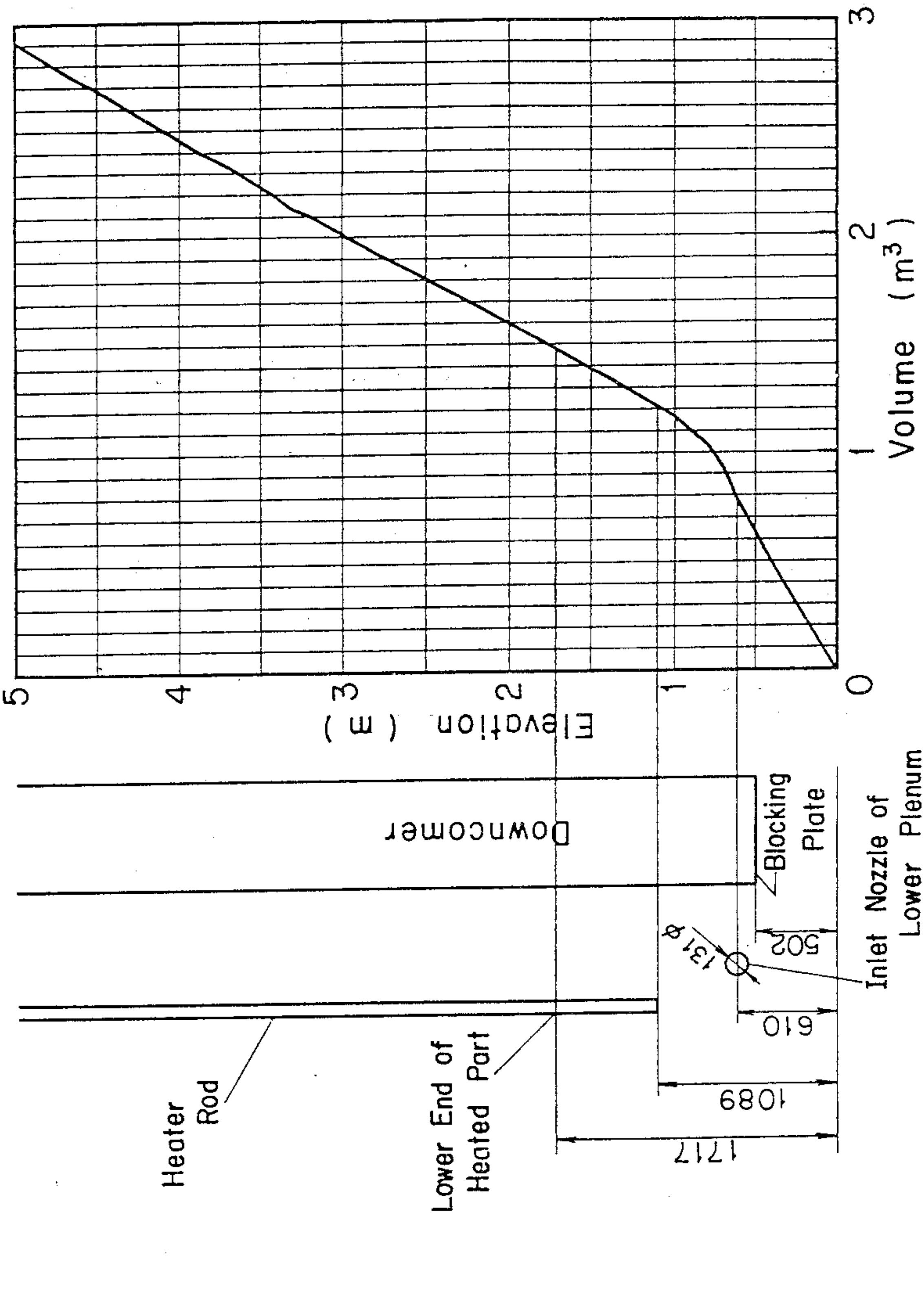


Fig.3-7 The Relationship of the Water Level and the Fluid Volume in the Pressure Vessel Excluding the Downcomer

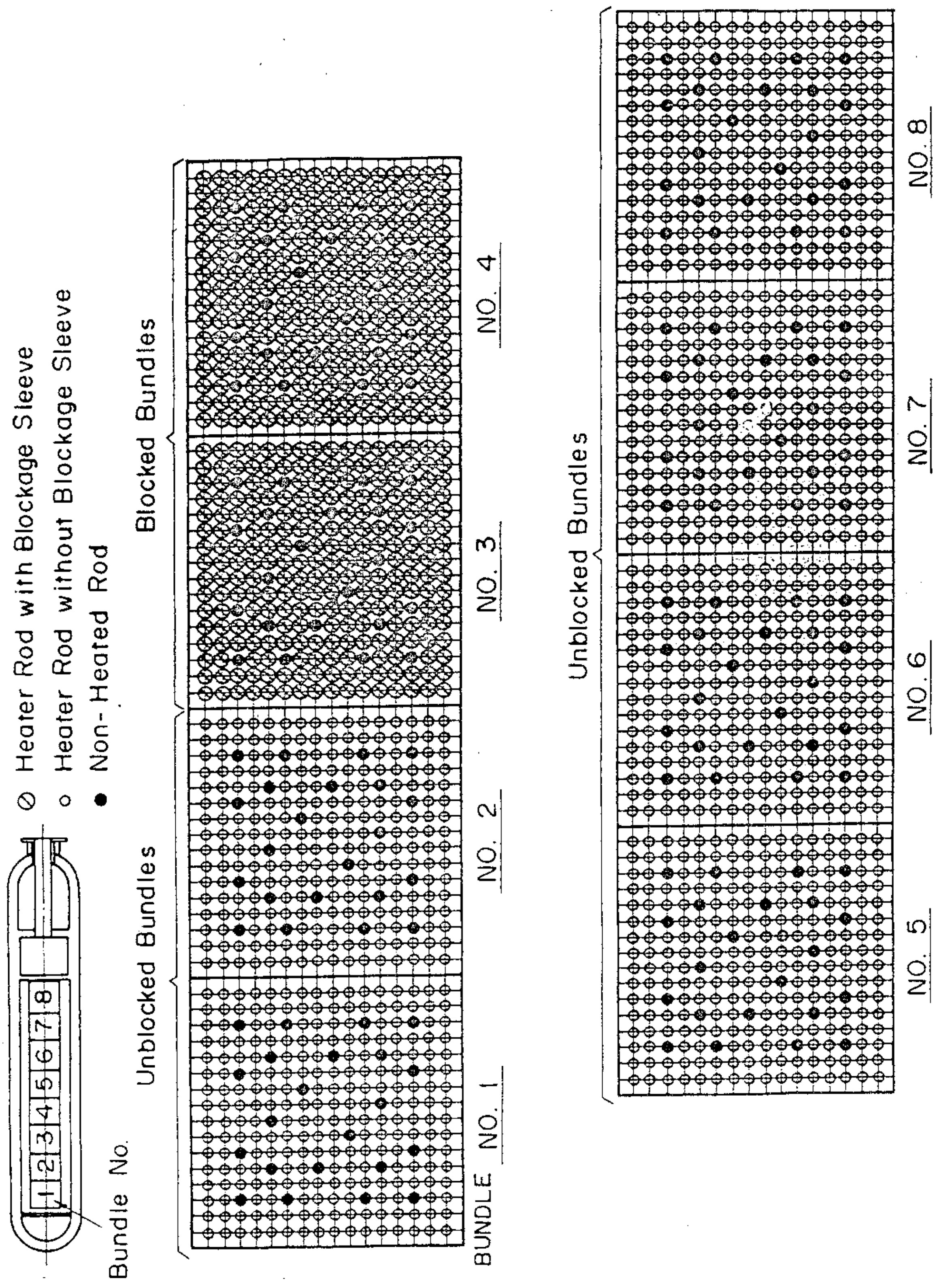


Fig.3-8 Arrangement of Heater Rod Bundles

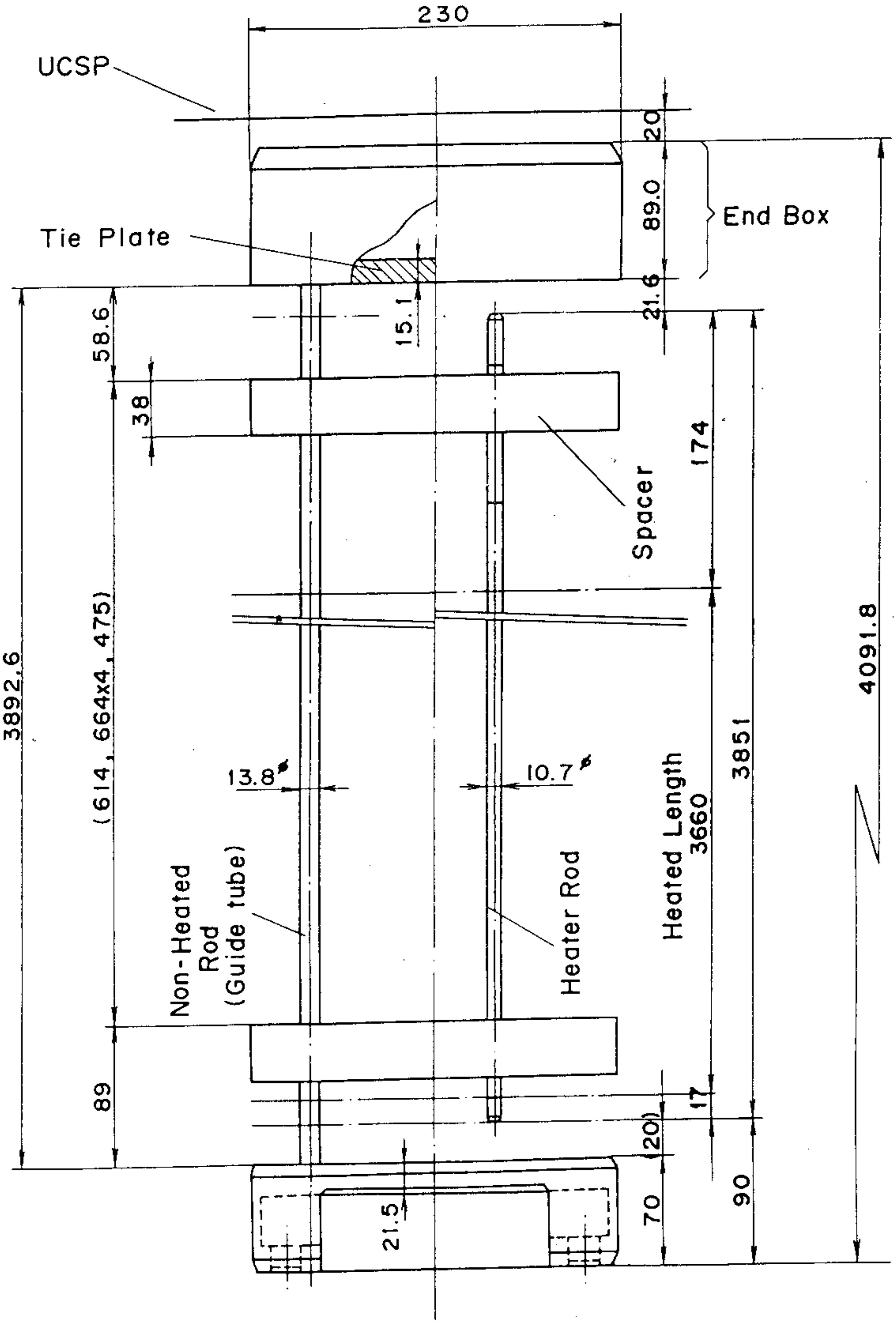


Fig.3-9 Reference Dimension of a PWR Core to Be Simulated

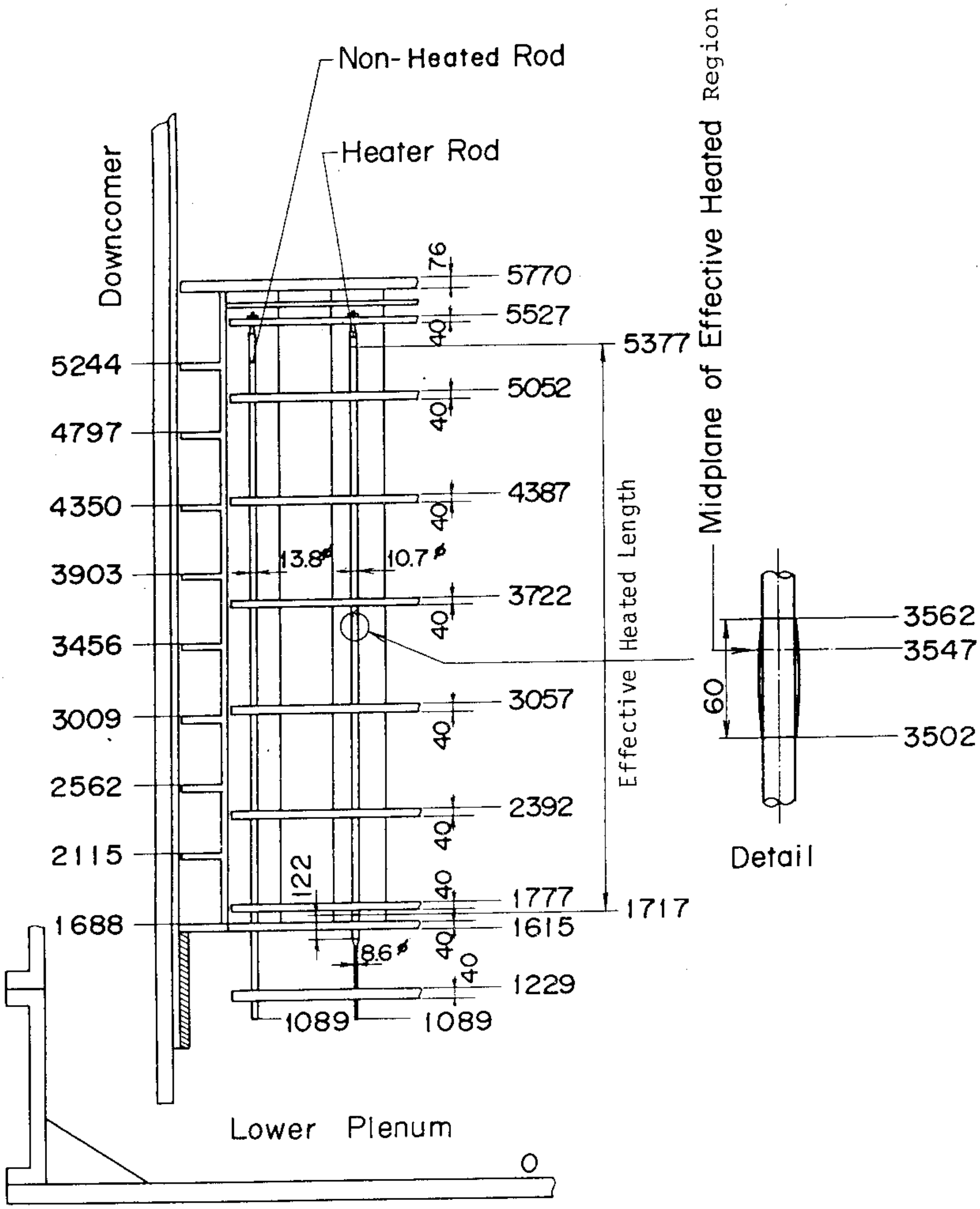


Fig.3-10 Relative Elevation and Dimension of the Core in the SCTF

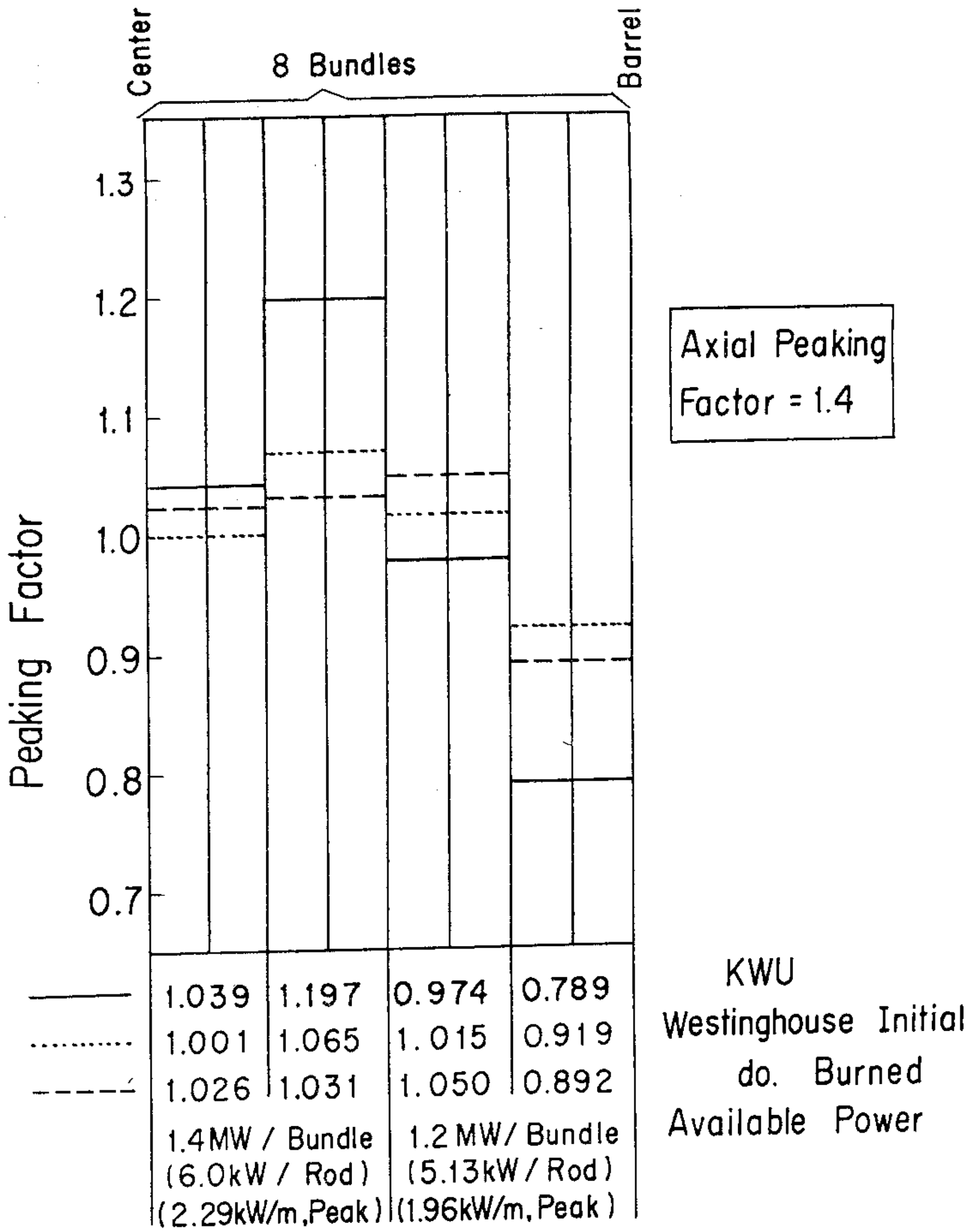


Fig.3-11 Concept of the Bundlewise Radial Power Distribution in the SCTF

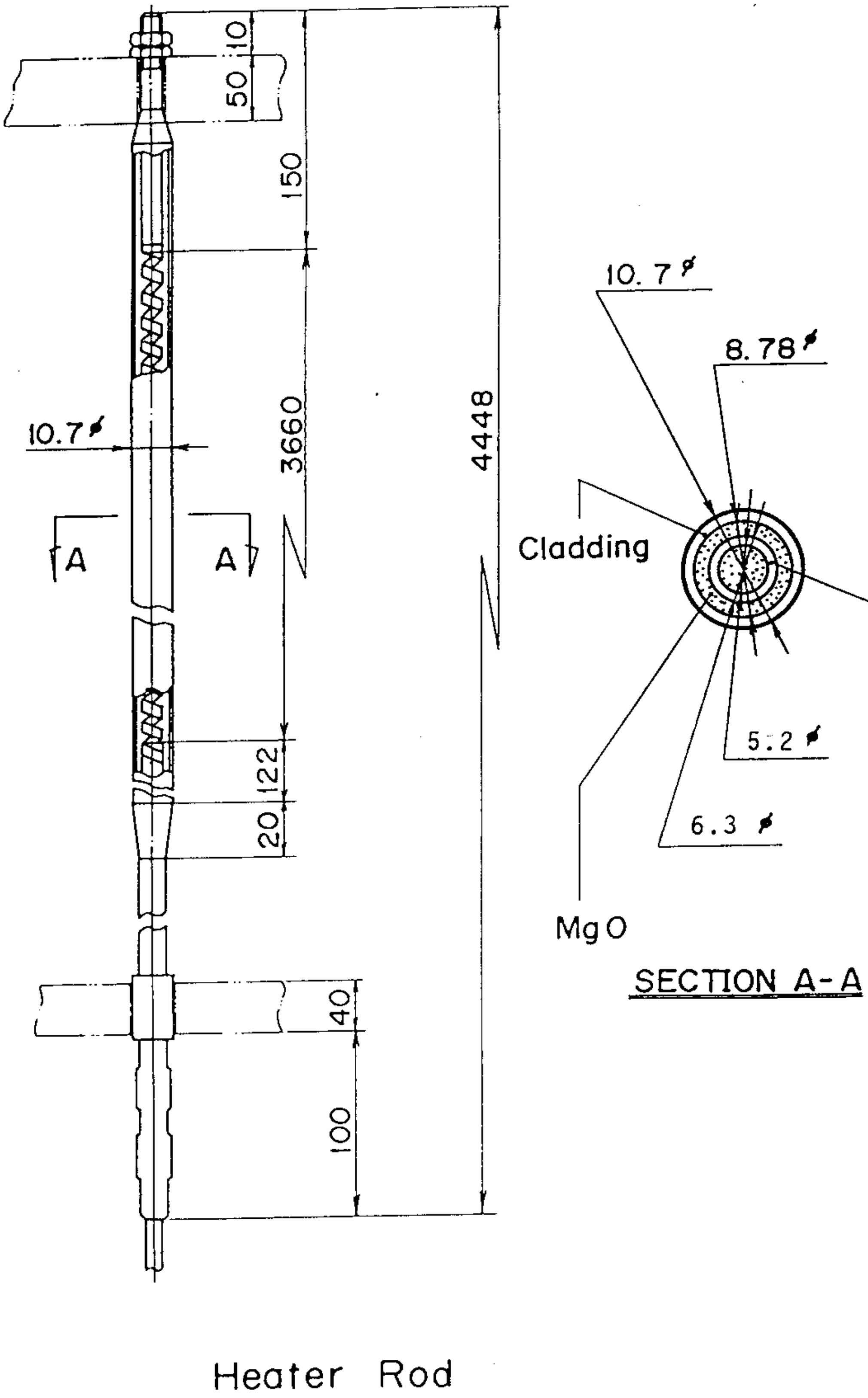


Fig.3-12 Dimension and Configuration of Heater Rods

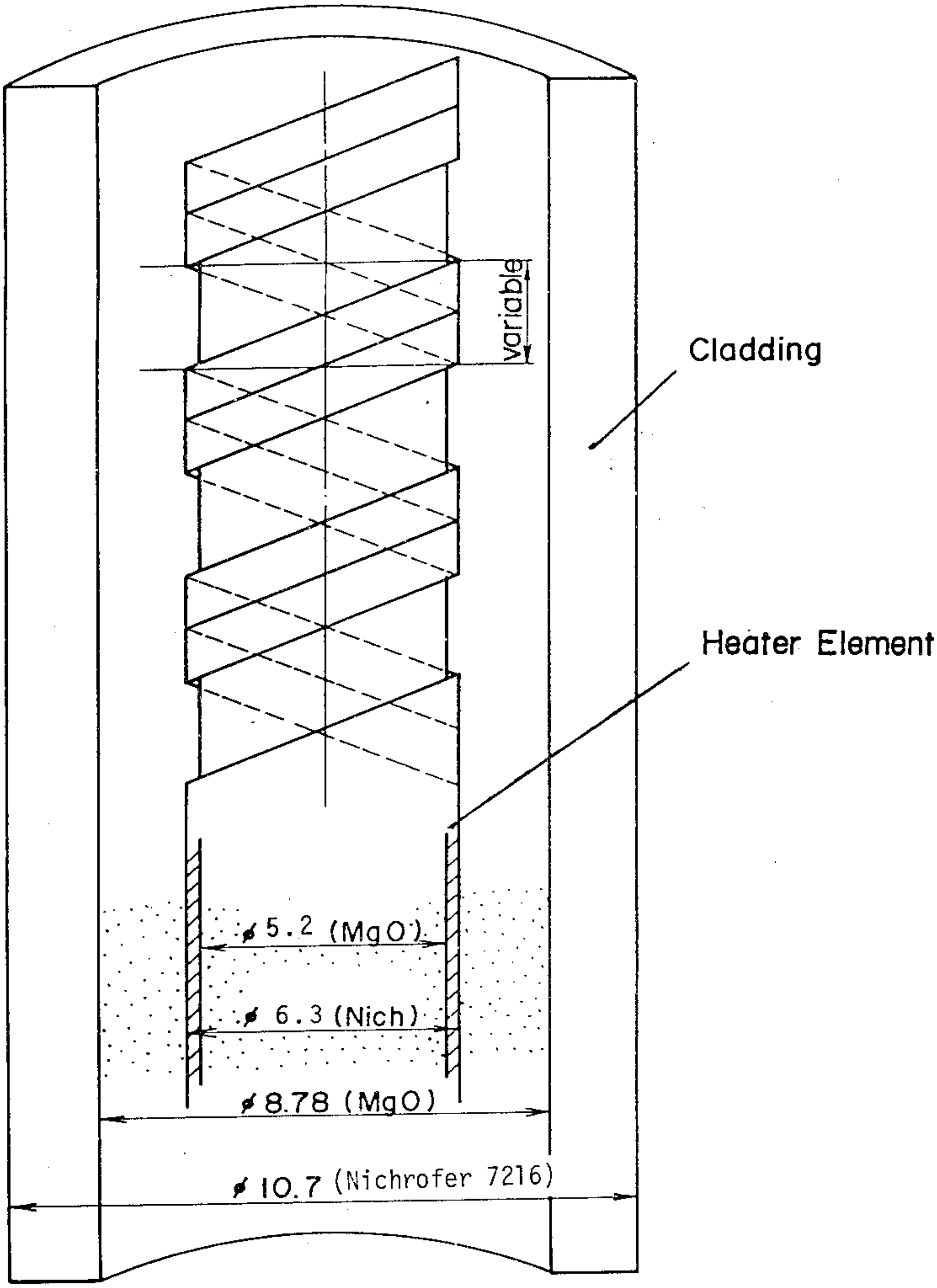


Fig.3-13 Cross Section of Heated Part of Heater Rods

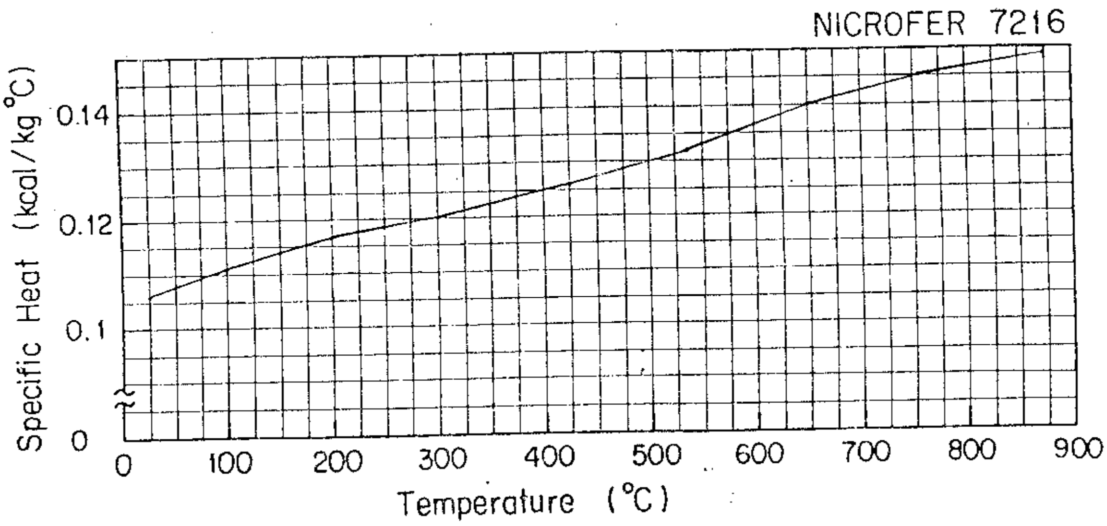


Fig.3-14 Specific Heat of Heater Rod Cladding

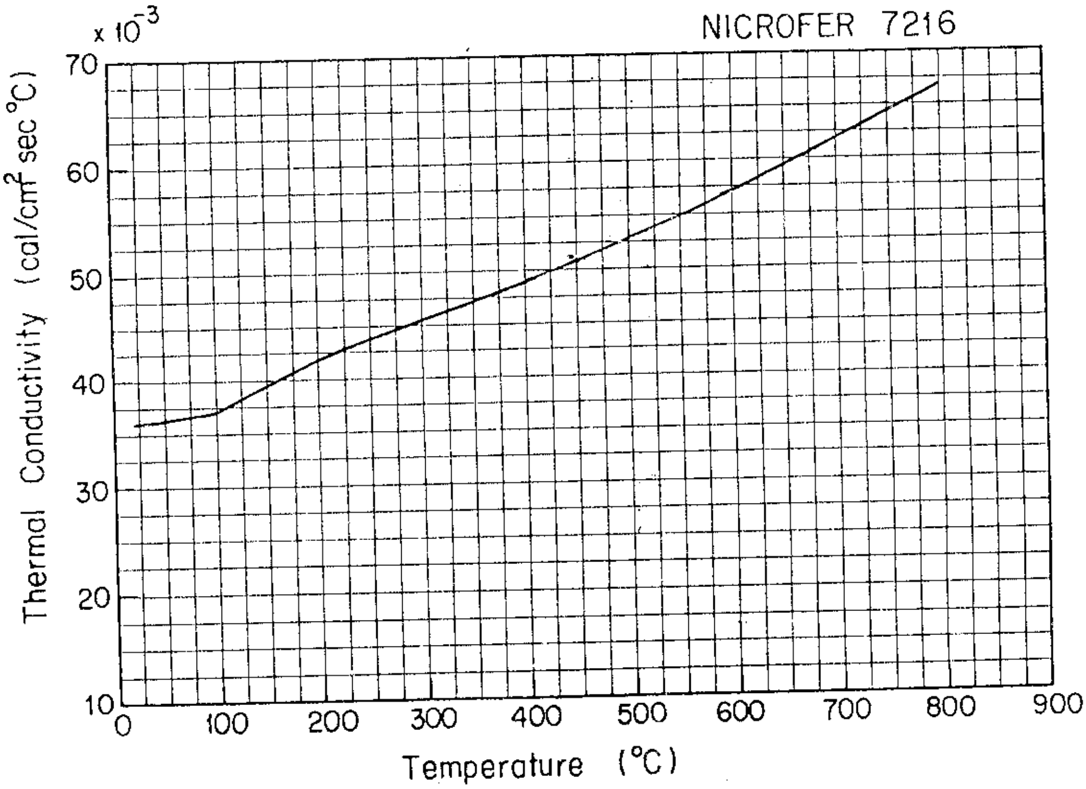


Fig.3-15 Thermal Conductivity of Heater Rod Cladding

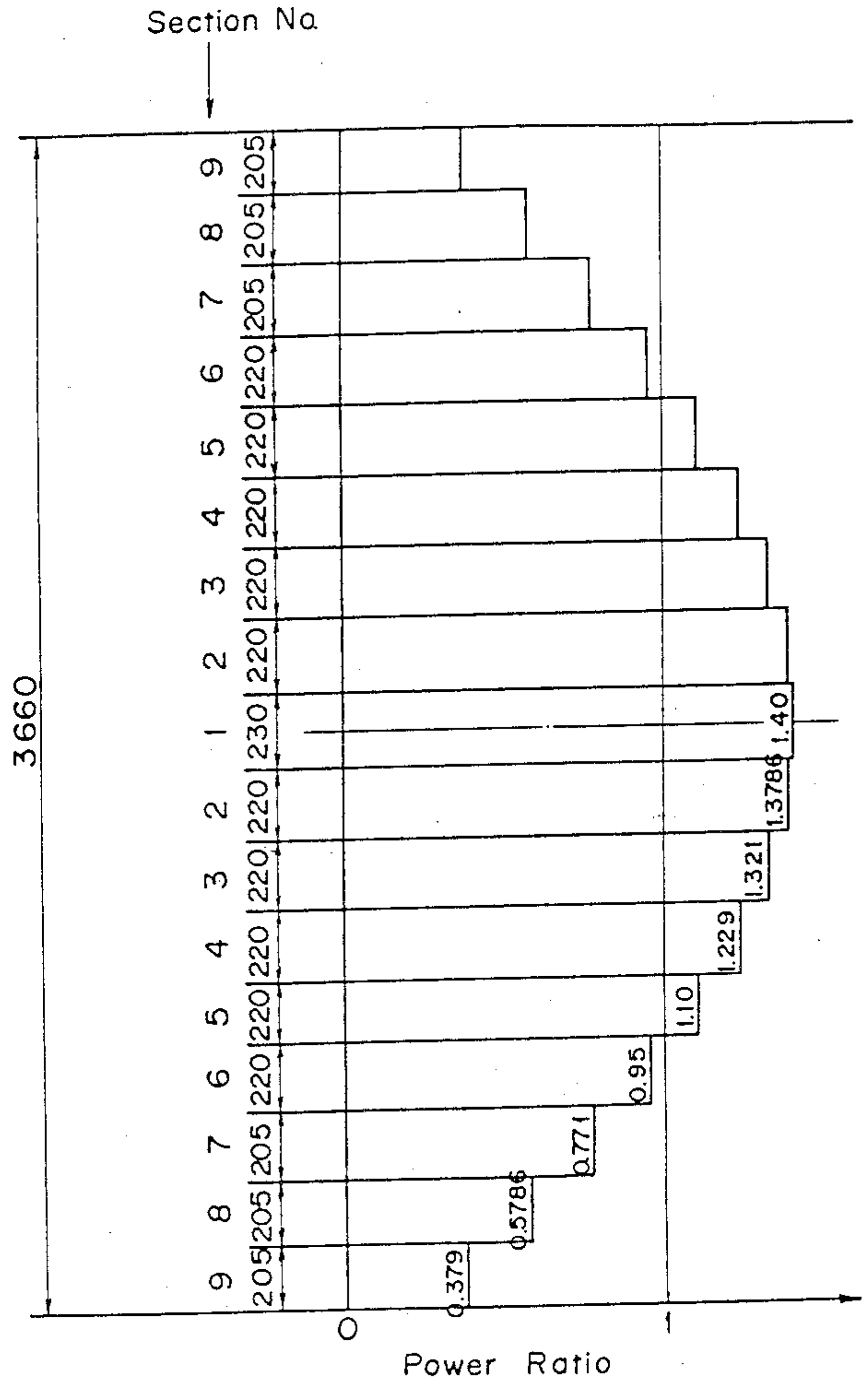


Fig.3-16 Axial Power Distribution of Heater Rods

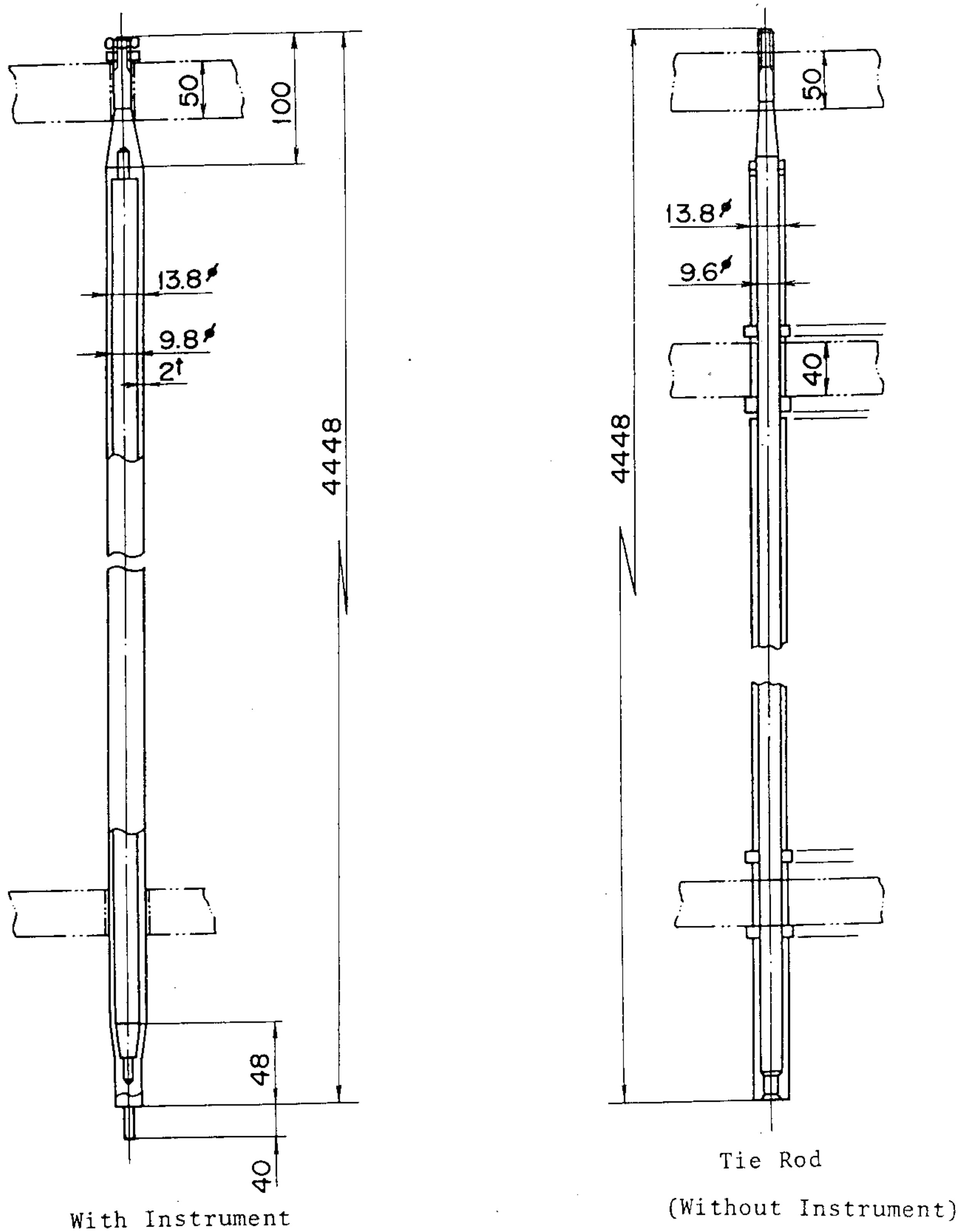


Fig.3-17 Configuration and Dimension of Non-Heated Rods

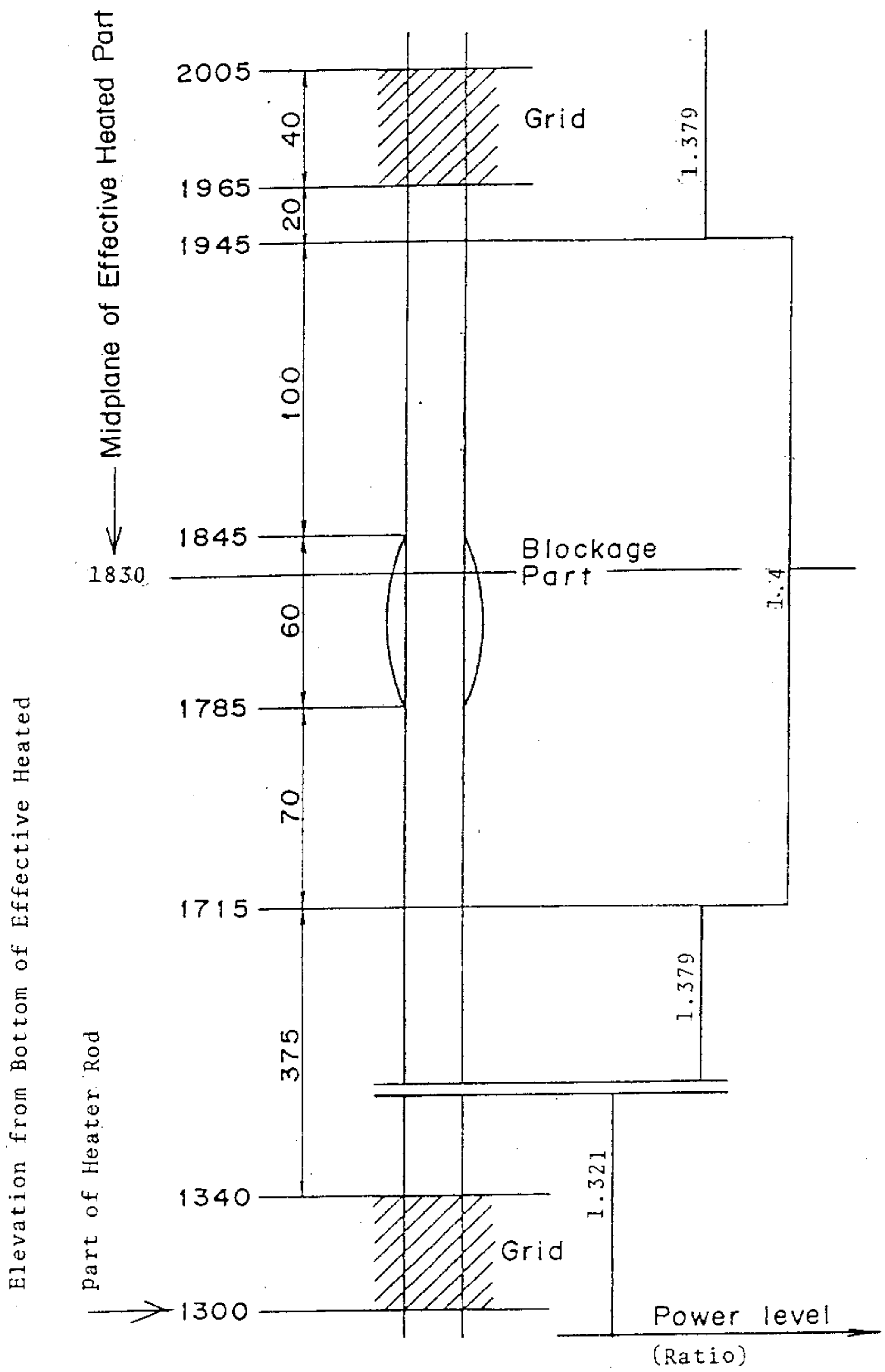


Fig.3-18 Location of Blockage Sleeves Attached on the Heater Rods

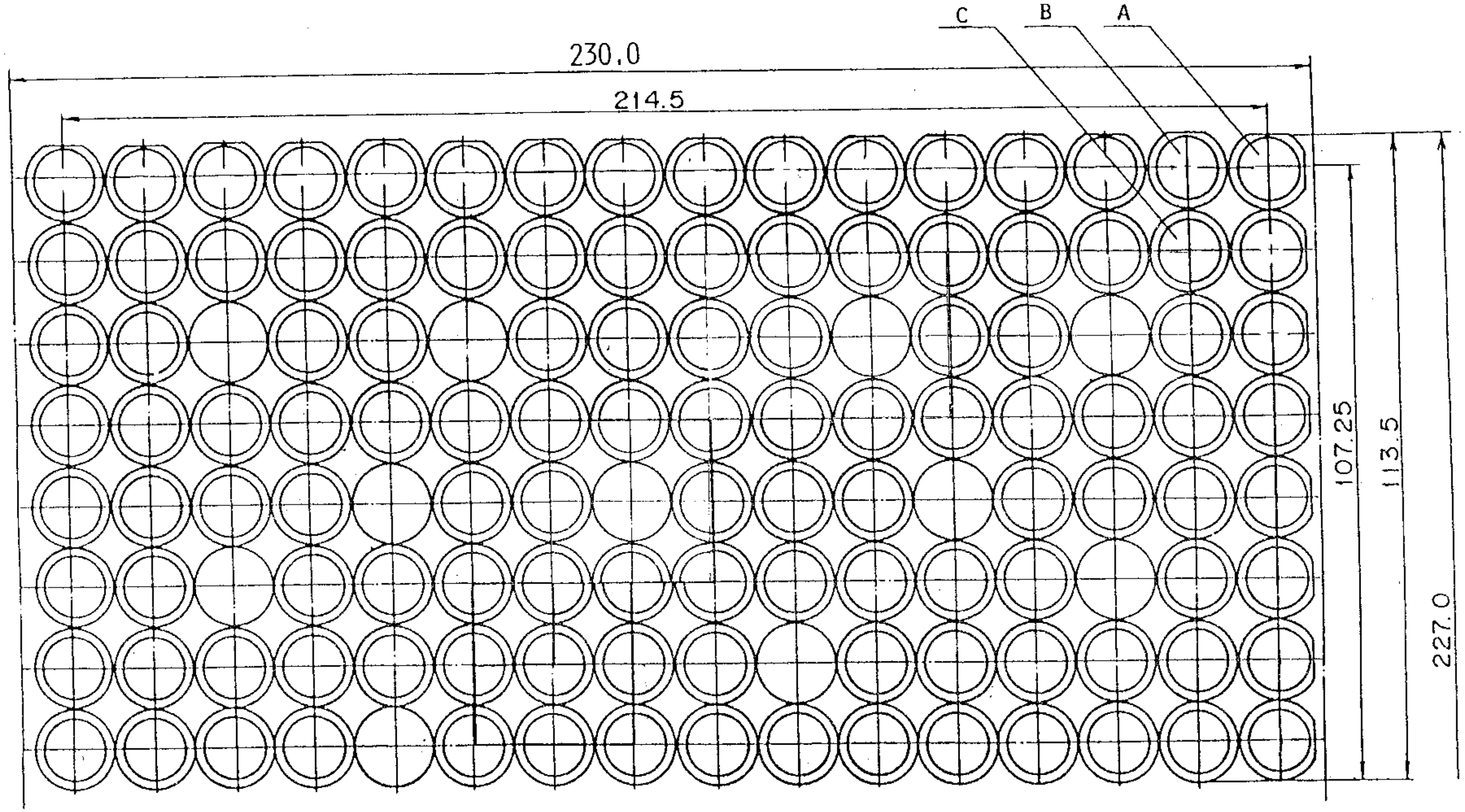


Fig.3-19 Arrangement of the Heater Rods with Three Kinds of Blockage Sleeve

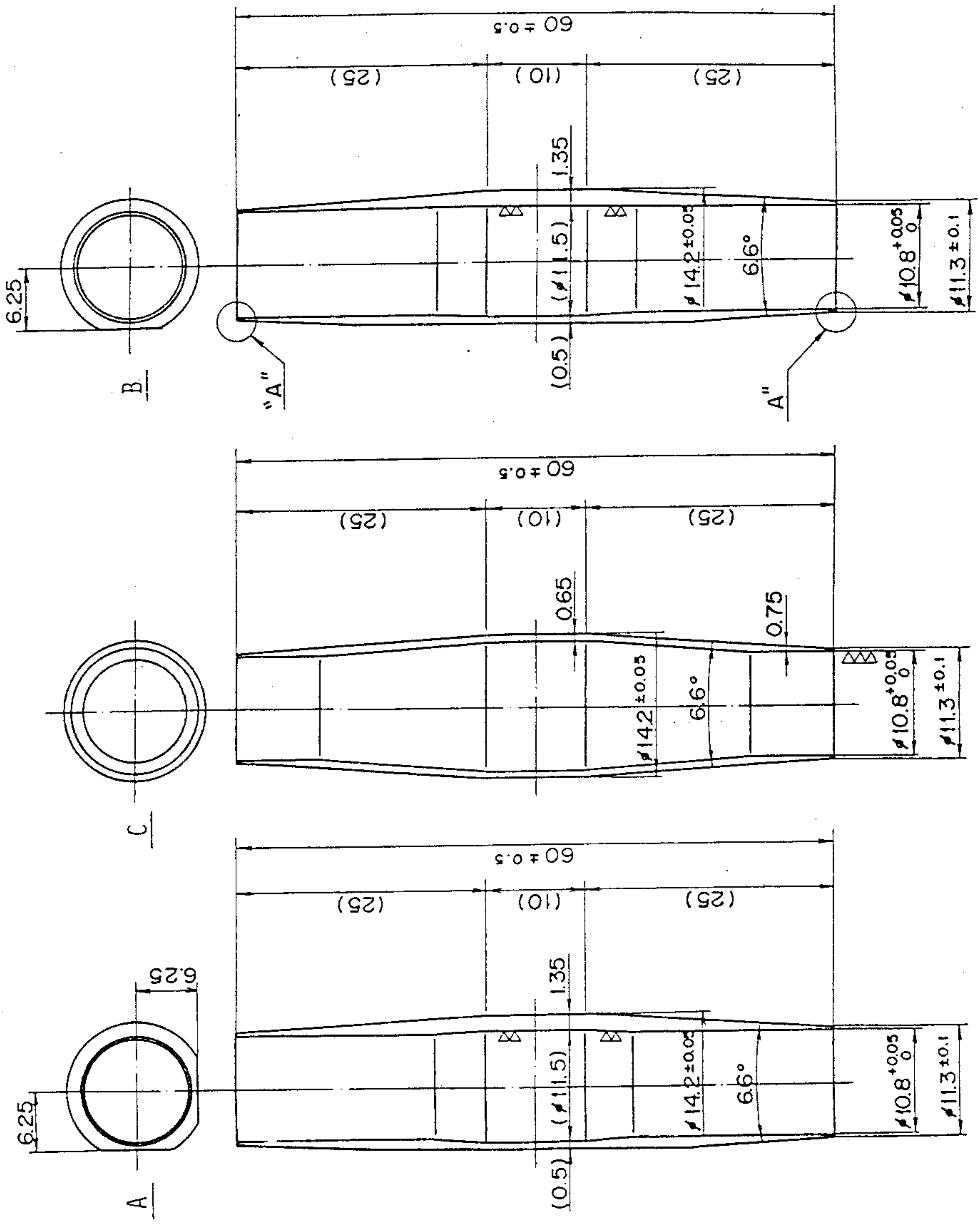


Fig.3-20 Configuration and Dimension of the Three Kinds of Blockage Sleeve

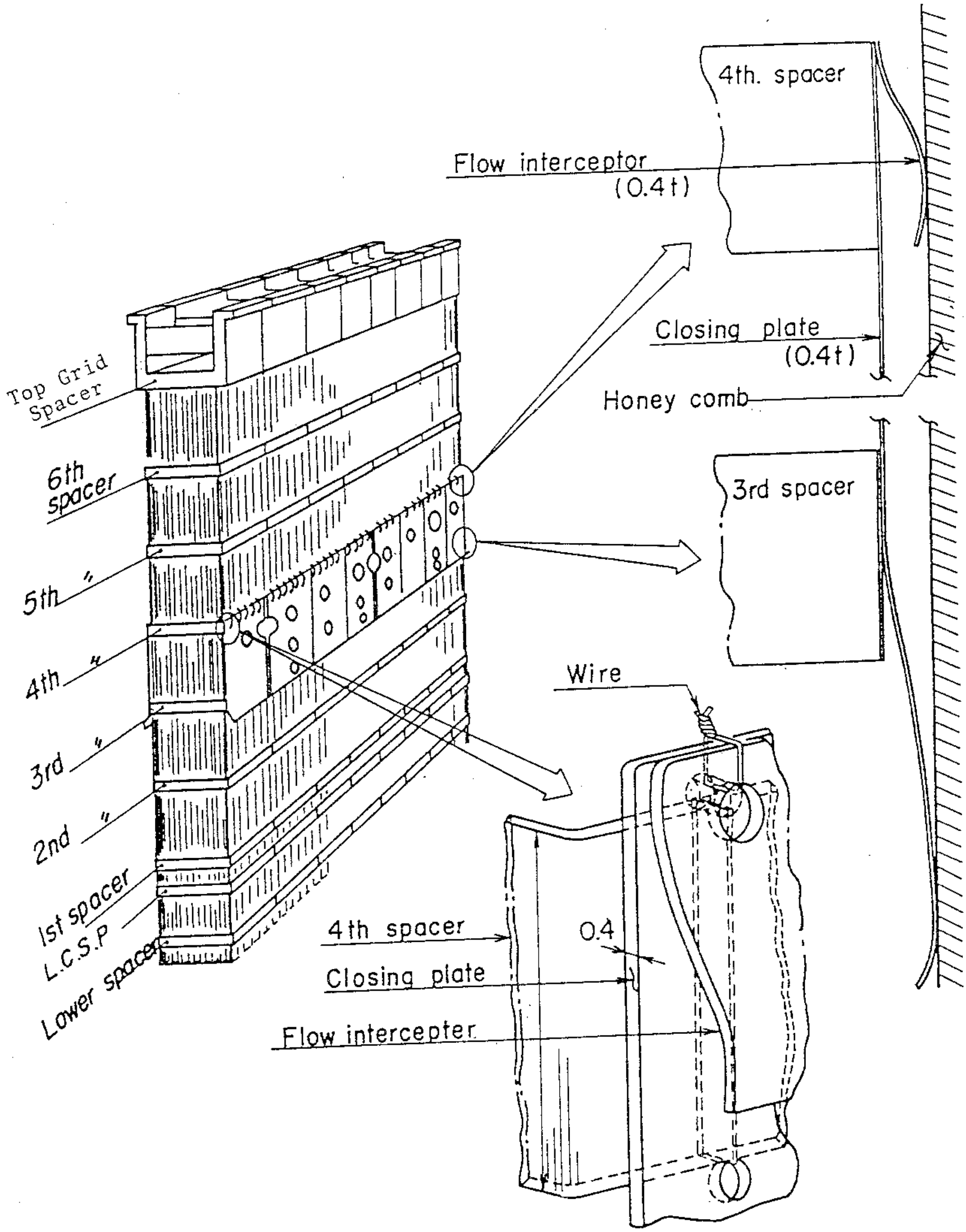


Fig.3-21 Trimetric View of Core with Closing Plates and Flow Intercepters

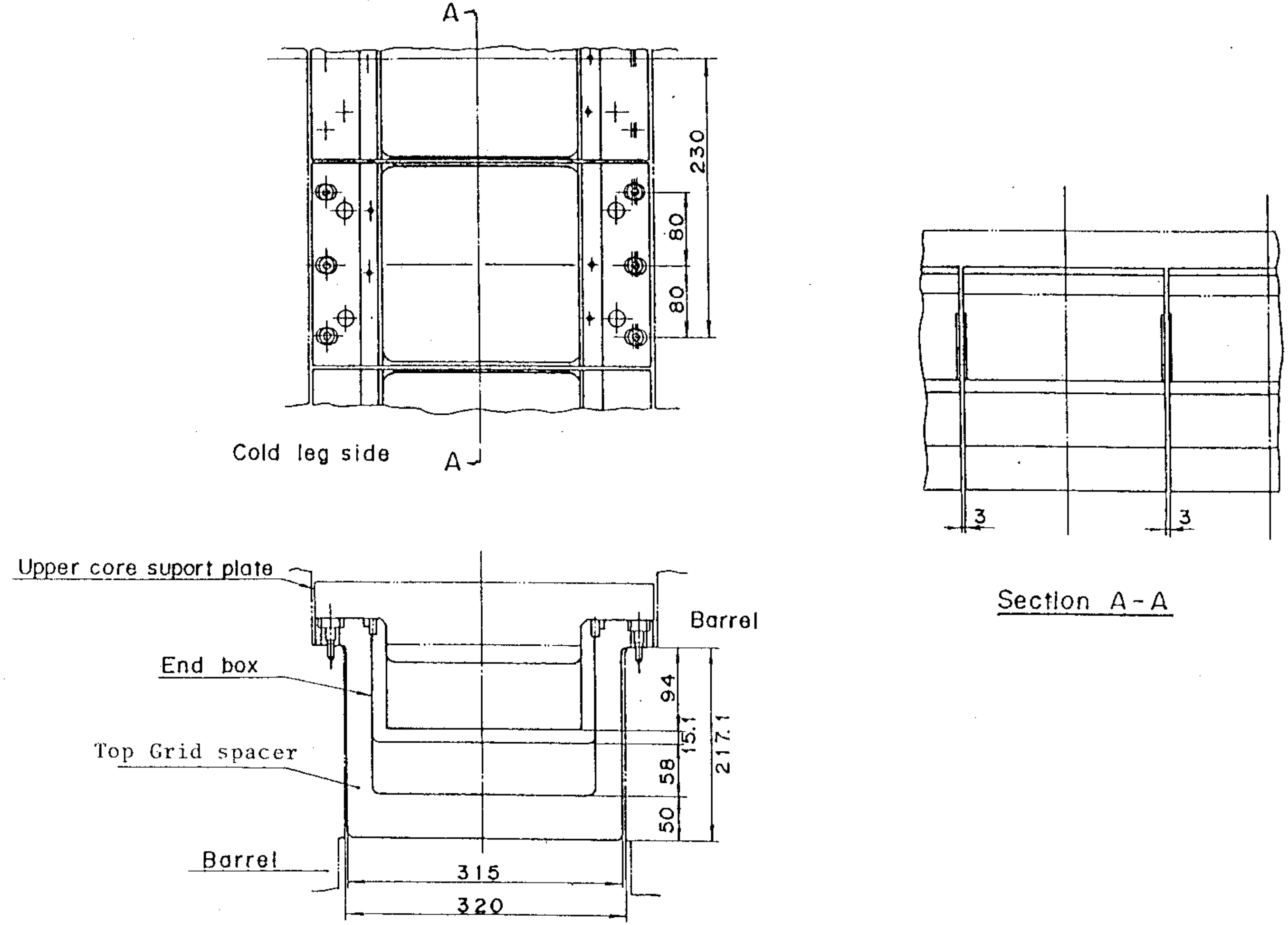


Fig.3-22 Arrangement and Principal Dimension of End Boxes and Top Grid Spacers

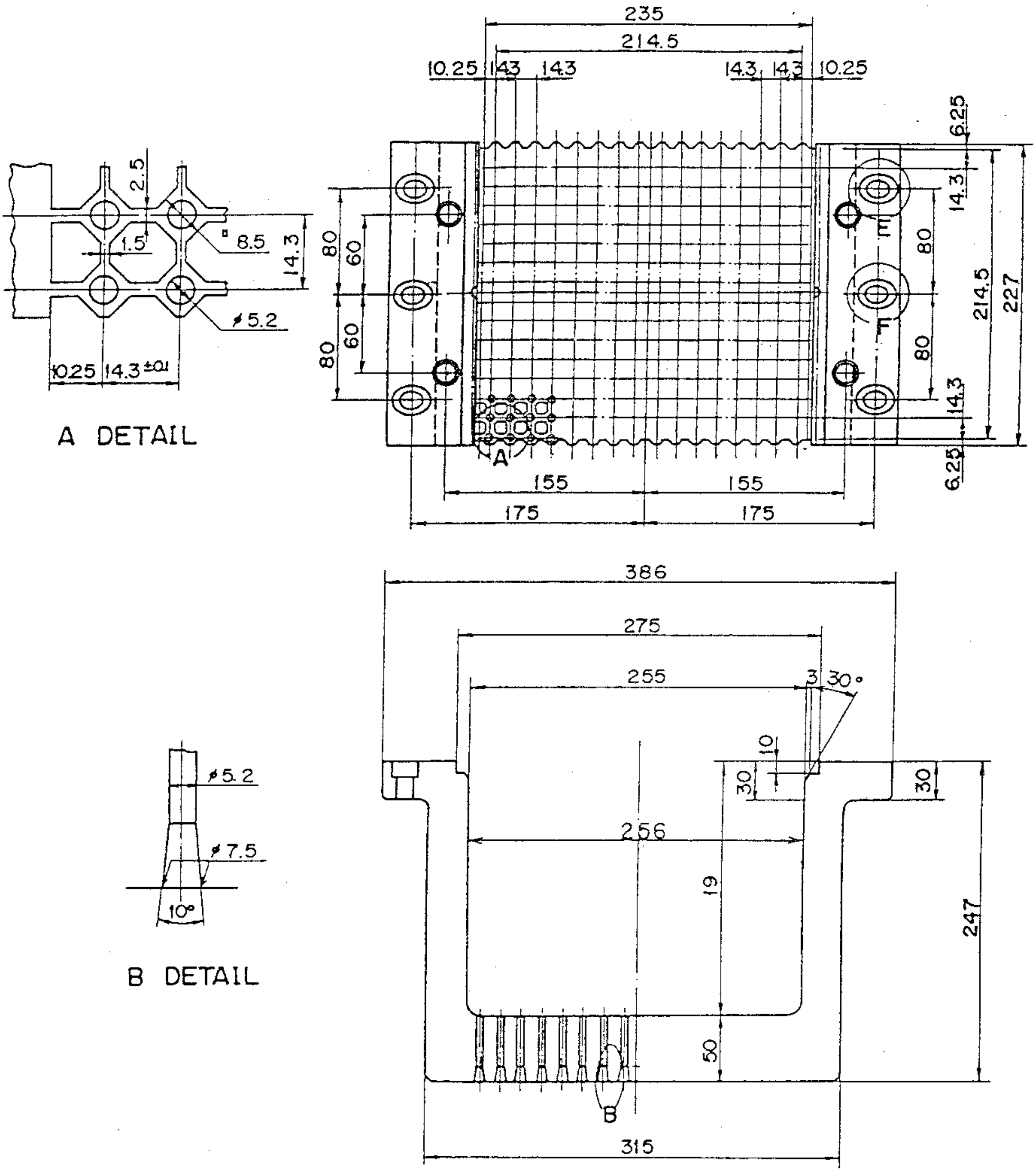


Fig.3-23 Dimension of Top Grid Spacers

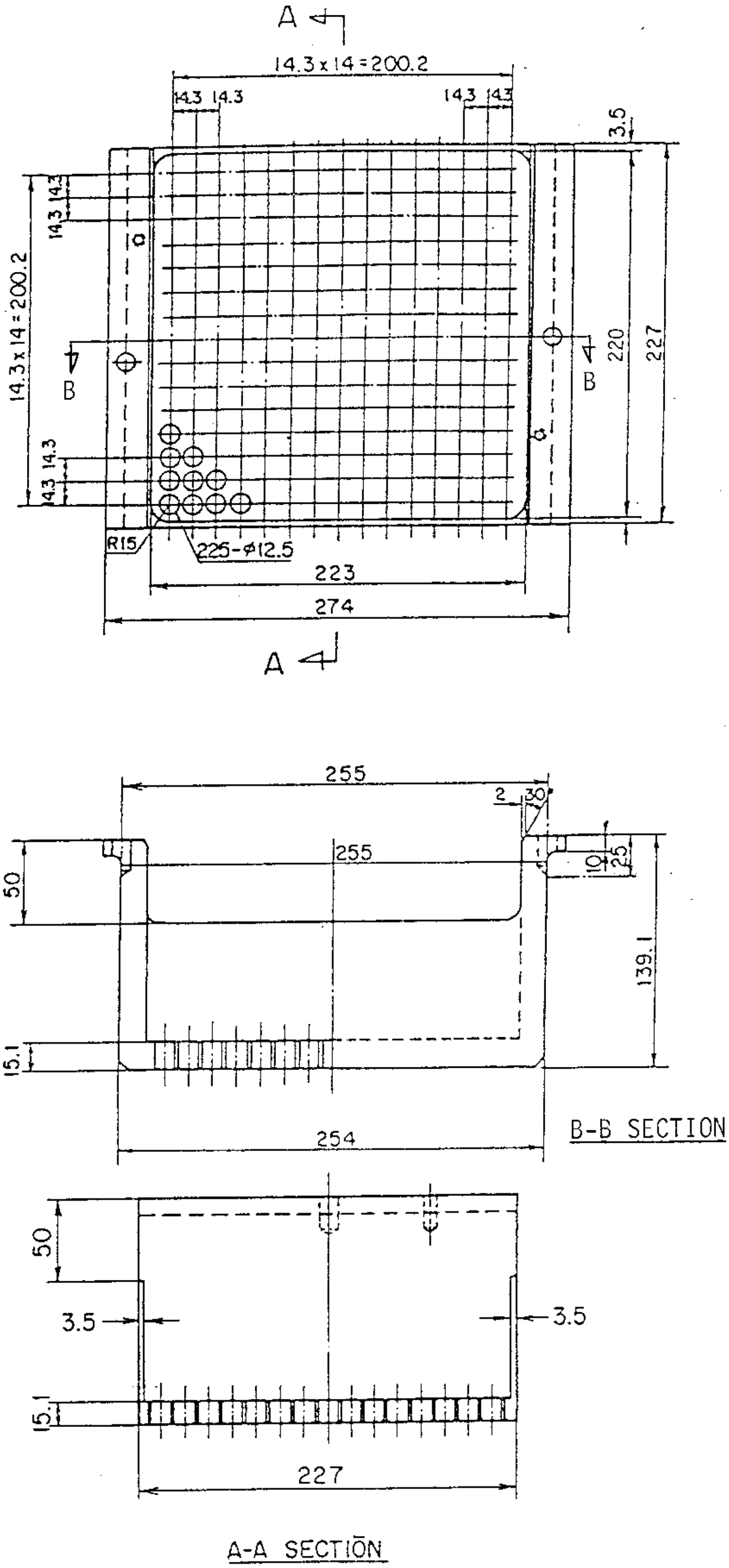


Fig.3-24 Dimension of End Boxes

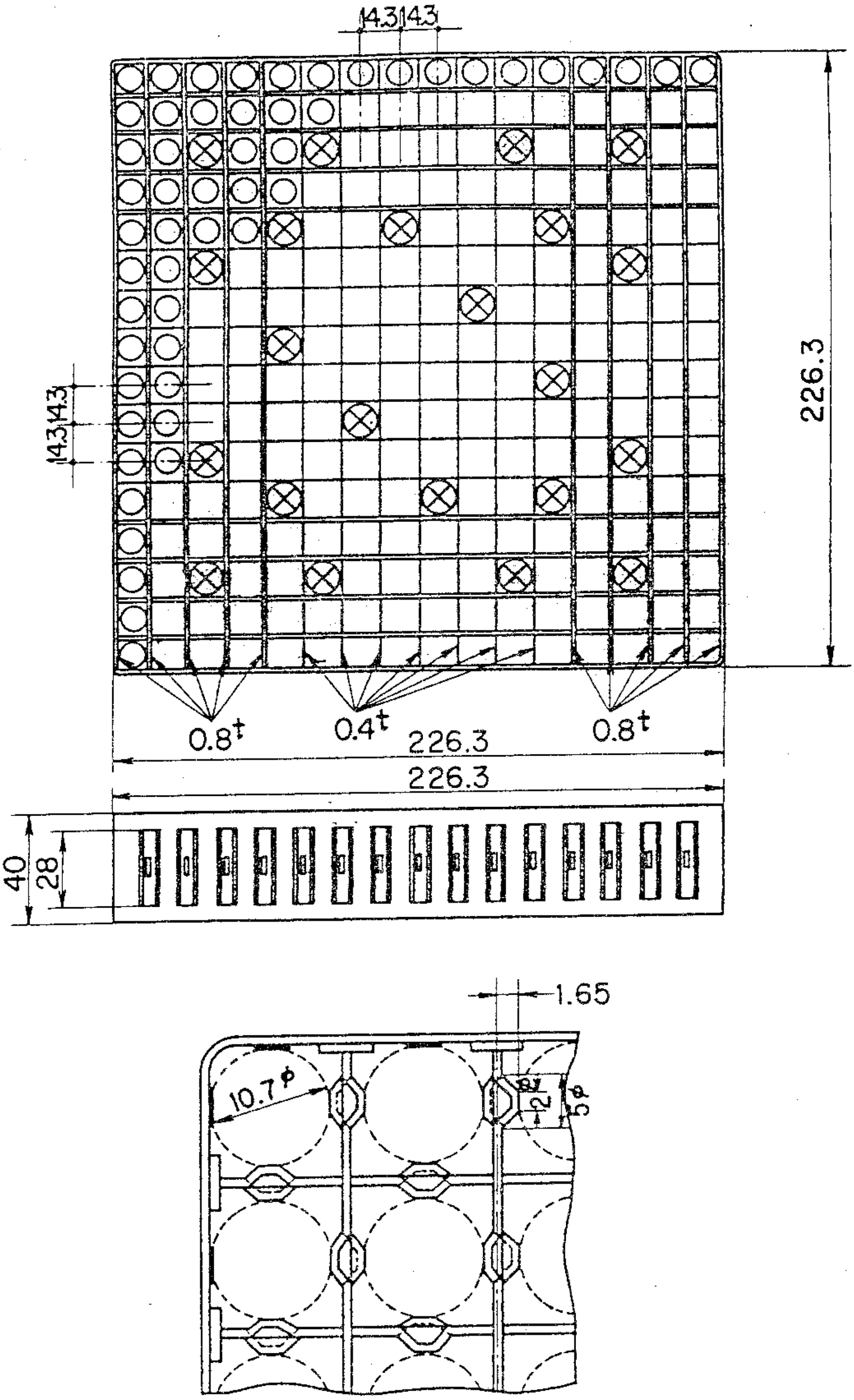
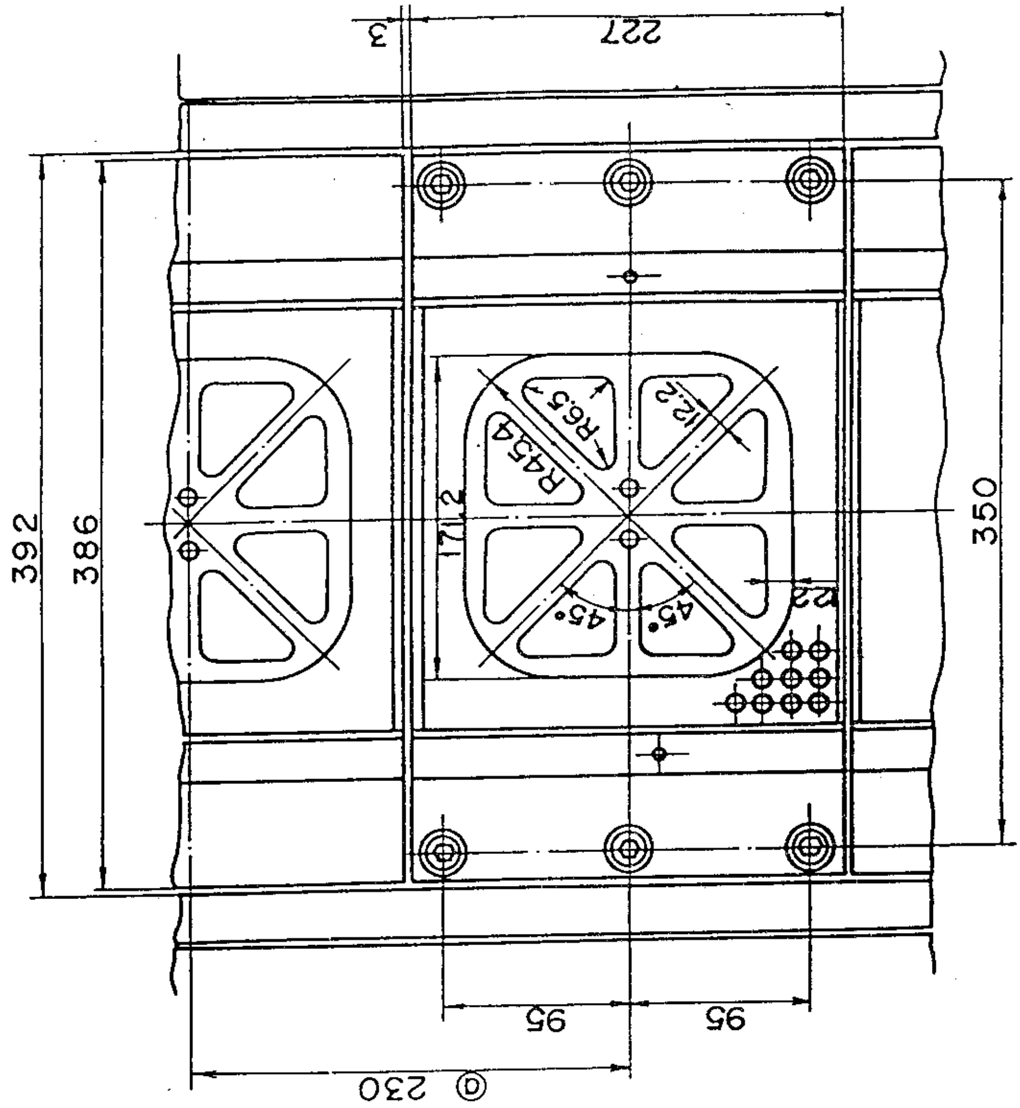


Fig.3-25 Dimension of Spacers except for Top Grid Spacers



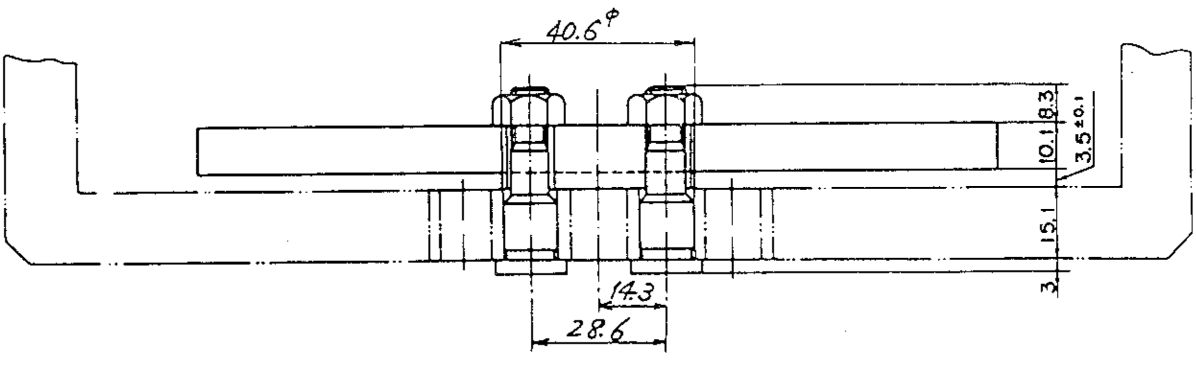


Fig.3-26 Configuration and Arrangement of Plugging Devices above Tie Plates

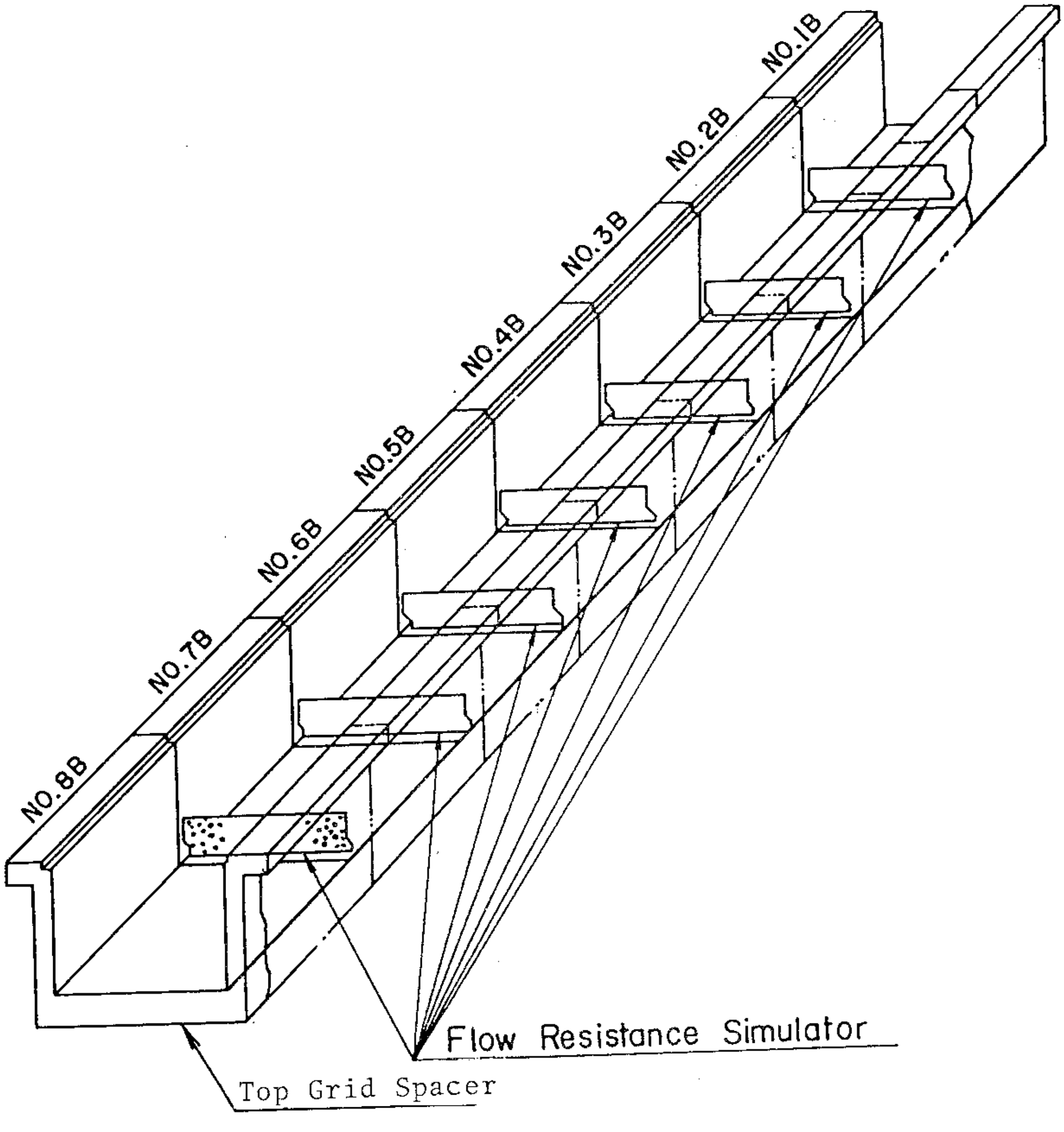


Fig.3-27 Concept of Cross-Flow Resistance Simulators above the Top Grid Spacers

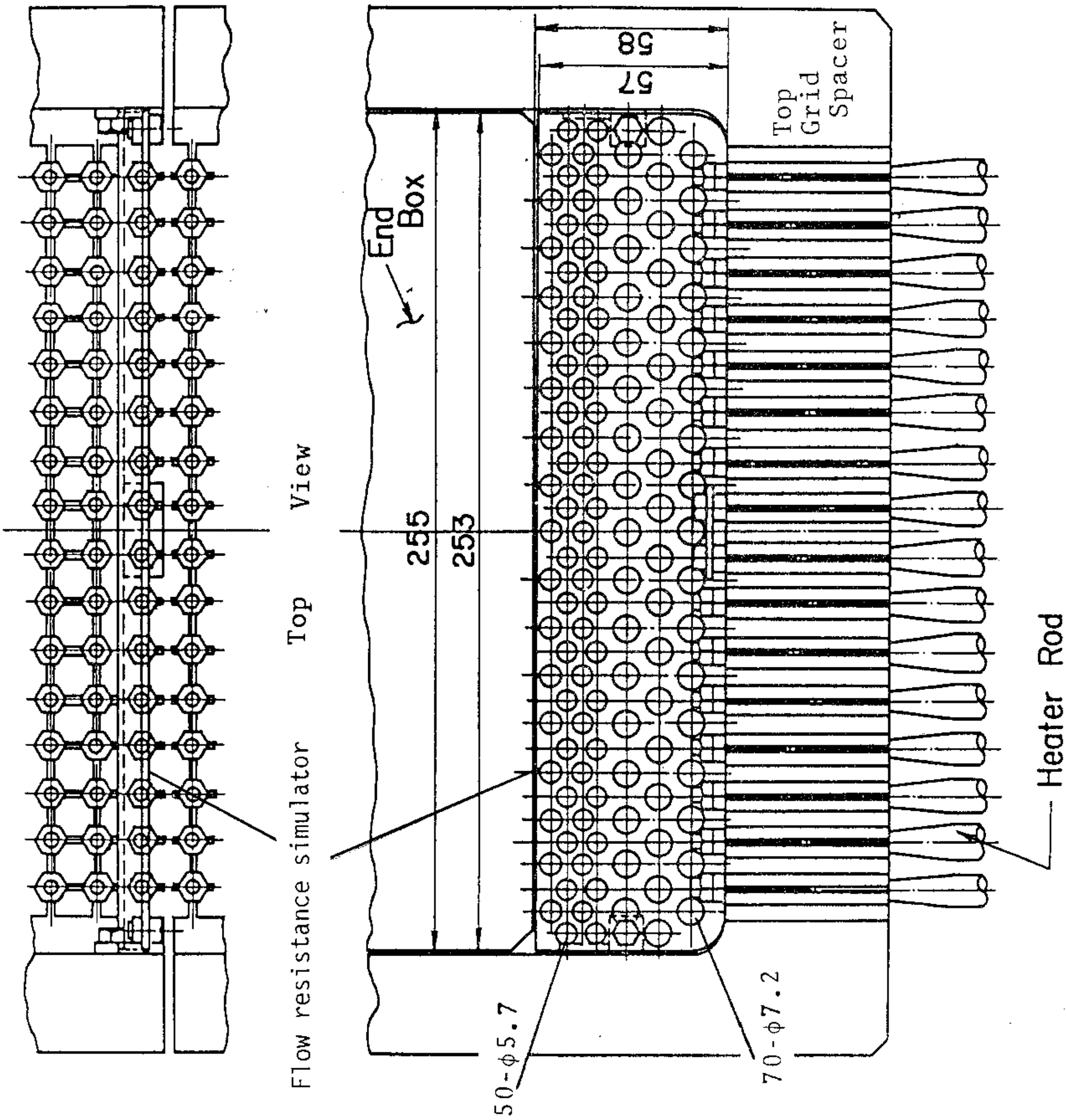


Fig.3-28 Dimension of Cross-Flow Resistance Simulators

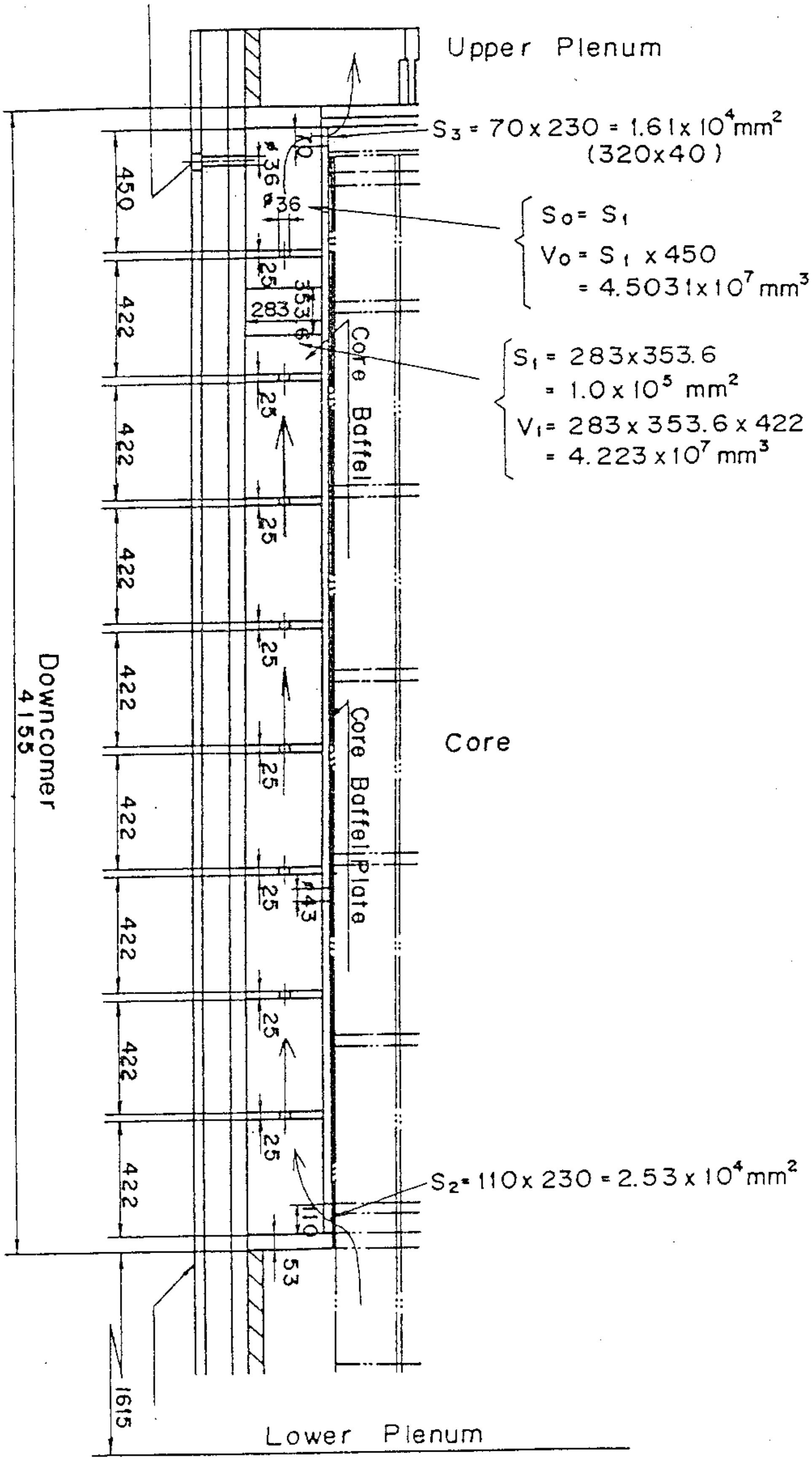


Fig.3-29 Dimension of Core Baffle Region

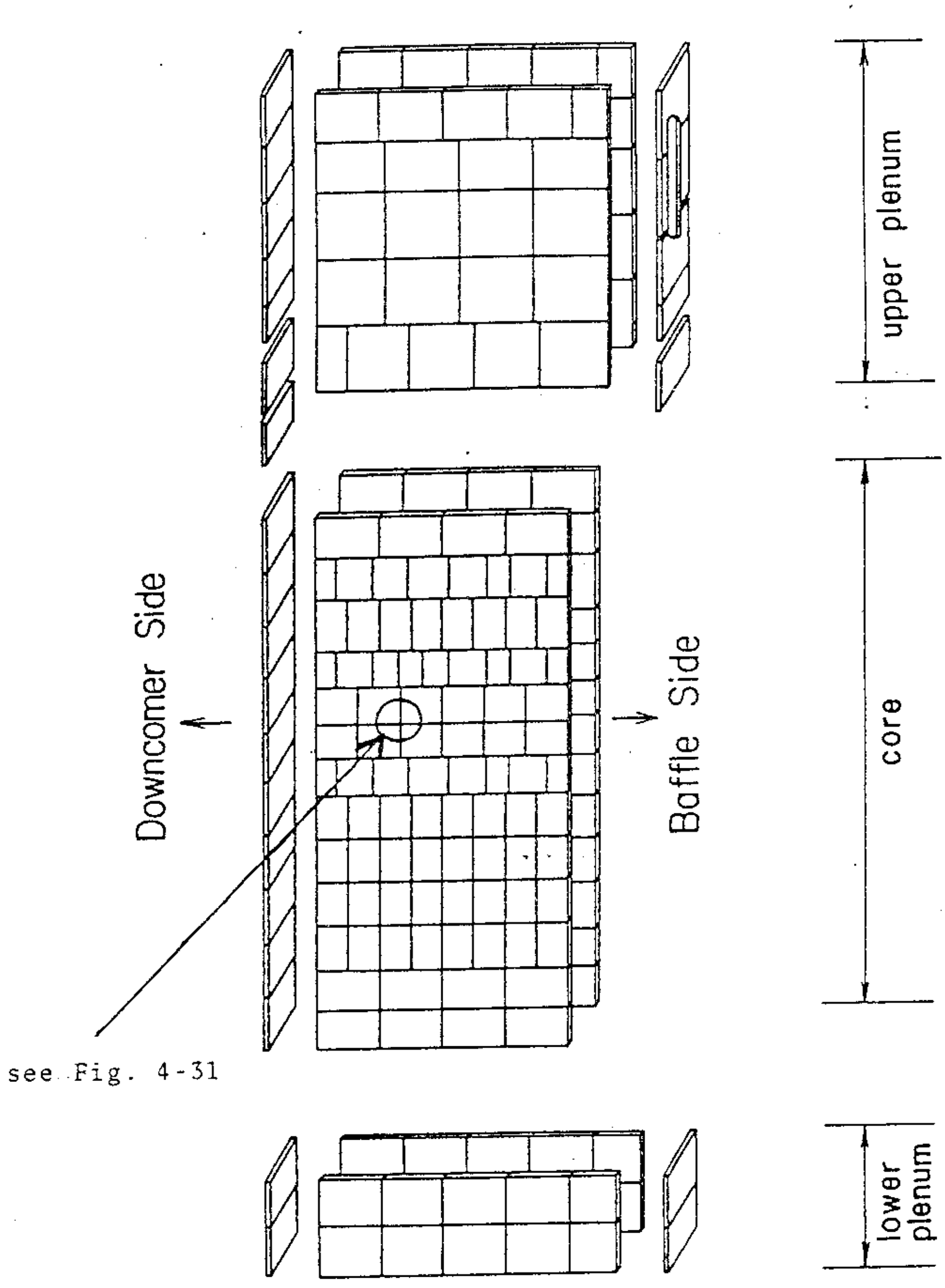


Fig.3-30 Concept of Arrangement of Thermal Insulator Panels in the Pressure Vessel

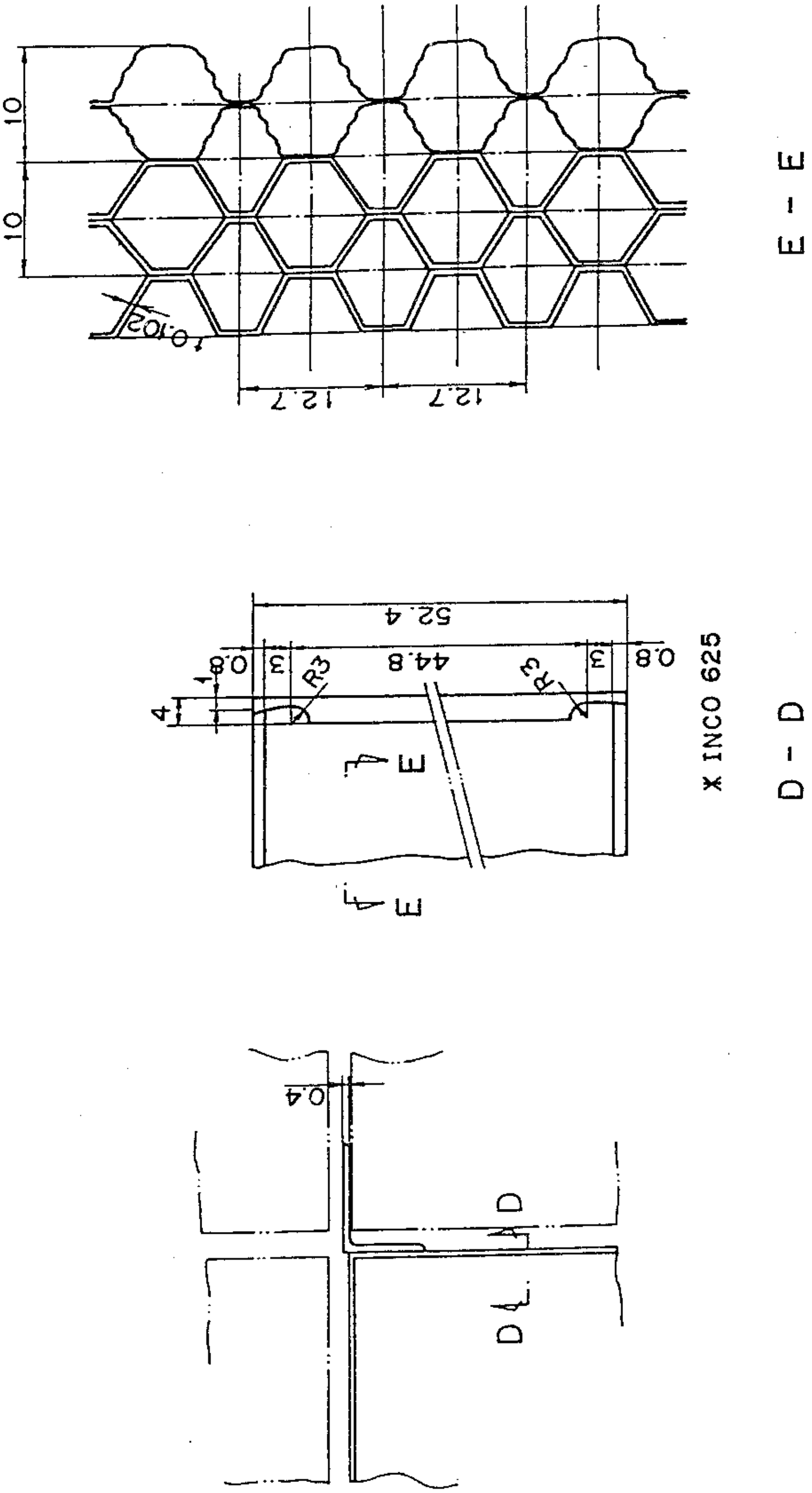


Fig.3-31 Dimension of Honeycomb Thermal Insulator

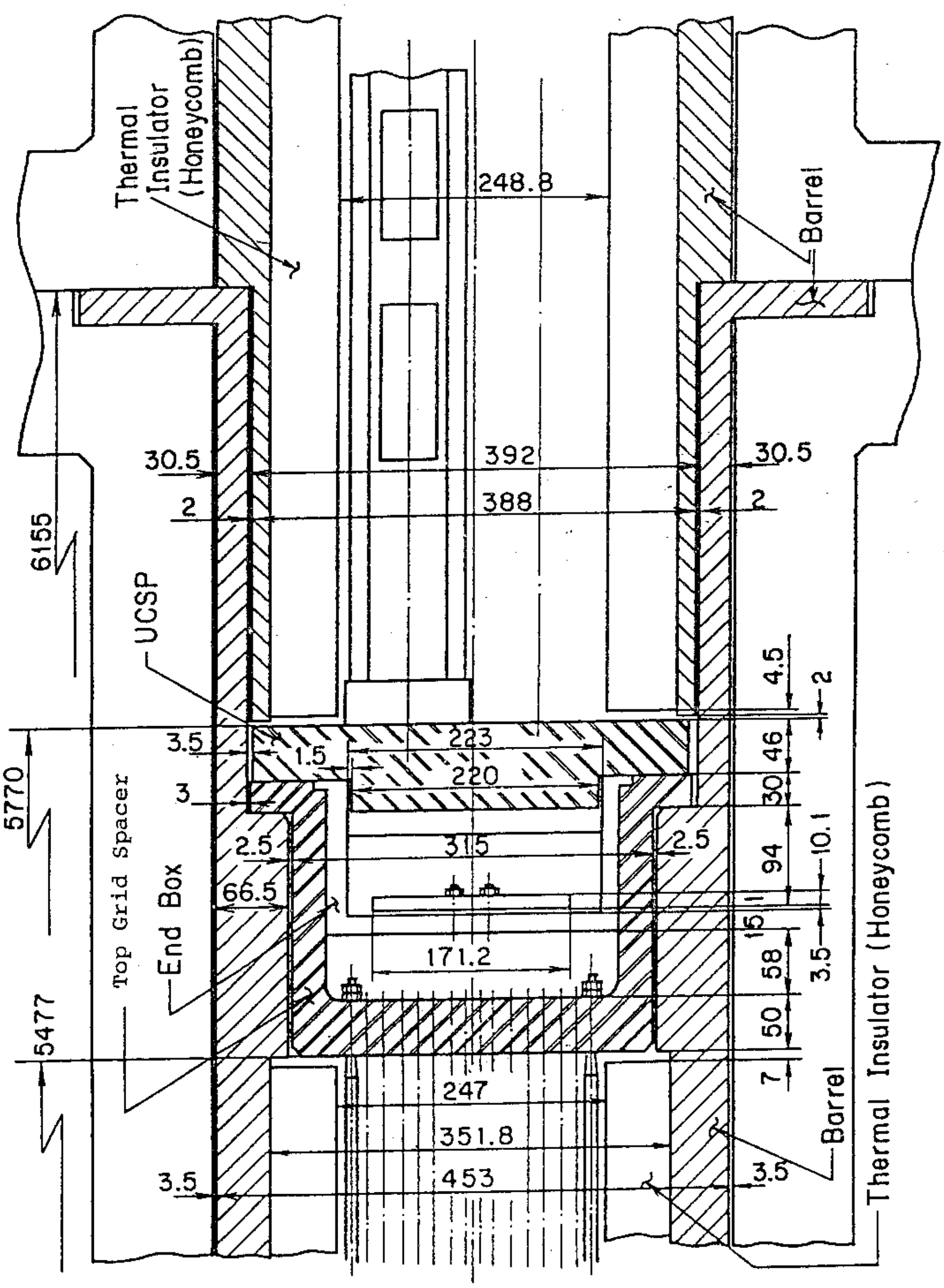


Fig.3-32 Arrangement and Dimension of the Interface between Core and Upper Plenum

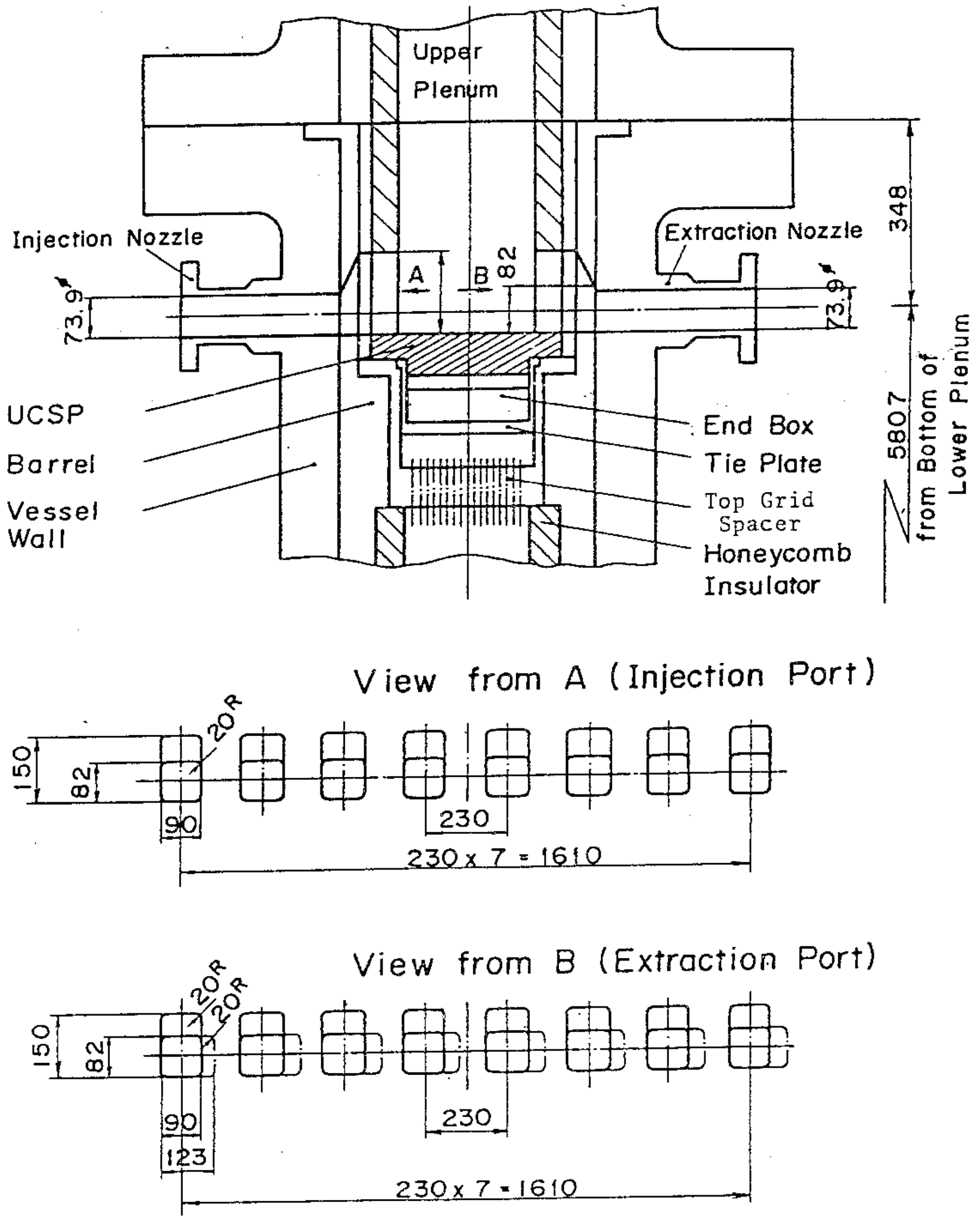


Fig.3-33 Arrangement and Dimension of the UCSP Water Injection and Extraction Nozzles

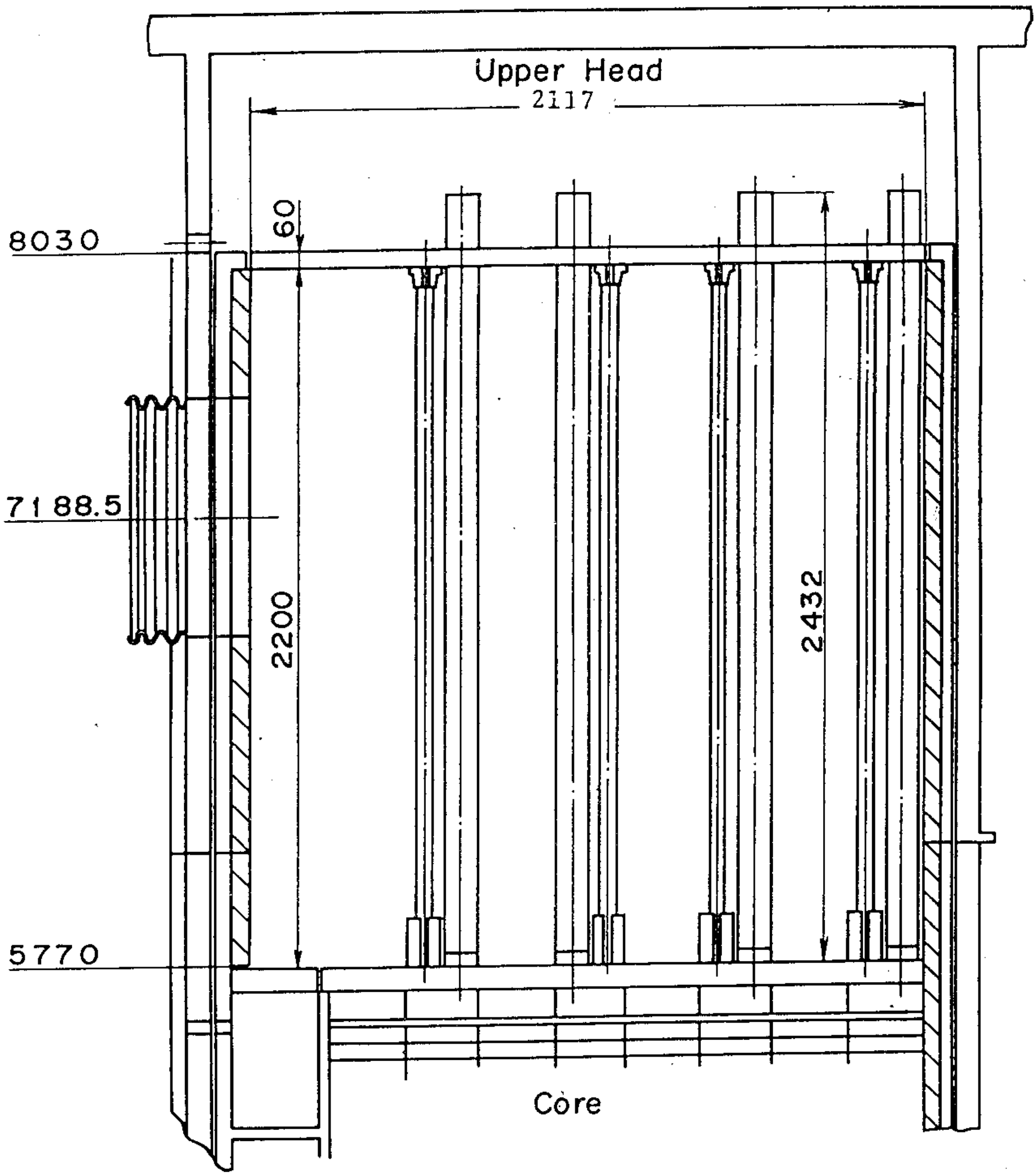


Fig.3-34 Schematic of Upper Plenum

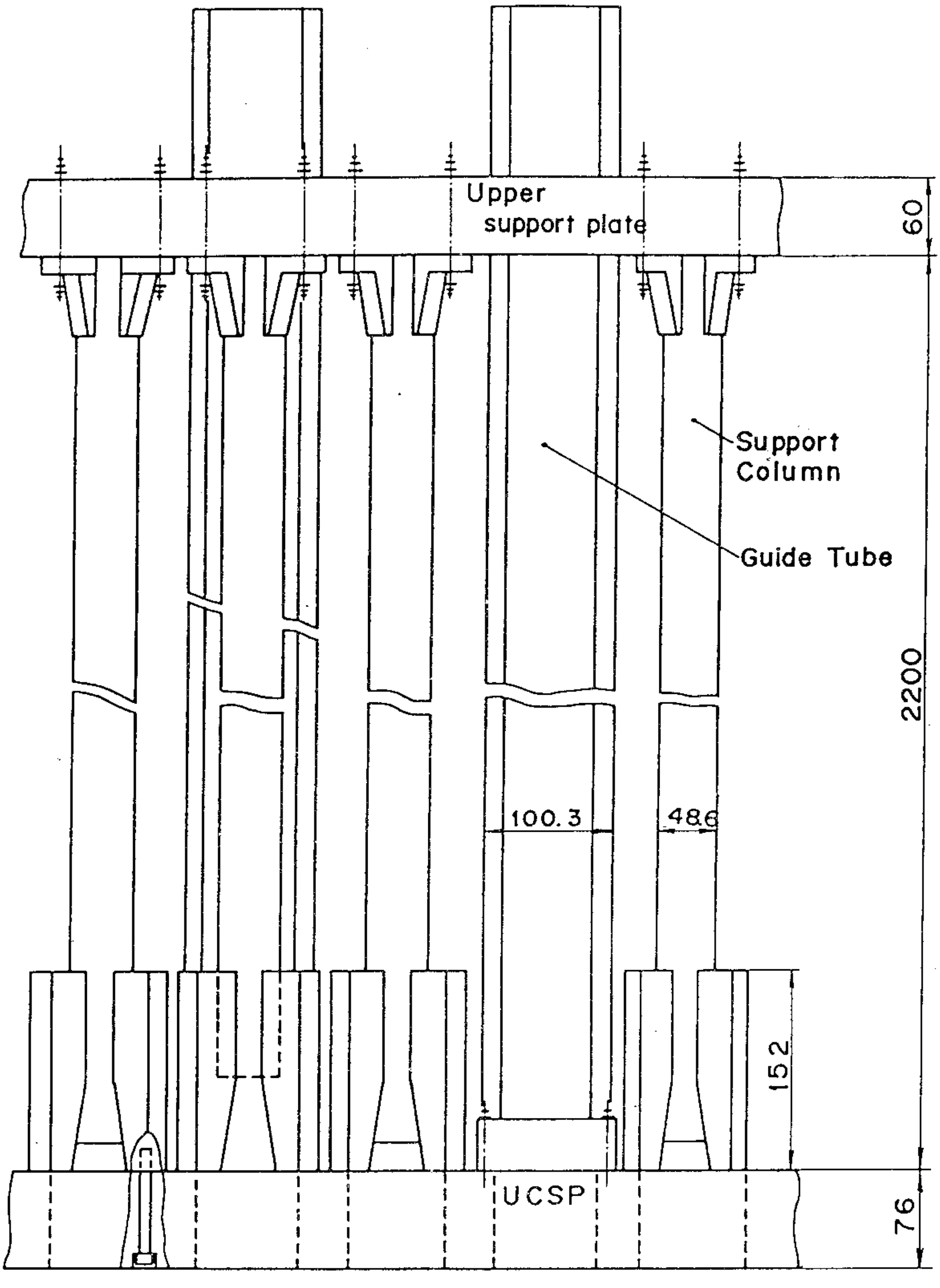


Fig.3-35 Schematic of Upper Plenum Internals

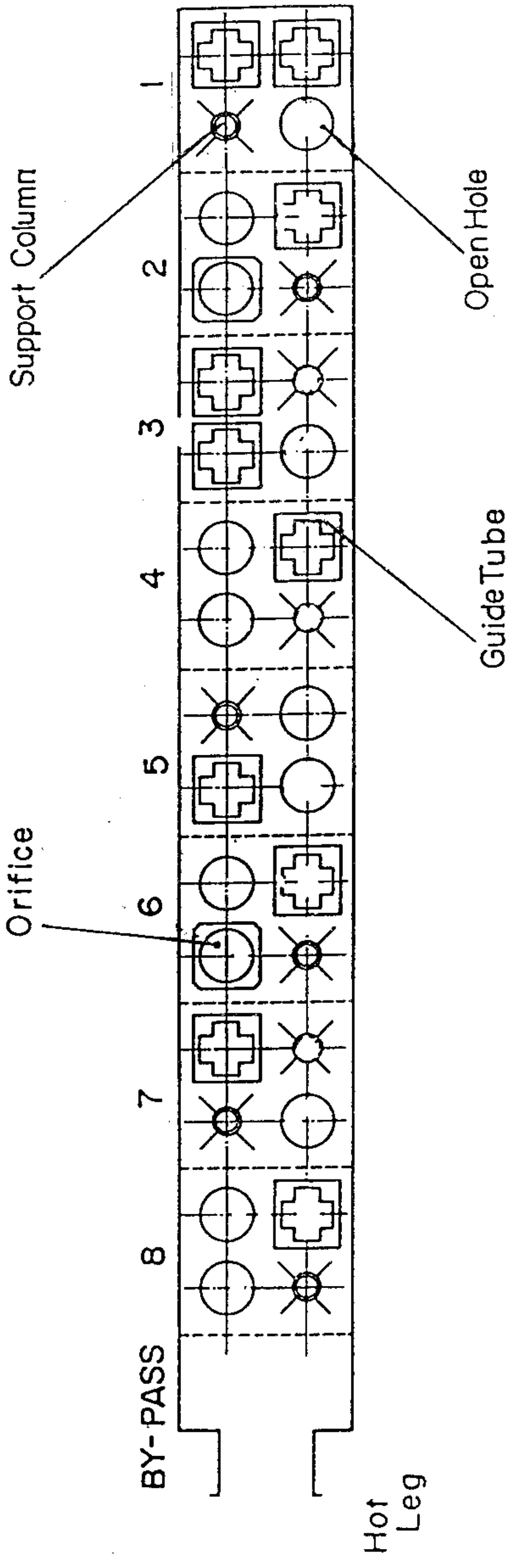


Fig.3-36 Arrangement of Upper Plenum Internals

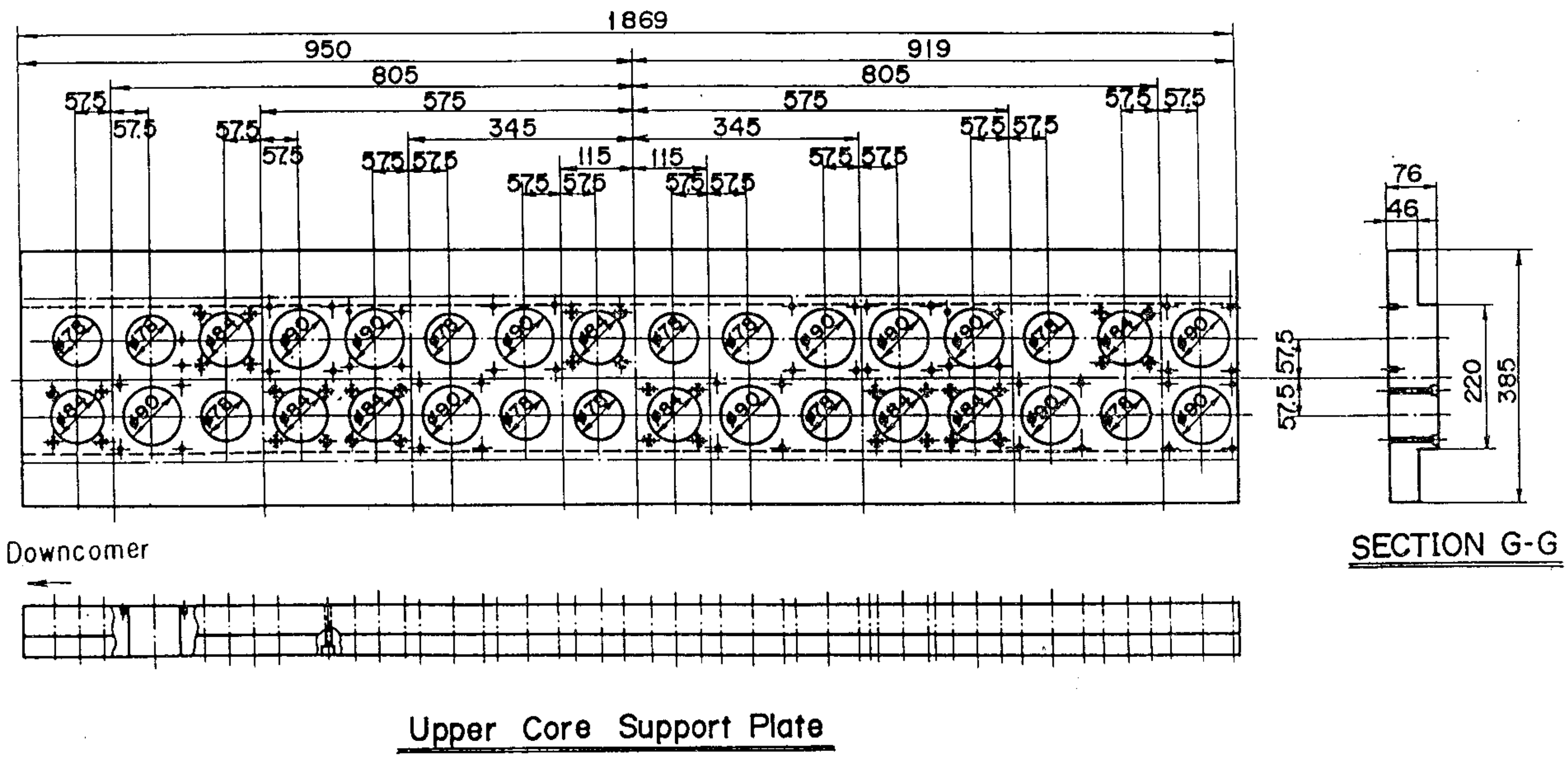


Fig.3-37 Dimension of Upper Core Support Plate

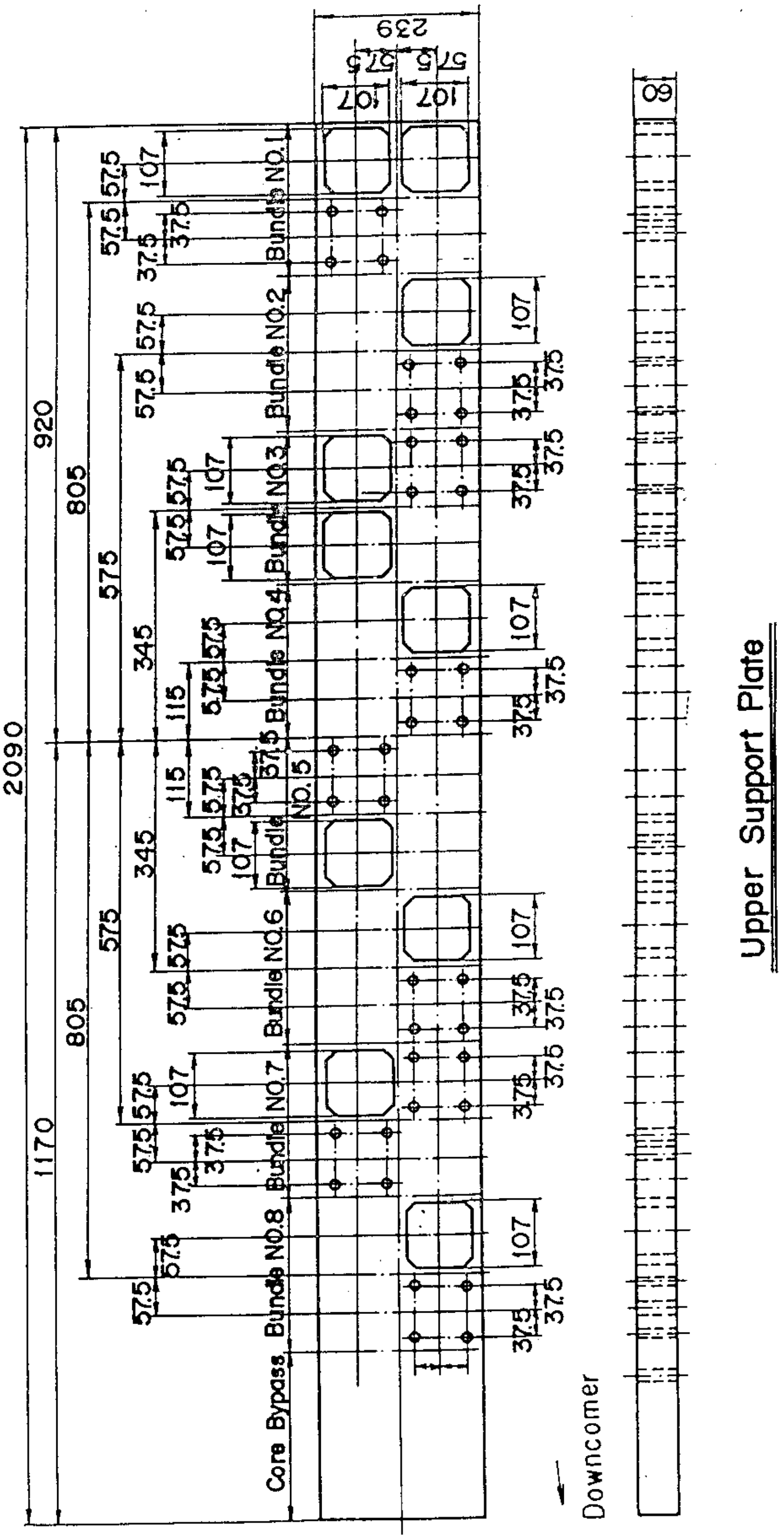


Fig.3-38 Dimension of Upper Support Plate

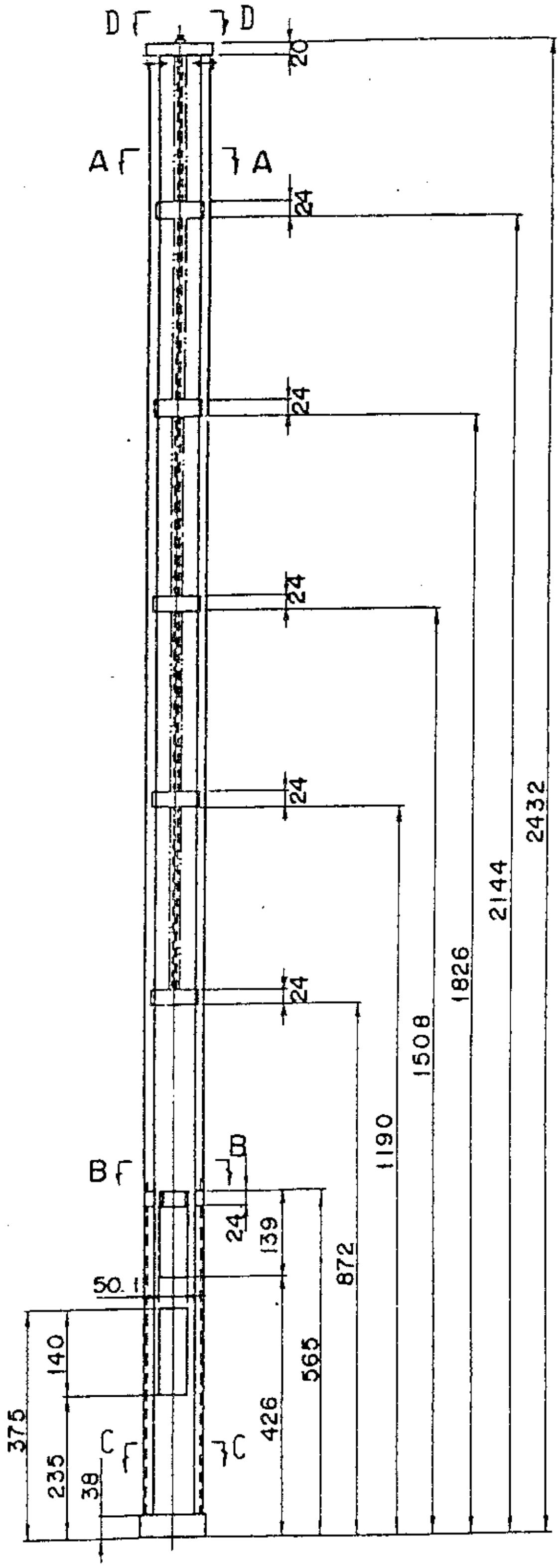


Fig.3-39 Dimension of Guide Tubes (1)

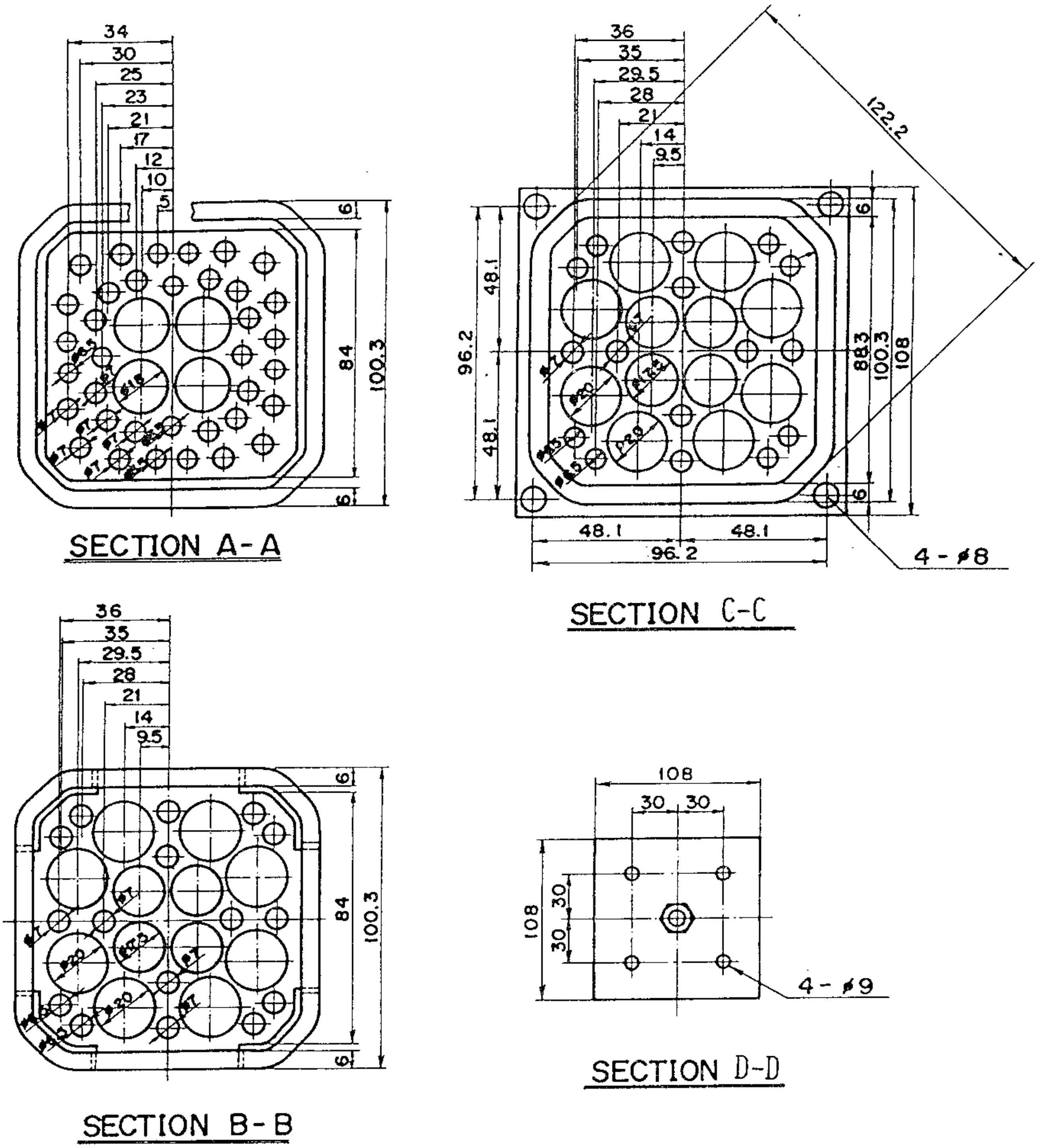


Fig.3-40 Dimension of Guide Tubes (2)

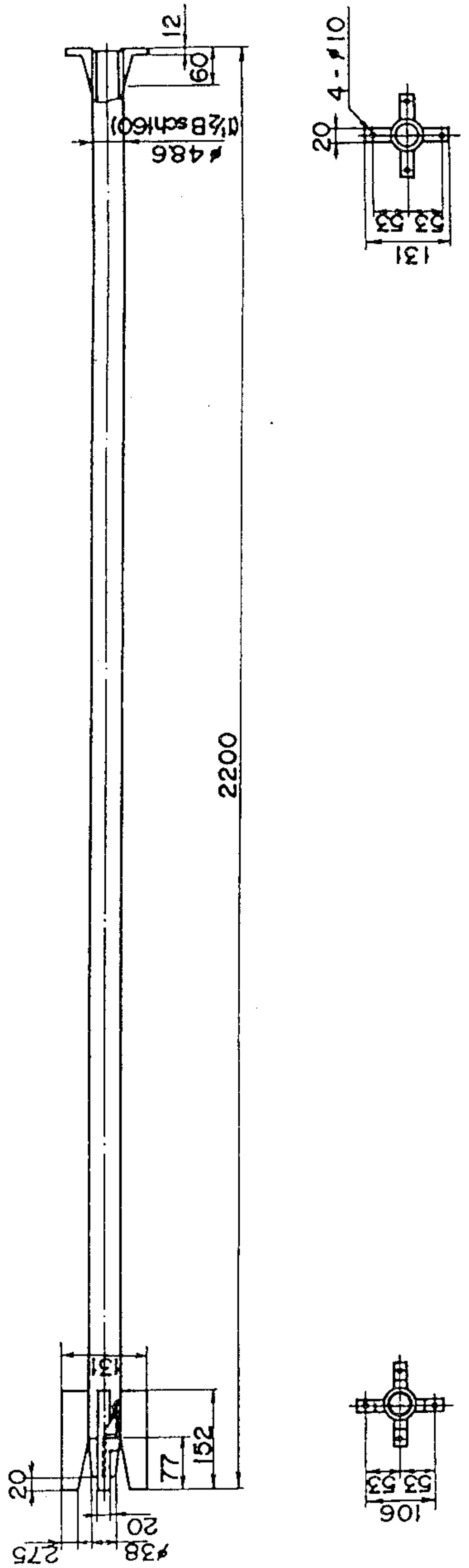


Fig.3-41 Dimension of Support Columns

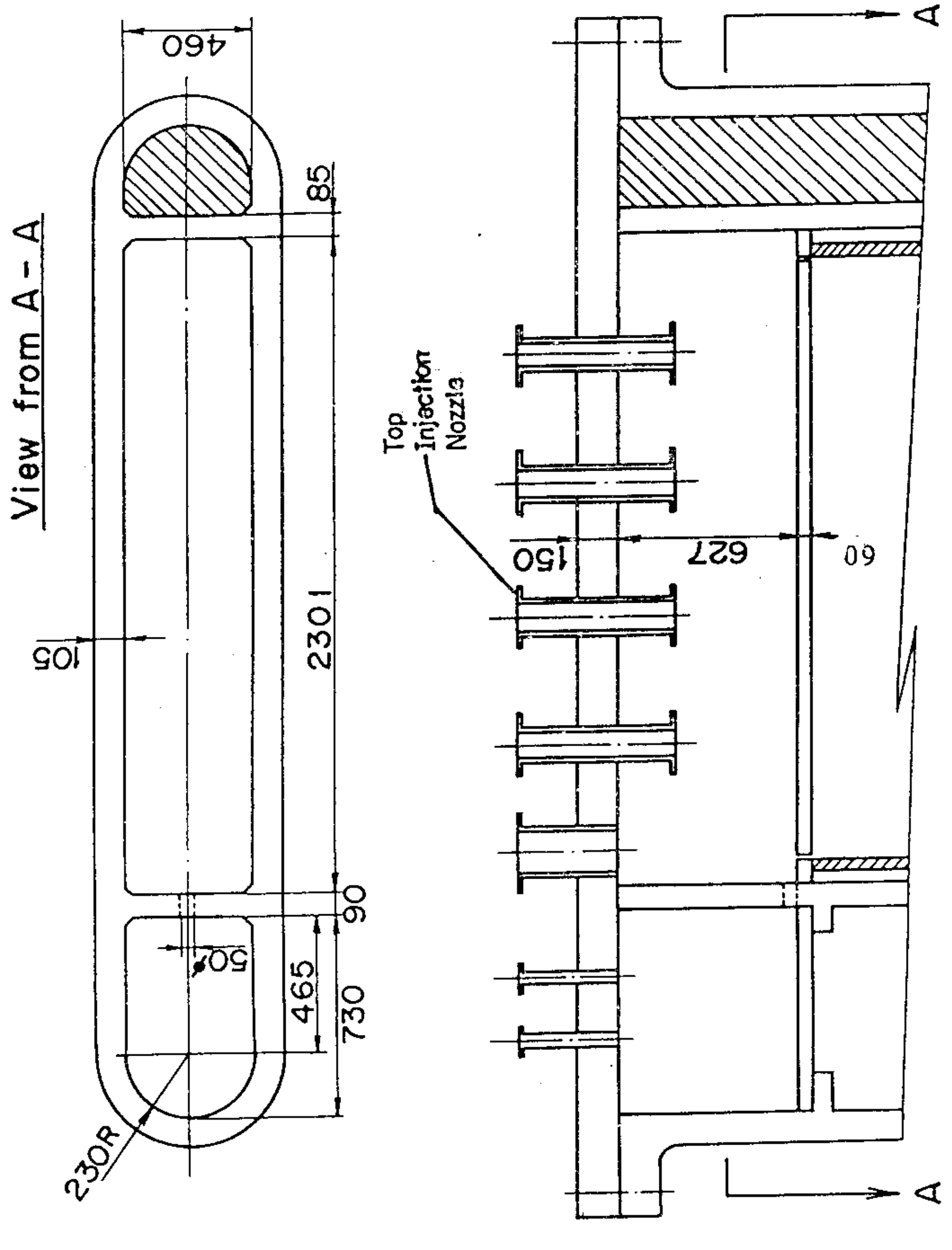


Fig.3-42 Schematic of Upper Head

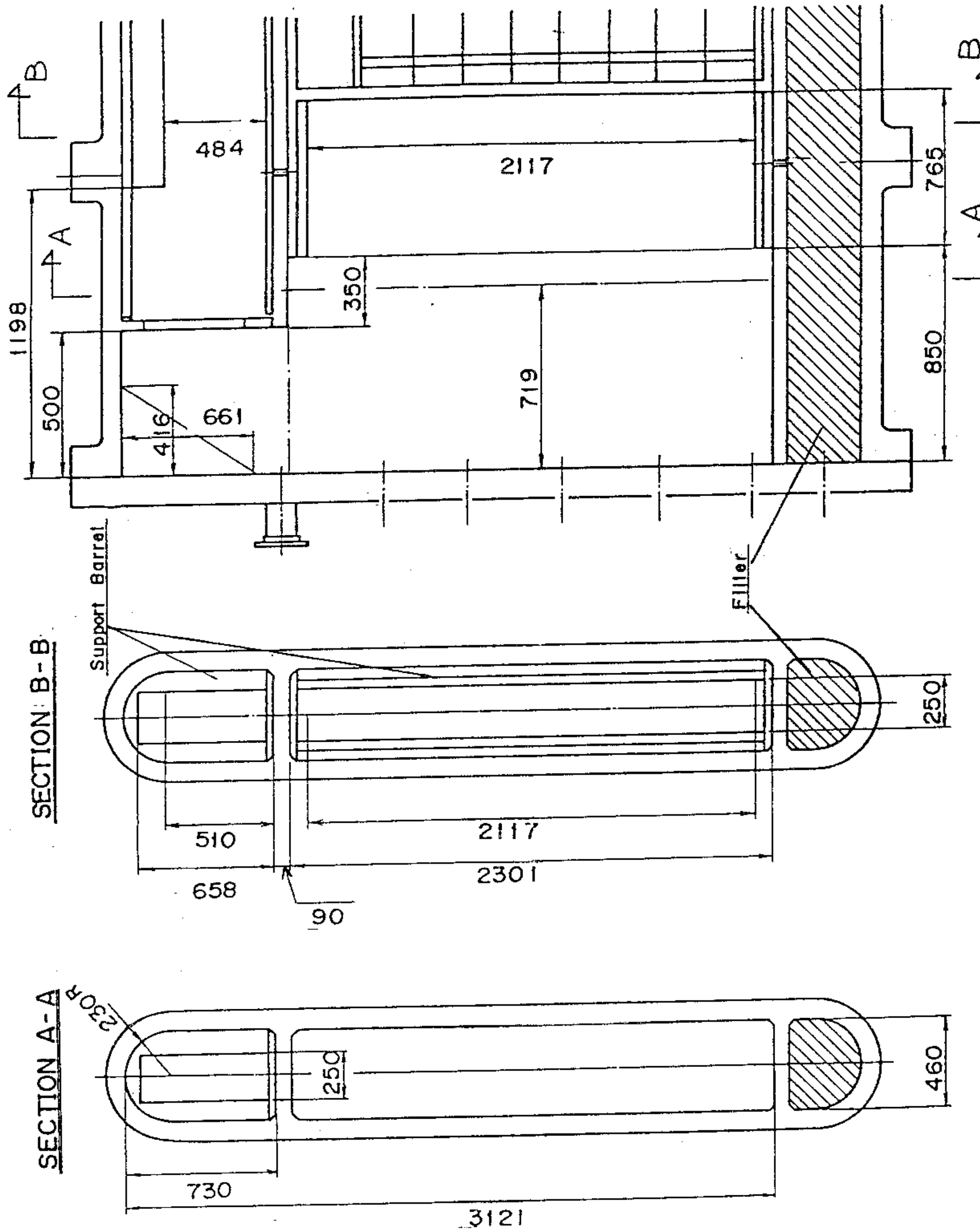


Fig.3-43 Schematic and Principal Dimension of Lower Plenum

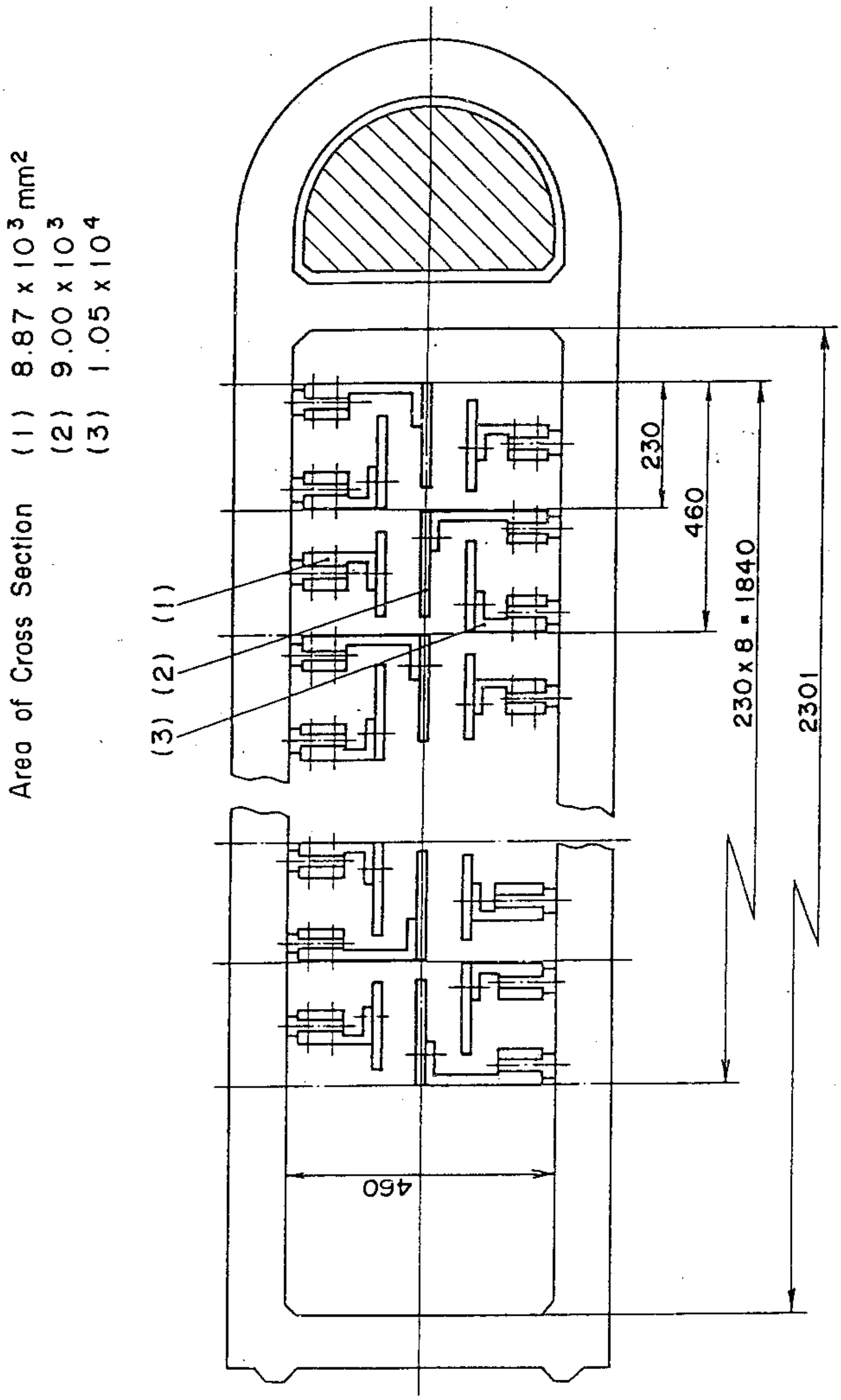


Fig.3-44 Arrangement of Electrodes in the Lower Plenum

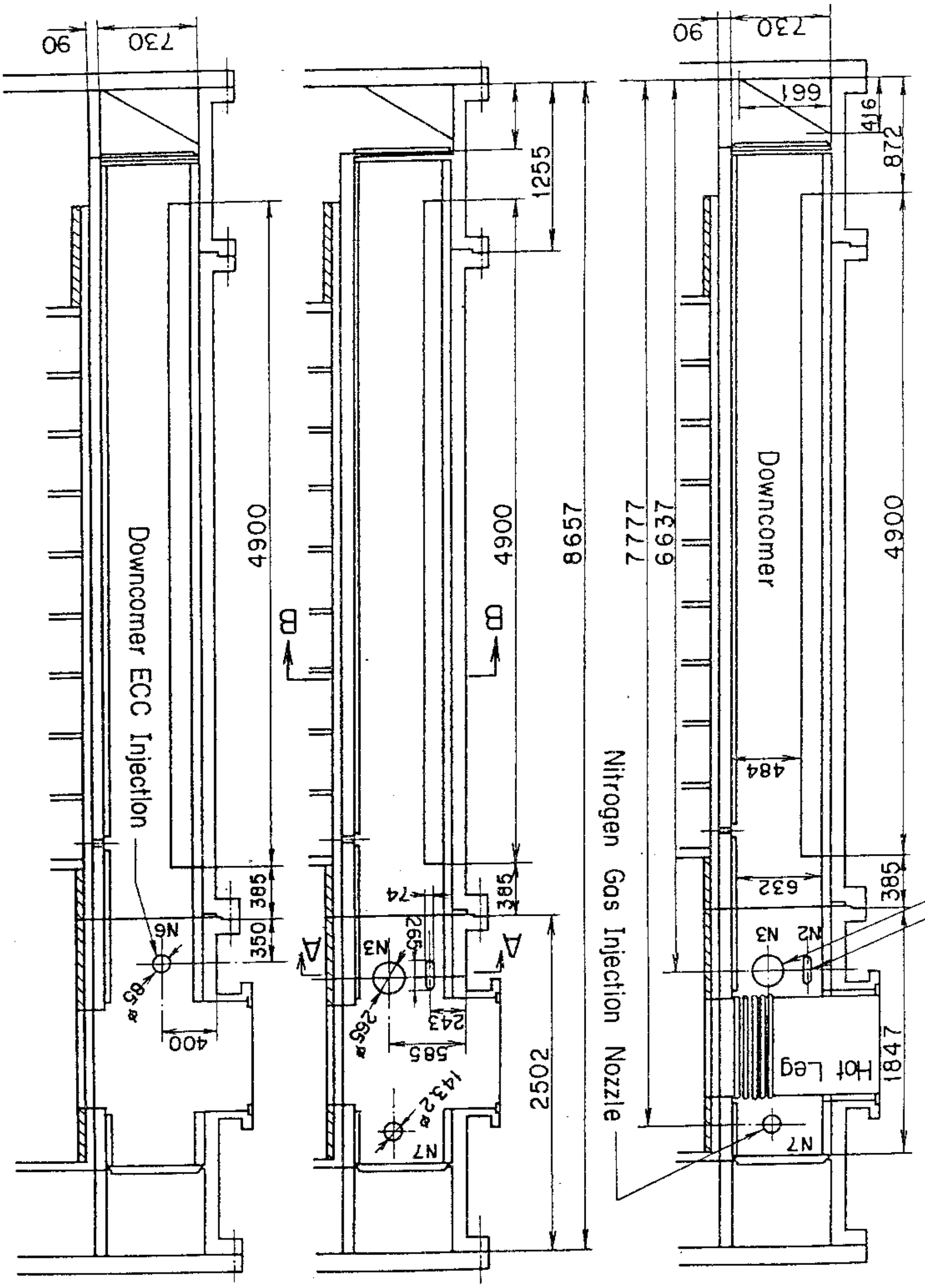


Fig.3-45 Configuration and Dimension of Downcomer Including Upper Annulus

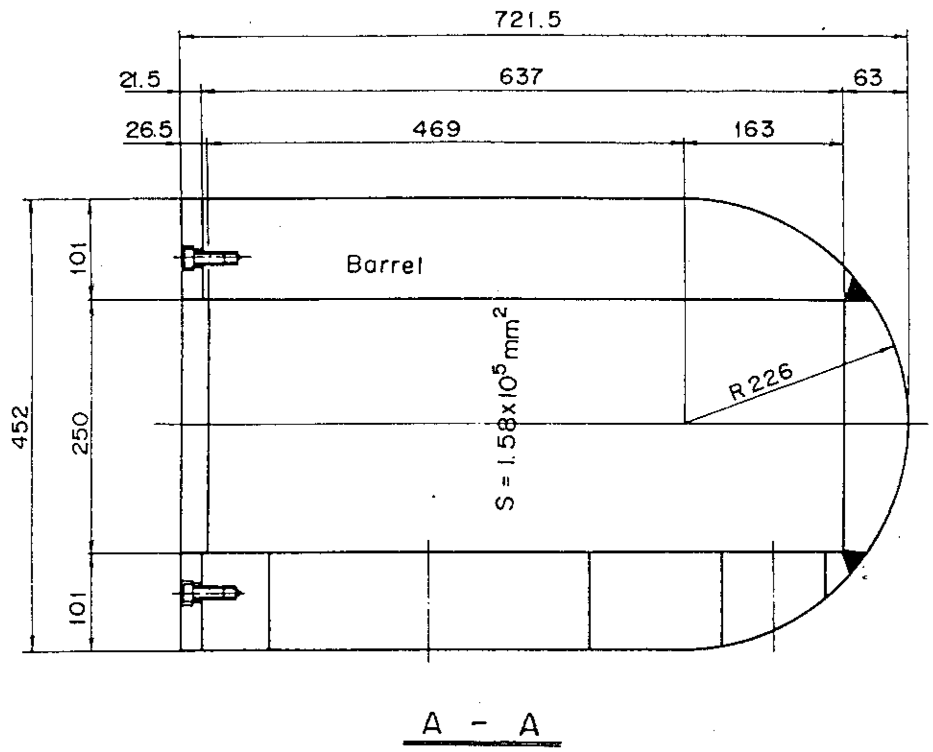


Fig.3-46 Cross Section of Downcomer (1)

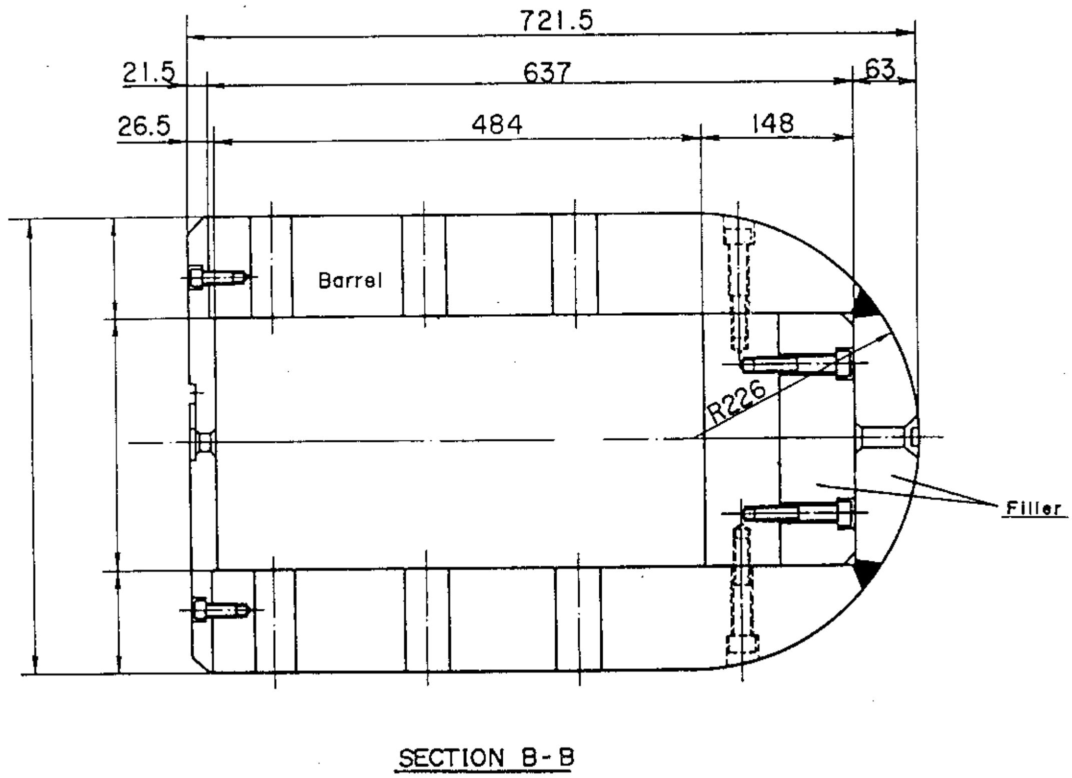


Fig.3-47 Cross Section of Downcomer (2)

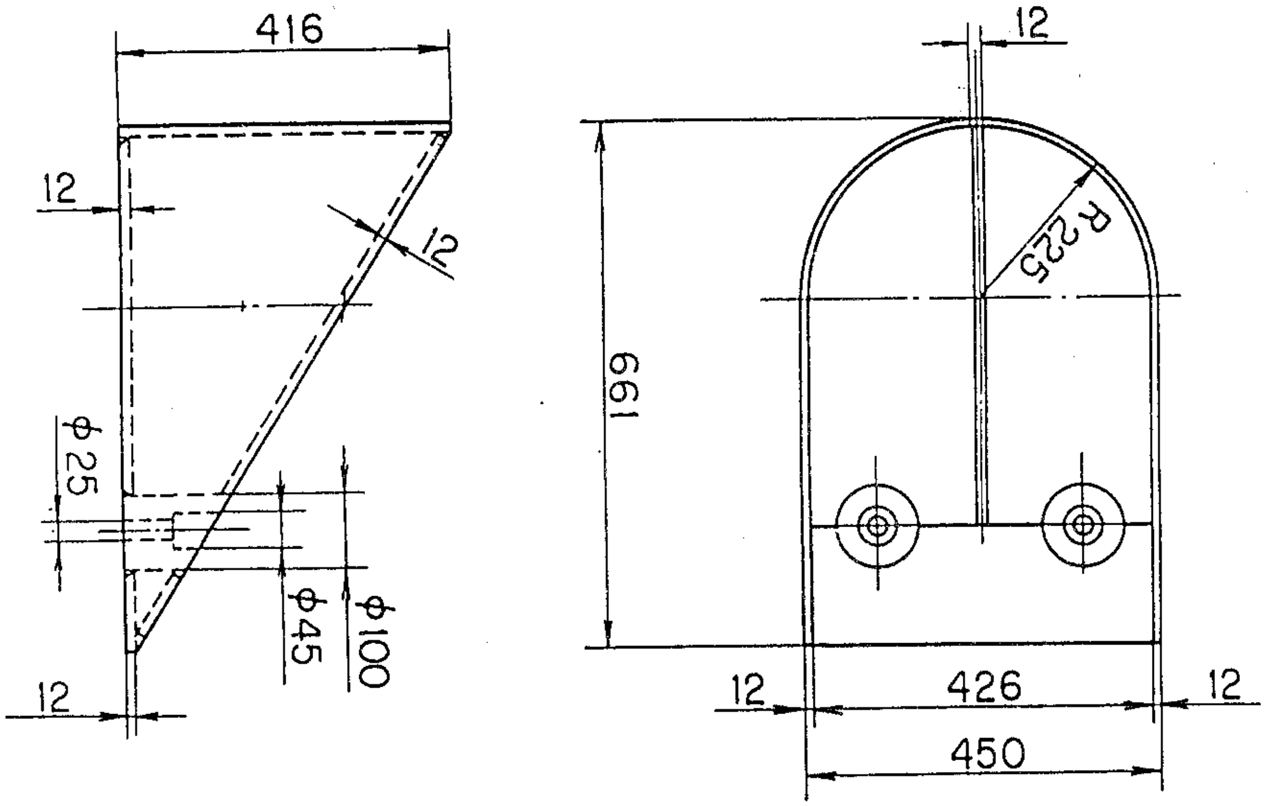


Fig.3-48 Dimension of Filler for Smoothing Flow from Downcomer to Lower Plenum

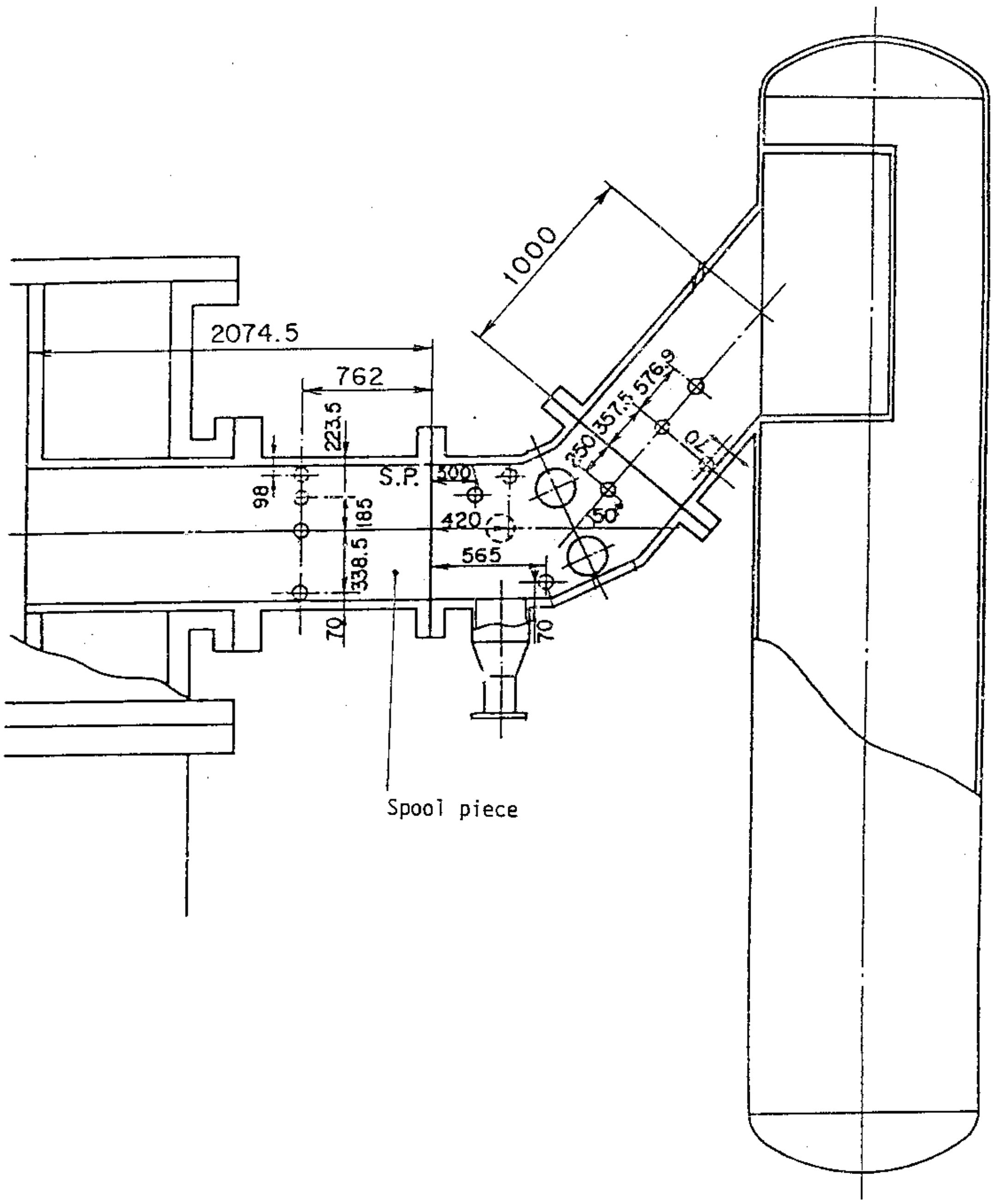


Fig.3-49 Arrangement of Hot Leg

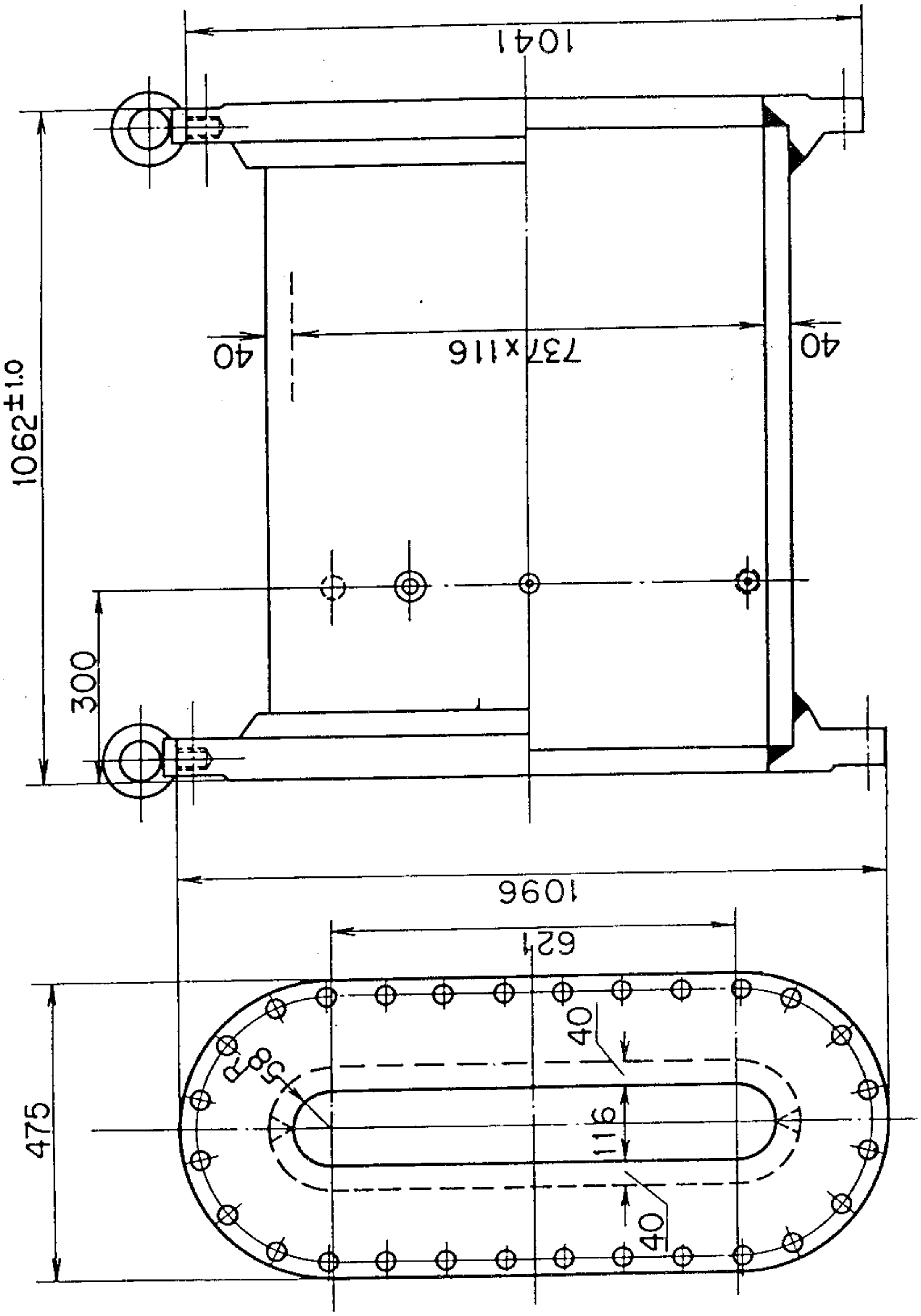


Fig.3-50 Dimension of Hot Leg Spool Piece

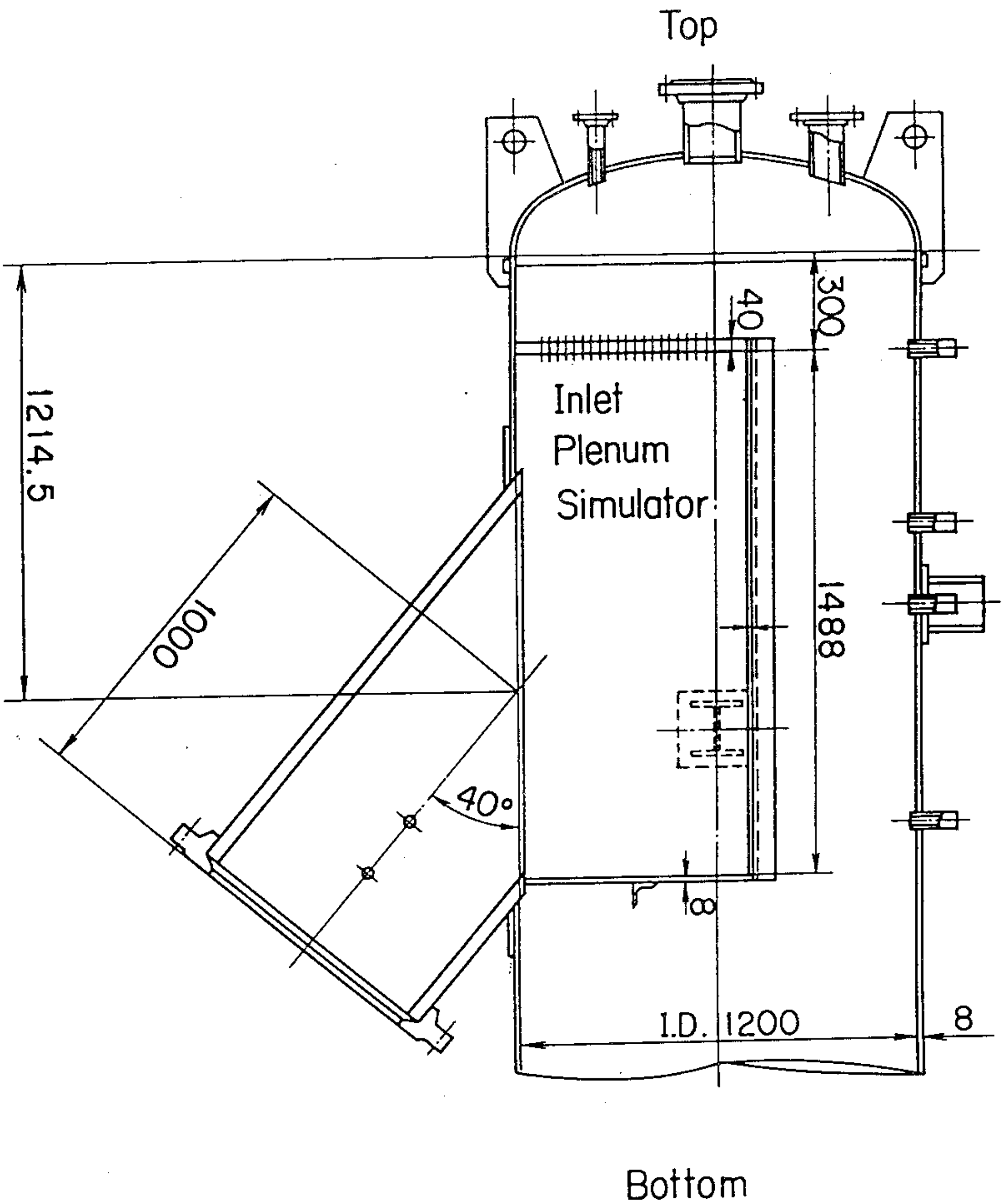


Fig.3-51 Top Half of the Steam-Water Separator

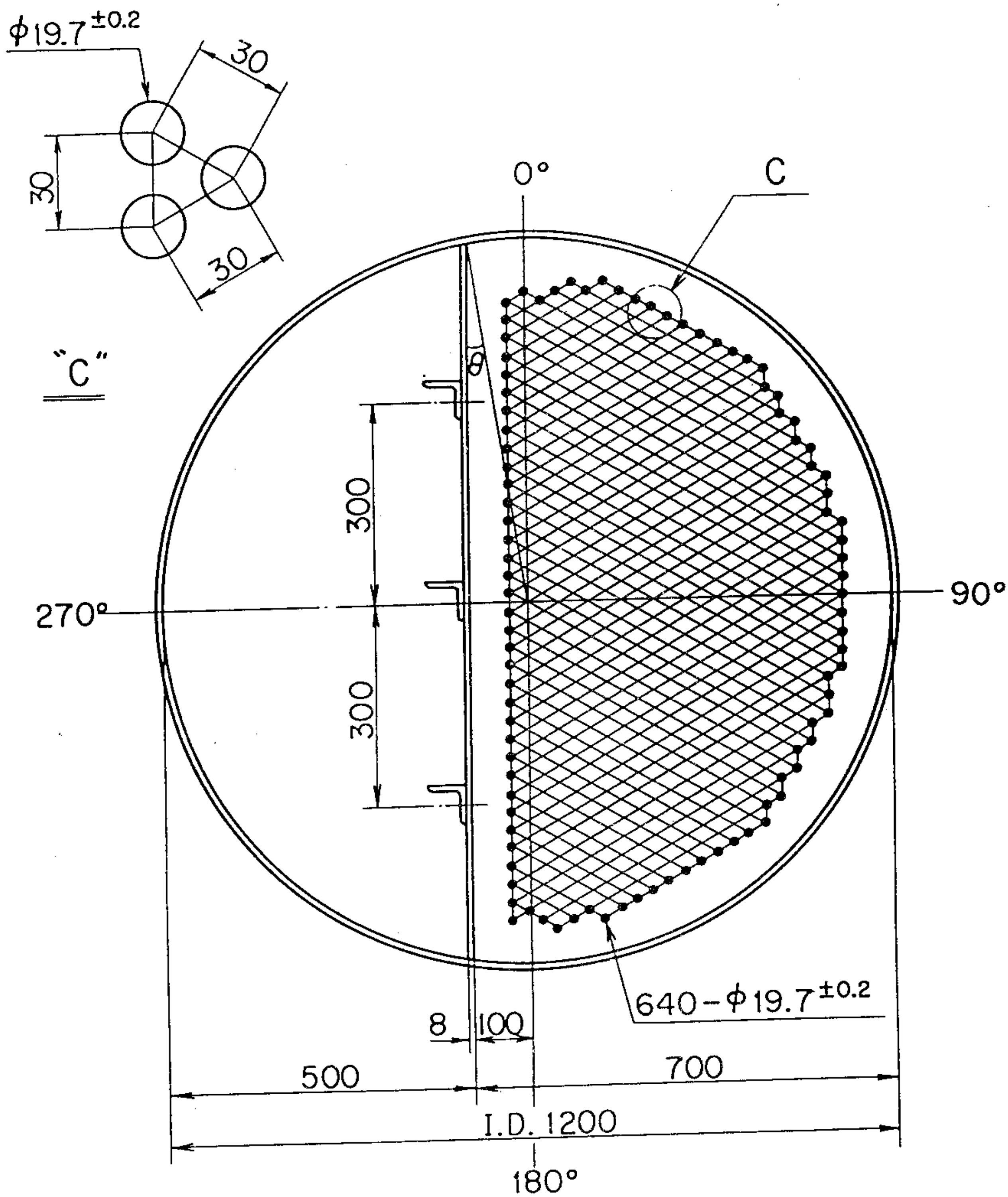


Fig.3-52 Arrangement and Dimension of Holes at the Top Plate of the Inlet Plenum Simulator

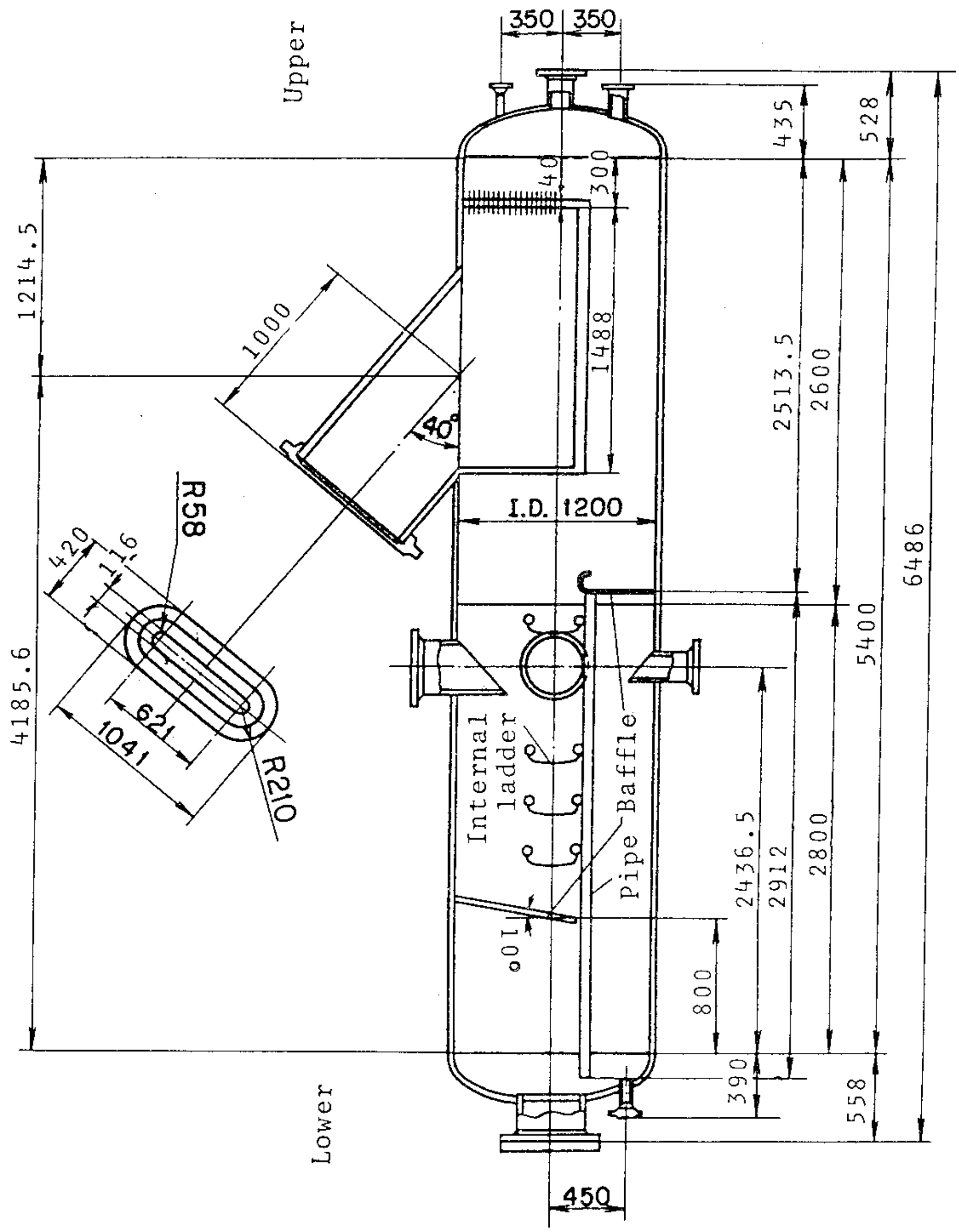


Fig.3-53 Steam-Water Separator

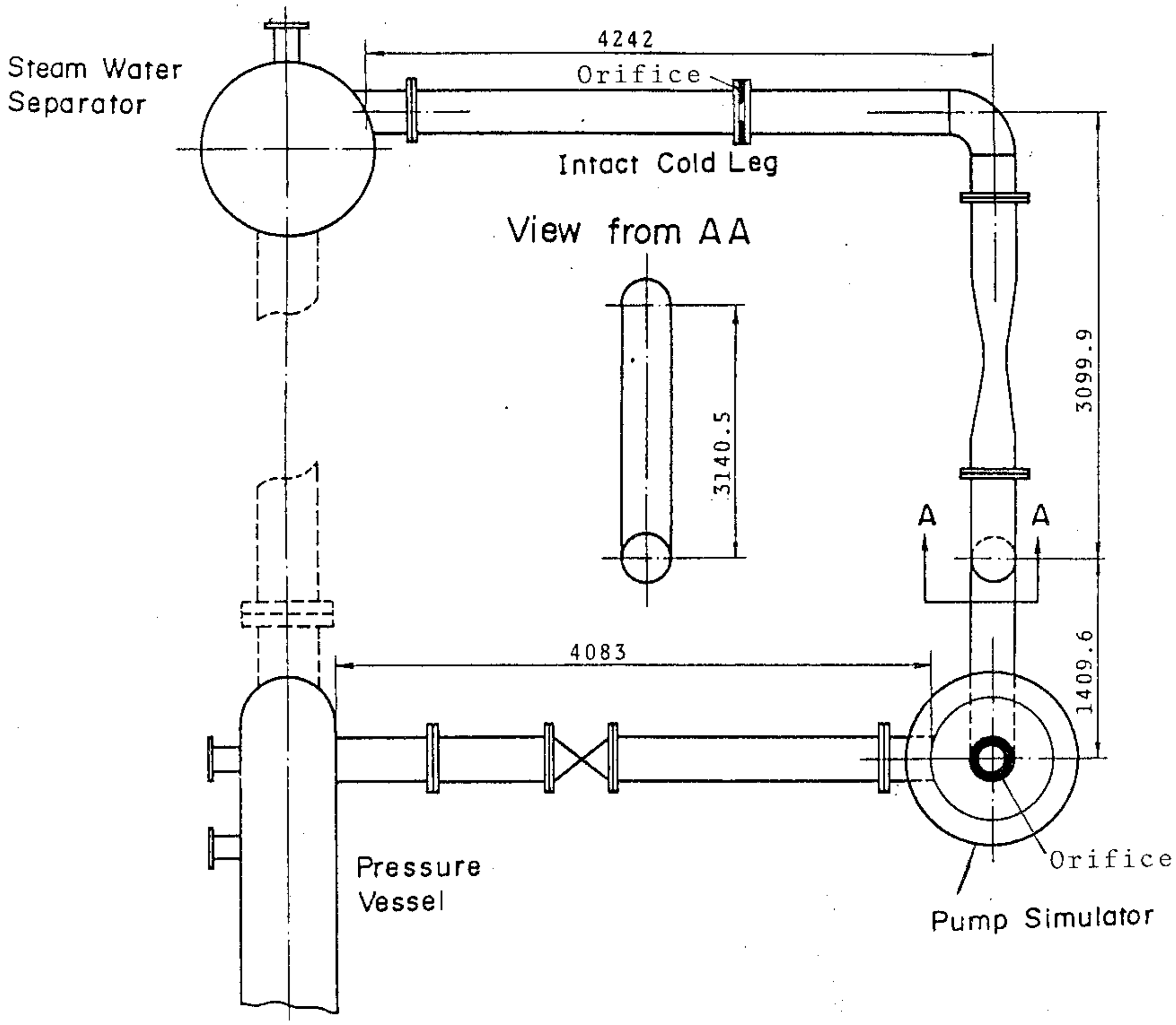


Fig.3-54 Arrangement of Intact Cold Leg

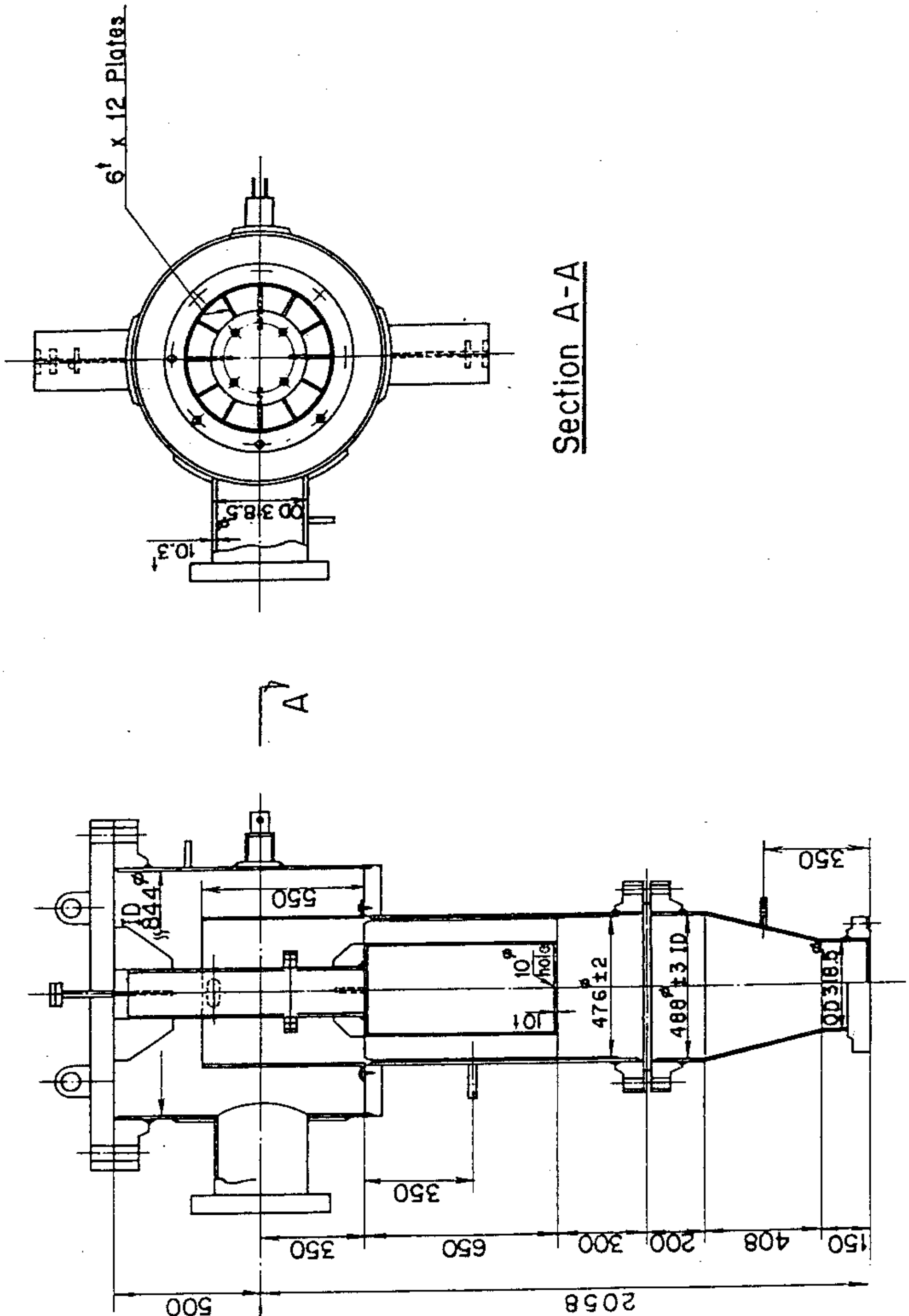


Fig.3-55 Configuration and Dimension of Pump Simulator

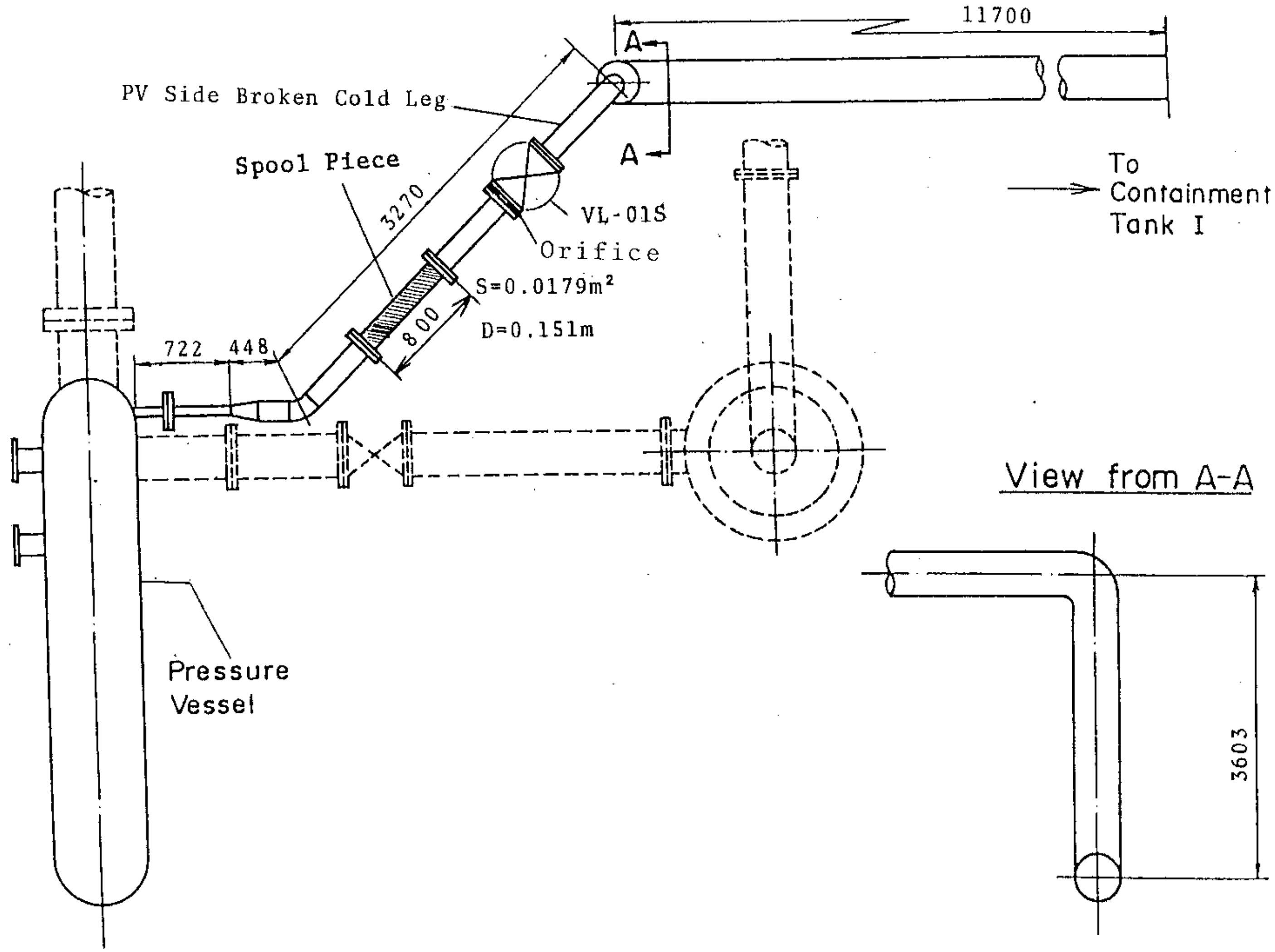


Fig.3-56 Arrangement of Pressure Vessel Side Broken Cold Leg

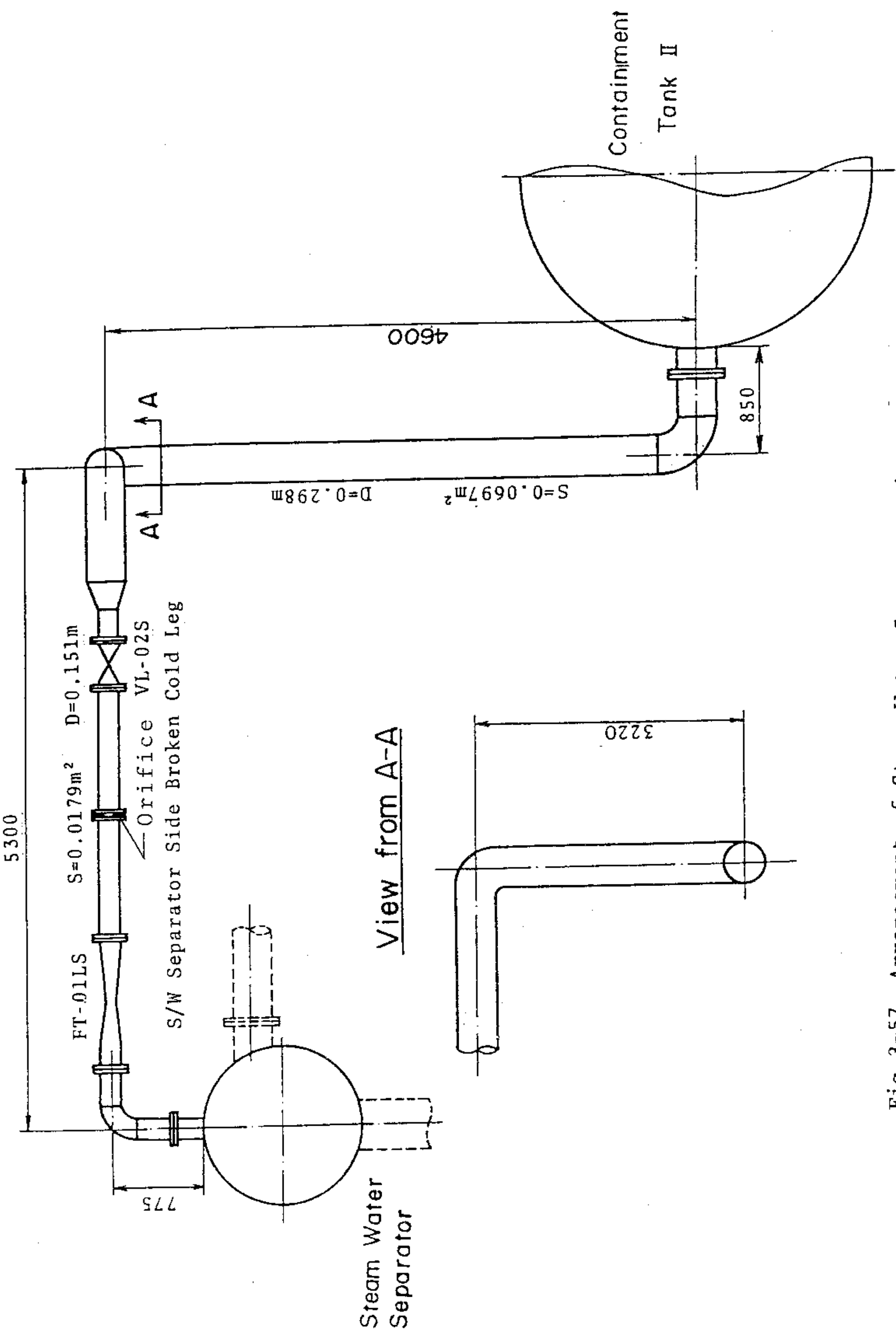


Fig.3-57 Arrangement of Steam-Water Separator Side Broken Cold Leg

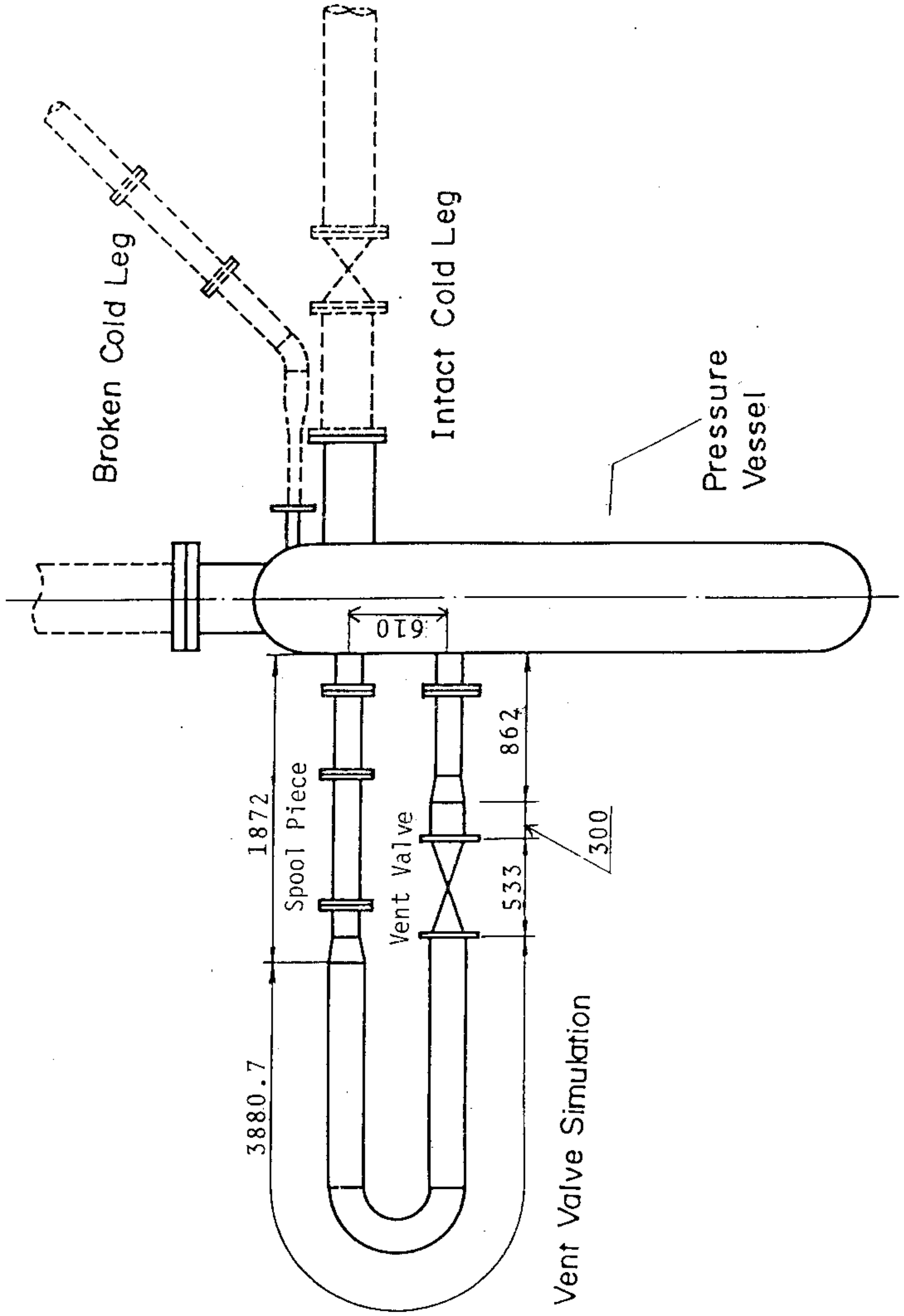


Fig.3-58 Arrangement of External Piping for Vent Valve Simulation

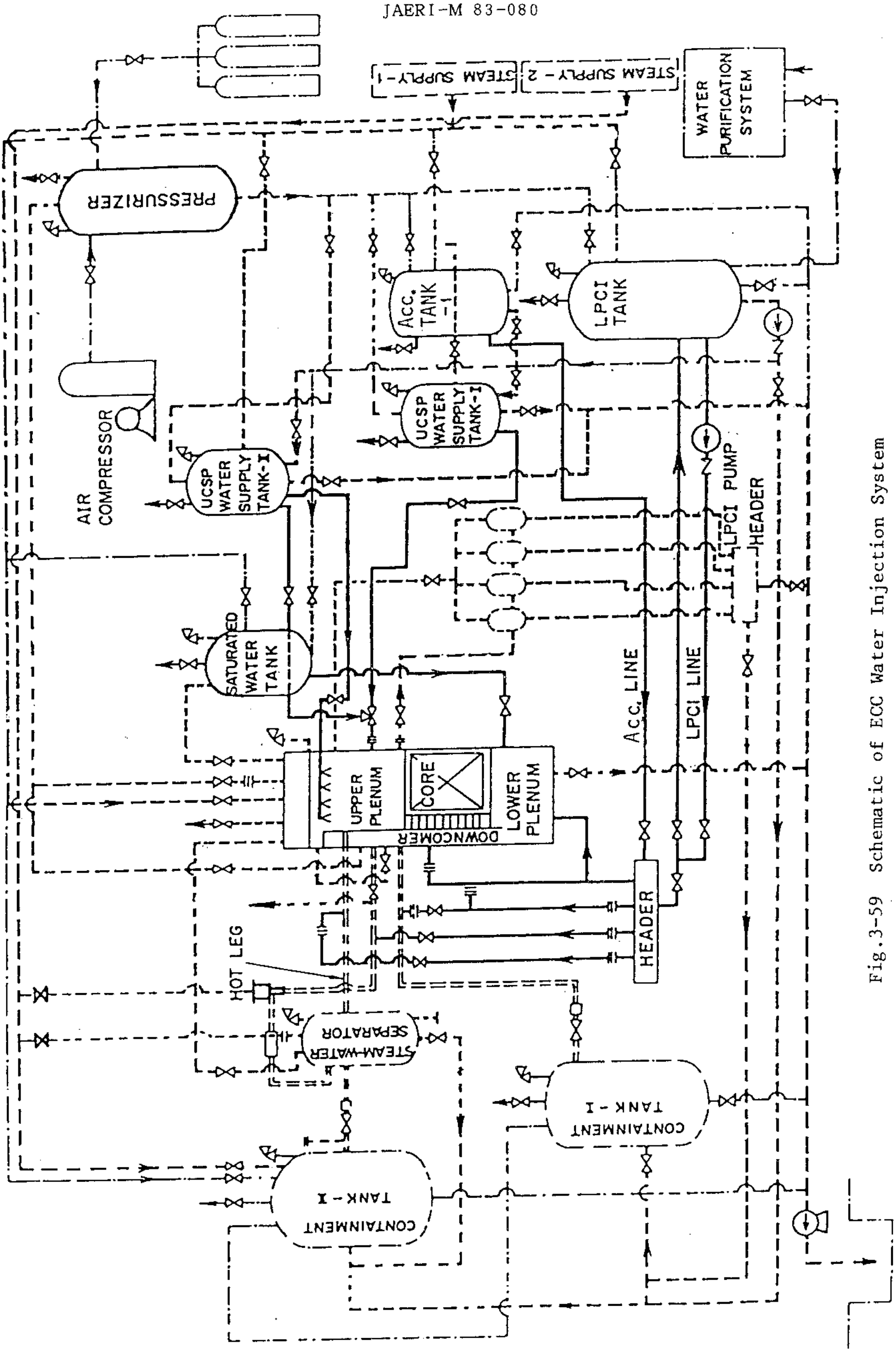


Fig.3-59 Schematic of ECC Water Injection System

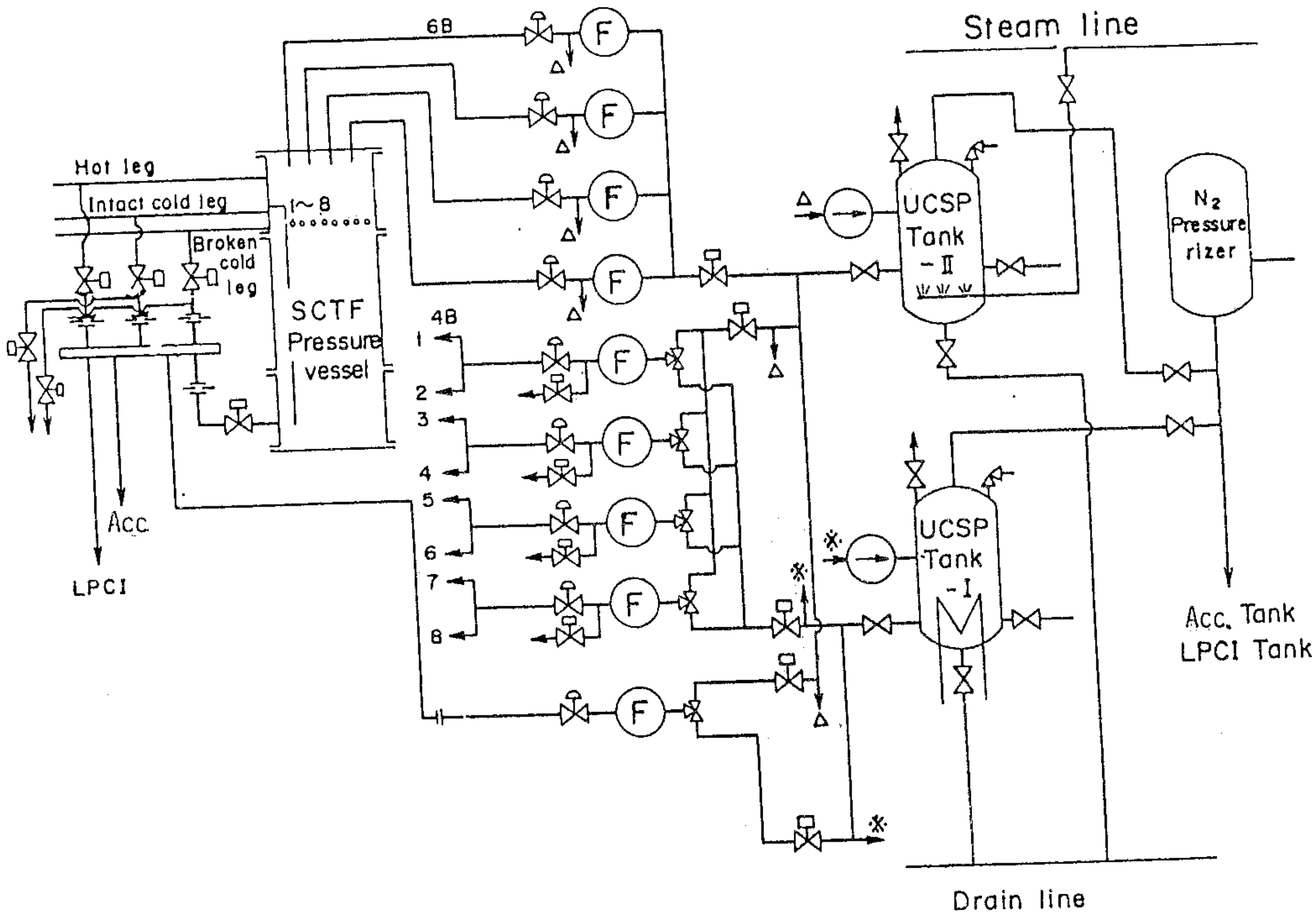


Fig.3-60 Schematic of UCSP Water Injection System

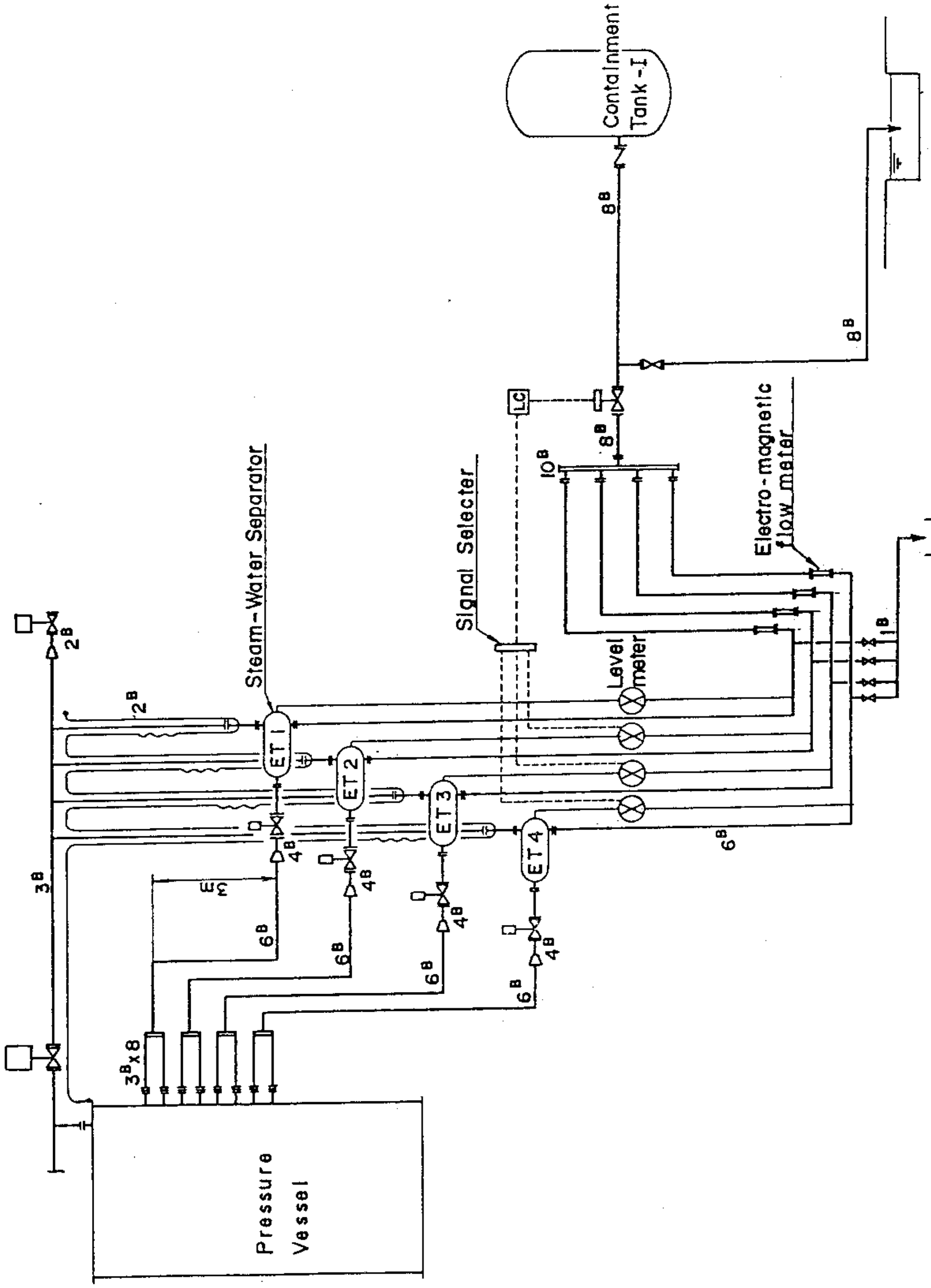


Fig.3-61 Schematic of UCSP Water Extraction System

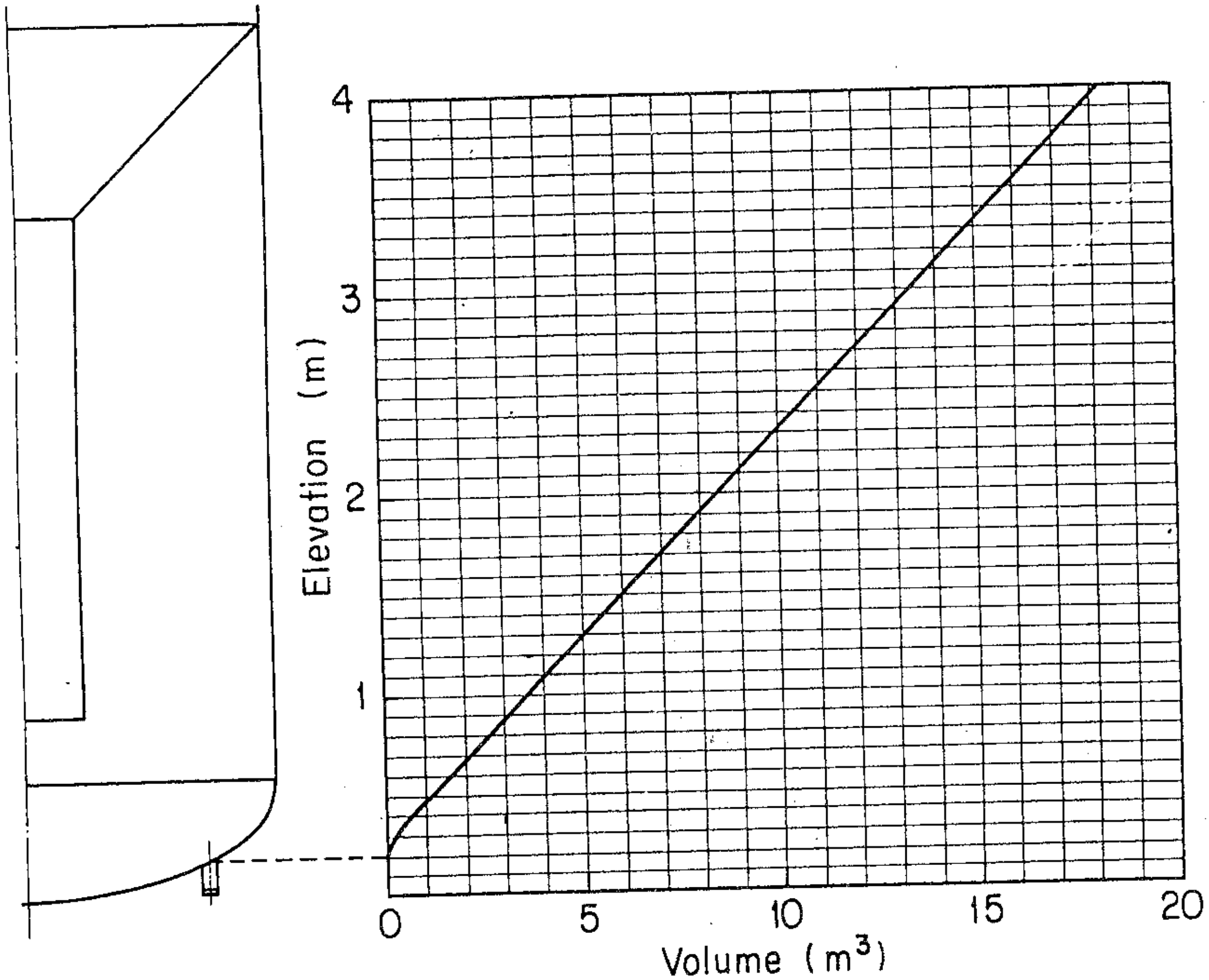


Fig.3-62 Relation of Water Level and Water Volume in the Containment Tank-I

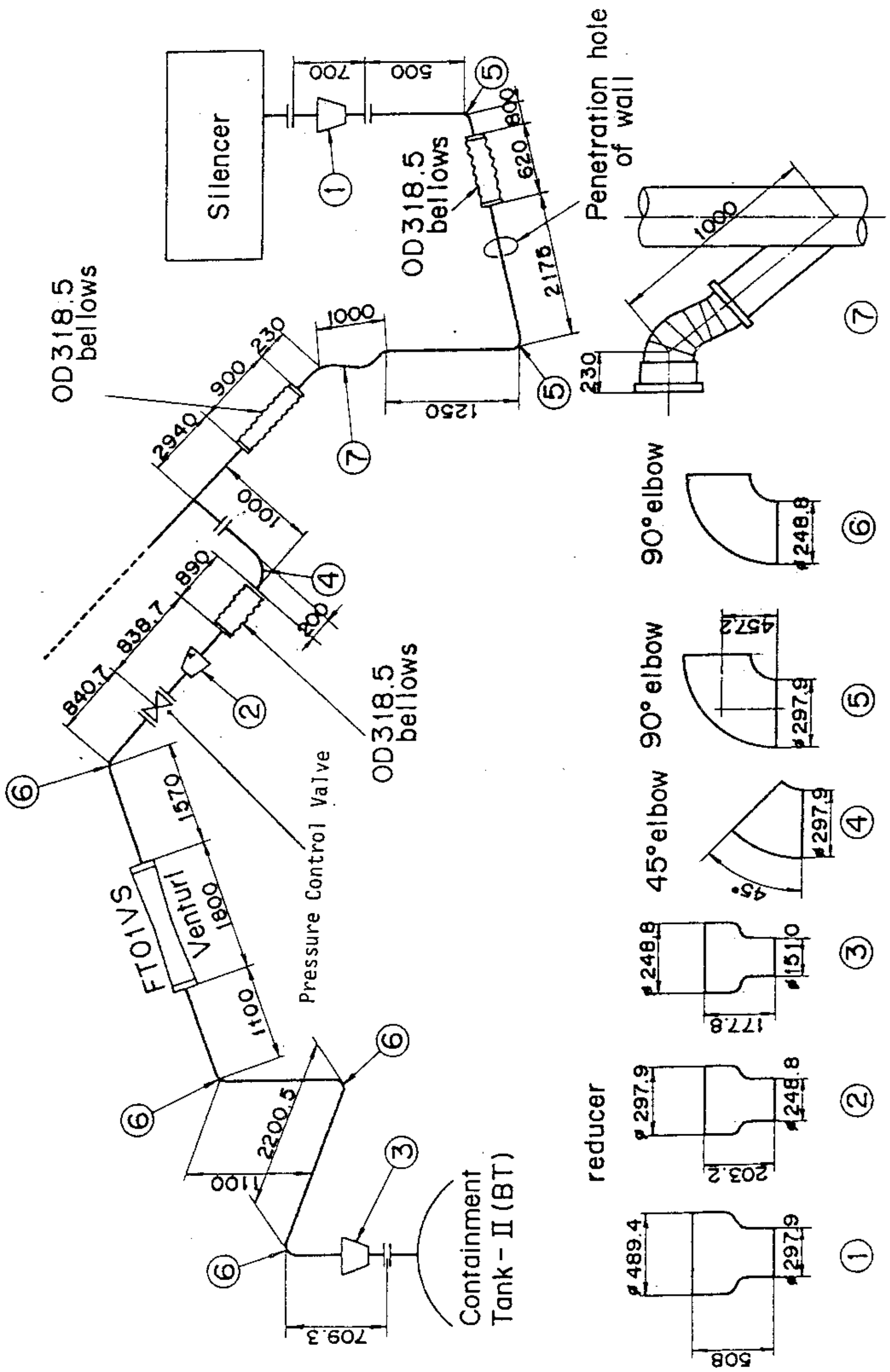


Fig.3-63 Pipe Arrangement from Containment Tank-II to Atmosphere

4. Instrumentation

4.1 Philosophy of Instrumentation

In order to achieve the objectives of the SCTF test program described in section 1.2, it is necessary to measure the complex transients of a lot of thermo-hydrodynamic variables in the system during the test. As the maximum number of instruments is limited due to the capacity of the data acquisition system, the structural restrictions, and economical reasons, the kind and the arrangement of instruments should be efficiently determined.

In the SCTF test, special emphasis is placed on the two-dimensional hydrodynamic behavior in the core due to the large scale slab configuration. Hence, most of the in-core instruments are arranged to detect the two-dimensional effects.

The two-phase flow characteristics at the interface region between the core and the upper plenum including the end box and the UCSP are also important especially for the combined injection tests and the coupling tests with the UPTF tests. Therefore, a large number of instruments are concentrated in this region. Since the SCTF has a very peculiar downcomer as described in section 3.6, special attention should be paid to application of the test results to an actual PWR.
The measured results of two-phase flow pattern and effective water head in the downcomer will give valuable information about the applicability of the SCTF data.

Pressure losses, flow rates and temperatures are also measured in the components of the system such as the hot leg, the broken and intact cold legs, the steam-water separator, and the containment tanks to determine the hydrodynamic behavior in whole system during the test.

Based on the above-mentioned philosophy, the location and the kind of instruments were determined.

4.2 Detailed Features of Instrumentation

4.2.1 Type of Measurements and Schematic Arrangement of Instrumentation

According to the 2D/3D agreement, the instrumentation in the SCTF has been provided by JAERI and USNRC. JAERI has provided 1,259 sensors, including temperatures, pressures, differential pressures, liquid levels, flow rates, flow velocities, and heating powers.

The types of measurements are listed in Table 4-1. Total error of all the JAERI-provided instruments including the error of data acquisition system is less than 1%.

USNRC has provided "advanced instrumentation" which has been developed at three laboratories. Film probes, impedance probes and string probes were provided by the Oak Ridge National Laboratory (ORNL), LLDs, FDGs, turbine meters, drag disks, γ-densitometers and spool pieces were provided by the Idaho National Engineering Laboratory (INEL), and video optical probes were provided by the Los Alamos National Laboratory (LANL). JAERI-supplied main computer program converts the recorded signals into the physical values and makes figures by using subroutines provided by the USNRC. The types of measurements of the USNRC-provided instruments are listed in Table 4-2. Two-phase instrumentation is basically flow regime dependent, therefore accuracy of the USNRC-provided instruments is unknown.

Schematic arrangements of the instruments provided by JAERI and the USNRC are shown in Fig.4-1 and Fig.4-2, respectively. Detailed features of the instrumentation are described below by using the identification system of instruments explained in Tables 4-3 through 4-5.

4.2.2 Pressure Vessel

4.2.2.1 Temperatures in Core

The thermocouple locations on the heater rods and non-heated rods are shown in Figs.4-3 through 4-6. These thermocouples are used for the temperature measurements of the heater rod surface, the non-heated rod surface, the fluid and the steam.

4.2.2.2 Temperatures in Pressure Vessel except Core

The vertical locations of temperature measurements in the pressure vessel except the core are shown in Fig.4-7. Figs.4-8 and 4-9 show the horizontal locations of temperature measurements in the upper plenum and the other portion in pressure vessel except the core, respectively.

The thermocouples for fluid temperature measurements at the core inlet are installed on the non-heated rods as shown in Fig.4-10. Fig.4-11 shows in detail the locations of fluid temperature measurements just above and below the end box tie plate. The configuration of the thermocouples for the temperature measurements at the center and periphery of the UCSP holes is shown in Fig.4-12.

The horizontal and vertical locations of the fluid temperature measurements above the UCSP, the surface temperature measurements of the upper plenum structures and the steam temperature measurements above the UCSP holse are shown in Figs.4-13 through 4-15, respectively.

4.2.2.3 Pressures

In the pressure vessel, absolute pressures are measured in the upper plenum, the core, the lower plenum and the downcomer as shown in Fig.4-16.

4.2.2.4 Differential Pressures

The vertical differential pressure measurement in the core are made by using D/P cells between the adjacent spacers, across each spacer, across the lower and upper half of the core, and across the core full height as shown in Fig.4-17. The measurement locations of the horizontal differential pressures are shown in Fig.4-18. Fig.4-18 also shows the locations of the differential pressure measurement between the end boxes and the hot leg nozzle.

The locations of the differential pressure measurements across end box tie plate are shown in Fig.4-19. The measurement location of the differential pressure between the top of upper plenum and the bottom of lower plenum is shown in Fig.4-16. The figure also shows the locations of the horizontal differential pressure measurements in the downcomer.

4.2.2.5 Liquid Levels (D/P cells)

Liquid level measurements in the downcomer and the lower plenum are made by using D/P cells as shown in Fig.4-16. The liquid level measurements on the UCSP and the end box tie plate are also made by using D/P cells as shown in Fig.4-19.

The vertical locations of liquid level measurements in the core baffles are shown in Fig.4-20.

4.2.2.6 Steam Velocities

The steam velocity measurements at the core outlet, above and below the end box tie plates, and in the upper plenum are made by using water purge type Pitot tubes. The installed locations are shown in Fig.4-21. The measured flow directions of each of the Pitot tubes are also indicated in Fig.4-21.

4.2.2.7 Fluid Densities

The fluid density measurements in the core, below the end box and in the upper plenum are made by using γ-densitometers. The vertical and horizontal locations are shown in Figs.4-23 and 4-24, respectively.

4.2.2.8 Flow Velocities (turbine meters and drag disks)

The USNRC-provided turbine flow meters are installed at the core inlet, above the UCSP holes and in the upper plenum to measure fluid velocities.

The fluid velocity measurements in the top and bottom of the downcomer are made by using the USNRC-provided drag disks. The two-phase mass velocities can be calculated from the combination of the drag disks and the string probes located at the same elevations.

At the inlet of the lower plenum, two JAERI-provided drag disks are installed to measure the liquid velocities into the lower plenum as shown in Fig.4-22.

The measurement locations of the USNRC-provided instruments in the pressure vessel are shown in Figs.4-23 and 4-24. The locations of the turbine flow meters in upper plenum are shown in Fig.4-25.

4.2.2.9 Film Velocities and Film Thicknesses

The film thicknesses and average film velocities are calculated by using the output from the film probes attached on the thermal insulator walls, the upper plenum structures and the non-heated rods.
The measurement locations of the film probes are shown in Figs.4-23, 4-24, 4-26 and 4-27.

4.2.2.10 Local Void Fractions and Droplet Velocities

The local void fraction measurements in the top and bottom of downcomer are made by using string probes and the locations are shown in Fig.4-23 and Fig.4-24. The local void fraction measurements are made by using prong probes in the upper plenum and by using flag probes in the core. The locations of the prong and flag probes are shown in Fig.4-26 and Fig.4-27, respectively.

4.2.2.11 Liquid Levels and Fluid Distributions (LLDs and FDGs)

The liquid level measurements in the core and the lower plenum are made by using liquid level detectors (LLDs). Each of them has twenty measuring points as shown in Fig.4-28.

The two-dimensional fluid distribution (8×8) measurements in the upper plenum and the three-dimensional distribution (2×3×7) measurements in the downcomer are made by using fluid distribution grids (FDGs), and the measuring points are also shown in Fig.4-28.

4.2.3 Primary System and Auxiliary Systems

Measurement locations are shown in the following figures.

Fig.4-29	Broken cold leg (steam-water separator side)
	Steam-water separator (azimutal location)
Fig.4-30	Steam-water separator (axial location)
Fig.4-31	Broken cold leg (pressure vessel side)
Fig.4-32	Intact cold leg and pump simulator (azimutal location)
Fig.4-33	Pump simulator (axial location)
Fig.4-34	Hot leg
Fig.4-35	Containment tank-I
Fig.4-36	Containment tank-II
Fig.4-37	Vent valve simulation
Fig.4-38	ECC Header
Fig.4-39	Extraction system
Fig.4-40	Acc tank

In these figures there are the lists of pressure tap location corresponding to the tag number. In these tables 'L' denotes the lower pressure side of D/P cell, and 'H' higher pressure side.

Elevations relative to bottom of pressure vessel are shown in the parenthesis. In the SCTF three spool pieces are installed. One is a hot leg spool piece. The others are a broken cold leg spool piece of pressure vessel side and a vent line spool piece. Fluid temperatures, void fractions, mass flow rates and fluid velocities can be obtained from the measurement by using these spool pieces.

4.3 Flow Observation

4.3.1 Location of View Windows

Fig.4-41 shows the location of view windows in the SCTF. The lightings are provided from the opposite sides except at the window in the middle of the upper plenum. The lighting for this window is a reflection type and has a lighting window just above the view window.

4.3.2 Cameras

The following cameras can be installed at the view windows:

5 sets of black/white TV camera,

1 set of colour TV camera, and

1 set of variable high speed cine camera.

Variable high speed cine camera is 1-PL-photo sonics. It uses a 16 mm cine film (max 1200 ft) and can be changed the speed during the operation from 10 frames per second to 500 frames per second by remote-control. The stop is automatically changed corresponding to camera speed. And this camera system also has the time display system with the minimum time interval of 1/1000 second.

4.3.3 Monitor System

The monitor system for the flow observation consists of:

5 sets of black/white monitor TV,

2 sets of colour TV,

6 sets of VHS system video recorder,

2 sets of U-matic video recorder, and

7 sets of time display system.

The VHS uses a 1/2 inches video tape and an U-matic 3/4 inches video tape. The minimum display time is 1 second.

This monitor system begins to operate by the start signal of experiment sequence computer.

4.3.4 Video Optical Probes (VOPs)

As one of the USNRC-provided instruments, two video optical probes are installed in the upper plenum and between the grid spacer and tie-plate. Their locations are also shown in Fig.4-41. These probes are the TV cameras protected by a water cooling jacket. The lighting is of reflection type with D.C. and pulsed lightings. The lighting condition is remote-controlled.

Table 4-1 Measurement Items of SCTF
(JAERI-provided instruments)

LOCATION	ITEM	PROBE	QUANTITY
1. CORE			
Center	pressure	DP cell	1
short range of core	diff. press.	DP cell	22
half length of core	diff. press.	DP cell	16
full length of core	diff. press.	DP cell	8
across spacers	diff. press.	DP cell	7
across end box	diff. press.	DP cell	8
across 4 assemblies	diff. press.	DP cell	3
across 8 assemblies	diff. press.	DP cell	3
below and above end box	steam velocity	Pitot-tube	3
sub channel	stea- velocity	Pitot-tube	13
below end box hole	fluid temp.	T/C	16
above end box hole	fluid temp.	T/C	16
core baffle	fluid temp.	T/C	6
non-heated rods	fluid temp.	T/C	96
	steam temp.	SSP	16
	clad temp.	T/C	108
heater rods	clad temp.	T/C	640
side walls	wall temp.	T/C	36
core baffle	wall temp.	T/C	6
core baffle	liquid level	DP cell	1
short range of core baffle	liquid level	DP cell	6
heated rod	power		8
			sum(1039)
2. UPPER PLENUM			
center	pressure	DP cell	1
across end box tie plate	diff. press.	DP cell	8
core outlet-hot leg inlet	diff. press.	DP cell	4
periphery of UCSP hole	fluid temp.	T/C	8
center of UCSP hole	fluid temp.	T/C	8
250mm & 1000mm above UCSP	fluid temp.	T/C	8
surface of UCSP	fluid temp.	T/C	8
above UCSP hole	steam temp.	SSP	8

Table 4-1 (Continued)

LOCATION	ITEM	PROBE	QUANTITY
surface of structre	wall temp.	T/C	15
side walls	wall temp.	T/C	8
above end box tie plate	liquid level	DP cell	8
above UCSP	liquid level	DP cell	9
above UCSP (v.)	steam velocity	Pitot-tube	2
inter-structures (h.)	steam velocity	Pitot-tube	2
			sum(97)
3. LOWER PLENUM			
below bottom spacer	pressure	DP cell	1
lower plenum - upper plenum	diff. press.	DP cell	1
core inlet	fluid temp.	T/C	8
inlet from downcomer	fluid temp.	T/C	2
side & bottom walls	wall temp.	T/C	4
below bottom spacer	liquid level	DP cell	1
			sum(17)
4. DOWNCOMER			
upper position	pressure	DP cell	1
horizontal direction	diff. press.	DP cell	1
four levels	fluid temp.	T/C	8
side wall	wall temp.	T/C	2
inner wall	wall temp.	T/C	2
below cold leg level	liquid level	DP cell	1
above cold leg level	liquid level	DP cell	1
below core inlet level	liquid level	DP cell	1
bottom	momentum flux	Drag disk	2
			sum(19)
5. HOT LEG			
full length	diff. press.	DP cell	1
multiple points	fluid temp.	T/C	3
	steam temp.	SSP	3
	wall temp.	T/C	1
	liquid level	DP cell	2
			sum(10)

Table 4-1 (Continued)

LOCATION	ITEM	PROBE	QUANTITY
6. S-W SEPARATOR SIDE BROKEN COLD LEG			
across resistance simulator	diff. press.	DP cell	1
S-W separator to containment tank-II	flow rate	Venturi	1
multiple points	fluid temp.	T/C	1
	steam temp.	SSP	1
	wall temp.	T/C	1
			sum(5)
7. INTACT COLD LEG			
full length	diff. press.	DP cell	1
across resistance simulator	diff. press.	DP cell	1
across pump simulator	diff. press.	DP cell	1
	flow rate	Venturi	1
near resistance simulator	fluid temp.	T/C	1
pump simulator	fluid temp.	T/C	3
	wall temp.	T/C	1
			sum(9)
8. PV SIDE BROKEN COLD LEG			
	pressure	DP cell	1
full length	diff. press.	DP cell	1
across resistance simulator	diff. press.	DP cell	1
multiple points	fluid temp.	T/C	4
	wall temp.	T/C	2
	liquid level	DP cell	2
			sum(11)
9. VENT LINE			
across the length	diff. press.	DP cell	1
			sum(1)

Table 4-1 (Continued)

LOCATION	ITEM	PROBE	QUANTITY
10. S-W SEPARATOR			
	pressure	DP cell	1
between inlet and outlet	diff. press.	DP cell	1
SG plenum simulator	diff. press.	DP cell	1
SG plenum simulator	fluid temp.	T/C	2
top and bottom	fluid temp.	T/C	2
wall	wall temp.	T/C	2
full height	liquid level	DP cell	1
liquid extraction	flow rate	DP cell	1
			sum(11)
11. CONTAINMENT TANK-I			
	pressure	DP cell	1
downcomer - CT-I	diff. press.	DP cell	1
CT-II - CT-I	diff. press.	DP cell	1
	flow rate	DP cell	1
full height	liquid level	DP cell	1
		flot	1
top, middle & bottom	fluid temp.	T/C	3
wall	wall temp.	T/C	1
			sum(10)
12. CONTAINMENT TANK-II			
	pressure	DP cell	1
upper plenum - CT-II	diff. press.	DP cell	1
separator - CT-II	diff. press.	DP cell	1
steam blow line	flow rate	DP cell	1
full height	liquid level	DP cell	1
top, middle & bottom	fluid temp.	T/C	3
			sum(8)
13. ECC INJECTION SYSTEM			
Acc tank	pressure	DP cell	1
total and LPCI	flow rate	E-M flow meter	2
			1
Acc tank	fluid temp.	T/C	1
header	fluid temp.	T/C	2

Table 4-1 (Continued)

LOCATION	ITEM	PROBE	QUANTITY
Acc tank	liquid level	DP cell	1
			sum(8)
14. UCSP WATER EXTRACTION SYSTEM			
extraction line	flow rate	E-M flow meter	4
steam line	flow rate	DP cell	4
extraction line	fluid temp.	T/C	5
steam line	fluid temp.	T/C	1
extraction line	liquid level	DP cell	4
			sum(18)
15. SATURATED WATER TANK			
	fluid temp.	T/C	1
	liquid level	DP cell	1
			sum(2)
16. NITROGEN GAS SYSTEM			
	flow rate	DP cell	1
injection port	fluid temp.	T/C	1
			sum(2)

Note: v = vertical, h = horizontal

Total 1267

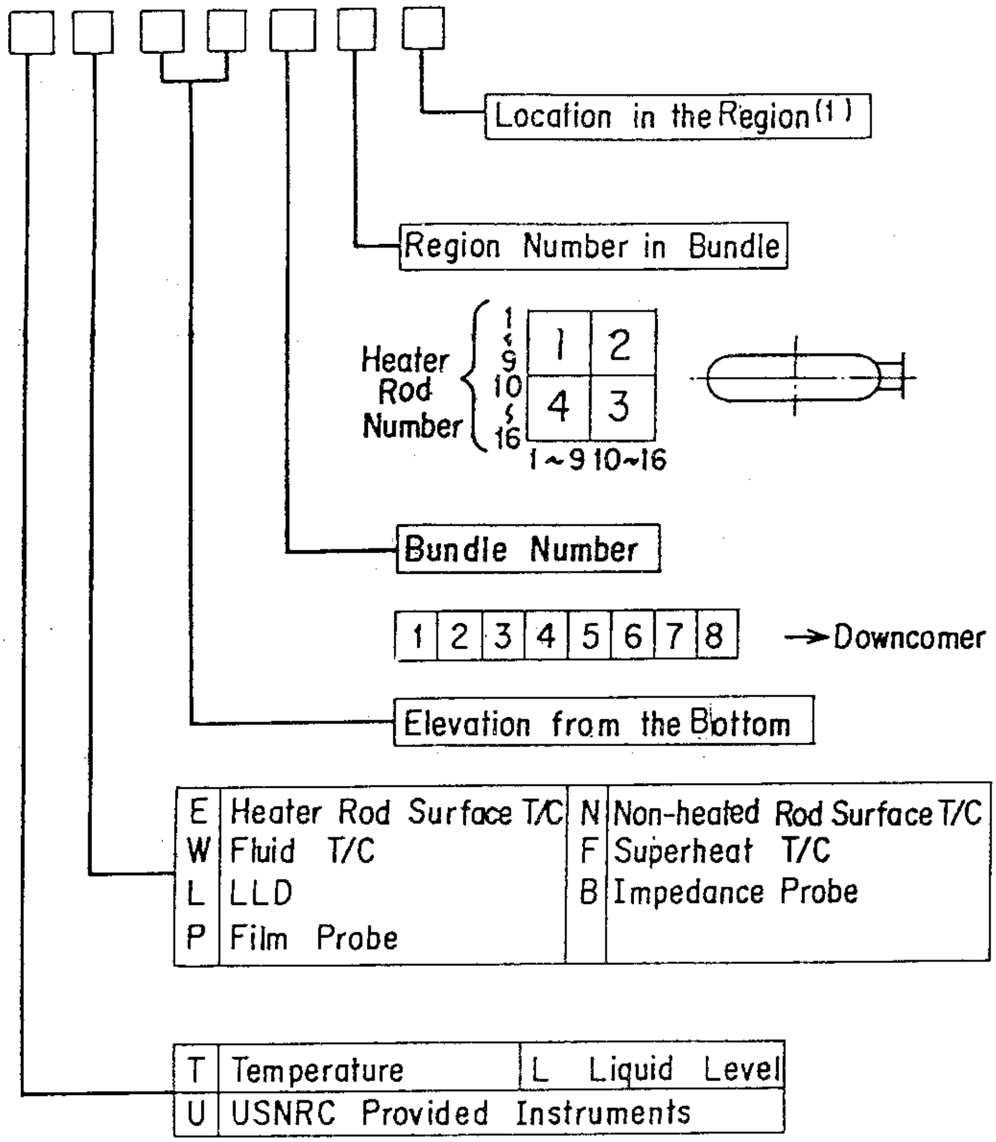
Table 4-2 Measurement Items of SCTF (USNRC-provided instruments)

LOCATION	ITEM	PROBE	QUANTITY
1. CORE			
non-heated rods	liquid level	LLD	20×4 = 80
non-heated rods	film thickness and velocity	film probe	6
non-heated rods	void fraction and droplet velocity	flag probe	8
side walls	film thickness and velocity	film probe	8
sub-channel	fluid density	γ-densitometer	10
end box	fluid density	γ-densitometer	5
end box	flow pattern	video optical probe	1
2. UPPER PLENUM			
full height	liquid level	FDG	8×8 = 64
structure surface	film thickness and velocity	film probe	6
side walls	film thickness and velocity	film probe	6
inter structure	void fraction	prong probe	8
above UCSP hole	velocity	turbine	8
inter structure	velocity	turbine	4
inter structure	fluid density	γ-densitometer	4
hot leg inlet	flow pattern	video optical probe	1
3. LOWER PLENUM			
core inlet	velocity	turbine	4
bottom	reference conductivity	reference probe	1
4. DOWNCOMER			
full height	liquid level	FDG	2×3×7 = 42
two levels	velocity	drag disk	3
two levels	void fraction	string probe	3

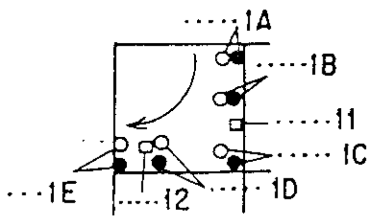
Table 4-2 (Continued)

LOCATION	ITEM	PROBE	QUANTITY
5. HOT LEG	mass flow rate fluid density void fraction	spool piece	1
6. PV SIDE BROKEN COLD -LEG	mass flow rate fluid density void fraction	spool piece	1
7. VENT LINE	mass flow rate void fraction	spool piece	1

Table 4-3 Description of Tag-ID Number (in-core)



Note : (1) for Heater Rod T/C



○ Upper half } Clockwise
● Lower half } A~E
□ Center } 1~2

Table 4-4 Description of Tag-ID Number (pressure vessel except core)

□ □ □□ □ □ □

Location (1)

Horizontal Region (2)

A	Lower Plenum	K	UP wall
B	Lower Plenum Wall	L	UP Structure
C	Core Inlet	M	UP Structure Surface
D	Core	N	Core Baffle
E	Core Side Wall	O	Core Baffle Wall
F	End Box	P	Downcomer
G	Across Spacers	Q	Downcomer Inner Wall
H	UCSP	R	Downcomer Outer Wall
I	UCSP Surface	S	Between Spacers
J	Upper Plenum (UP)		

Elevation from the bottom	00 ~ 99

E	T/C	T	Transducer	F	SSP
L	LLD	V	Pitot Tube	D	Drag Disk
P	Film Probe	B	Impedance Probe	S	String Probe
C	FD Grid	T	Turbine (UT)	G	γ-densitometer
R	Reference Probe				

T	Temperature	L	Liquid Level	P	Pressure
D	Differential Pressure	V	Fluid Velocity		
U	USNRC Provided Instruments				

Note :

(1) 1 ~ 9 → Downcomer

(2) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 9 |

1–8: Bundle Number; 0: Core Baffle; 9: Downcomer

Table 4-5 Description of Tag-ID Number (except pressure vessel)

□ □ □ □ □ □ □

S	Slab Core

P	Pipe Wall
V	Vessel Wall
W	Fluid

H	Hot leg	V	Vent Line
C	Intact Cold Leg	Z	Broken Cold Leg-PV Side
A	A	G	Steam-water Separator
T	LPCI	F	Containment Tank-I
D	Overflow, Drain	B	Containment Tank-II
J	LP Feed Line	S	Storage Tank
Q	Equalizing Line	I	Injection Water Tank
K	Extraction Line	M	Fuel Assembly
U	UCSP Feed Line	O	UCSP Water Supply tank
E	Containment Tank I-II Equalizing Line	N	Steam-Water Separator for Extraction Line
L	Broken Cold Leg- S/W Separator Side		
P	Pressurized Line	W	LP Feed Water Tank

Location	01 ~ 09

E	T/C	G	γ-Densitometer
T	Transducer	T	Turbine (UT)
F	SSP	D	Drag Disk
L	LLD	K	TV-Camera
S	String Probe		

T	Temperature	F	Flow Rate
P	Pressure	W	Heating Power
D	Differential Pressure	U	USNRC Provided Instraments
L	Liquid Level		

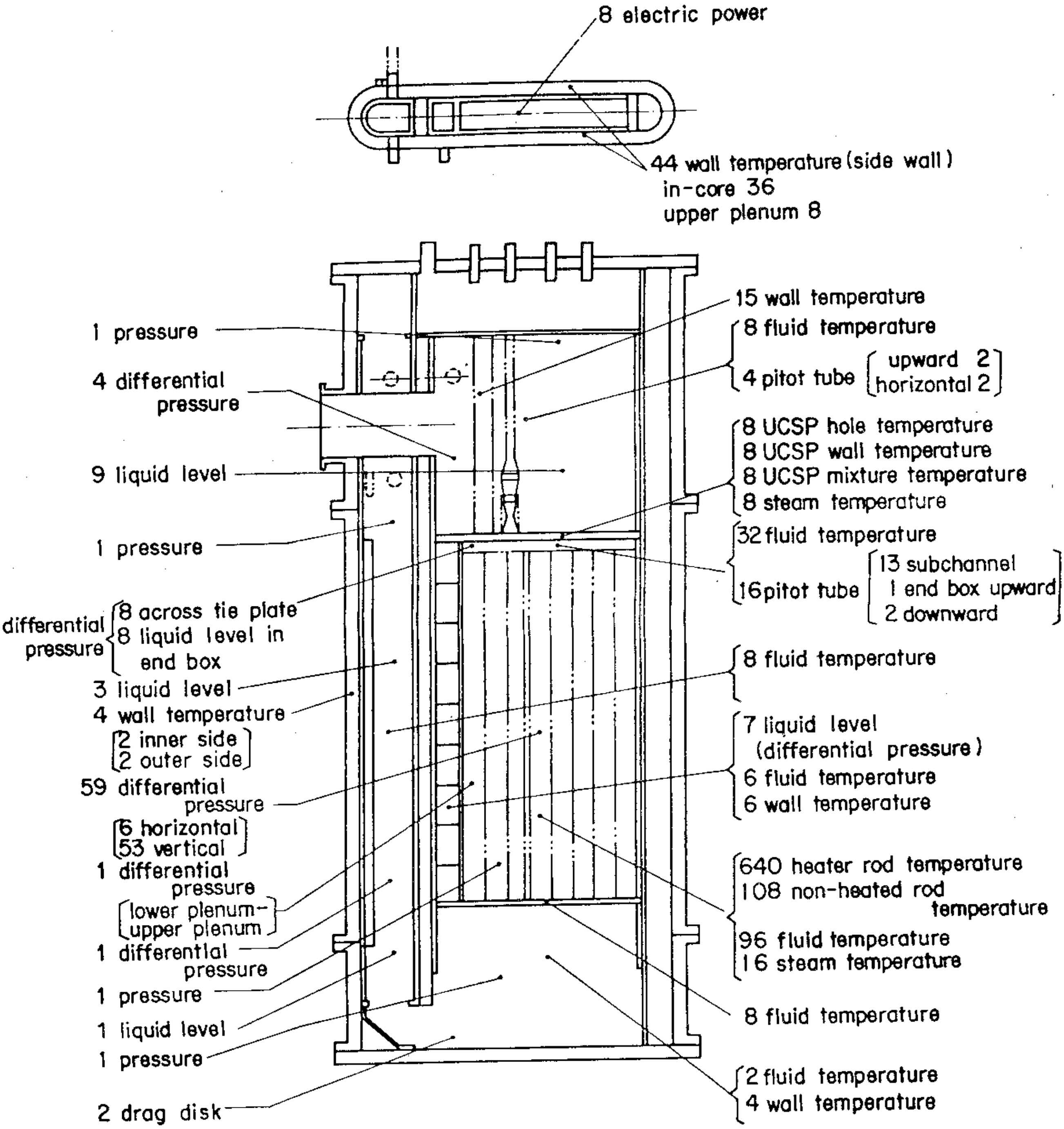


Fig.4-1 Schematic Arrangement of JAERI-Provided Instruments

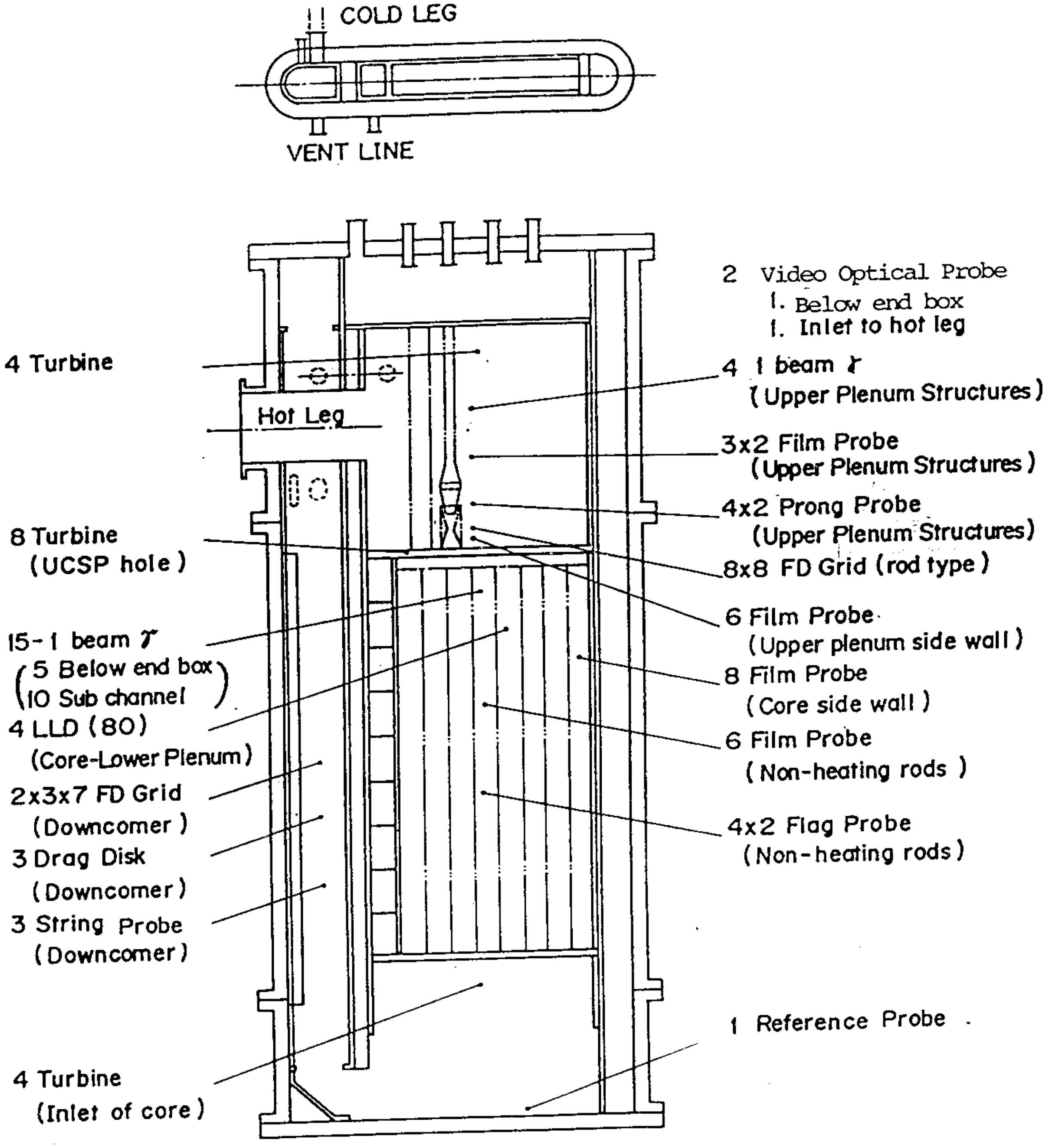


Fig.4-2 Schematic Arrangement of USNRC-Provided Instruments

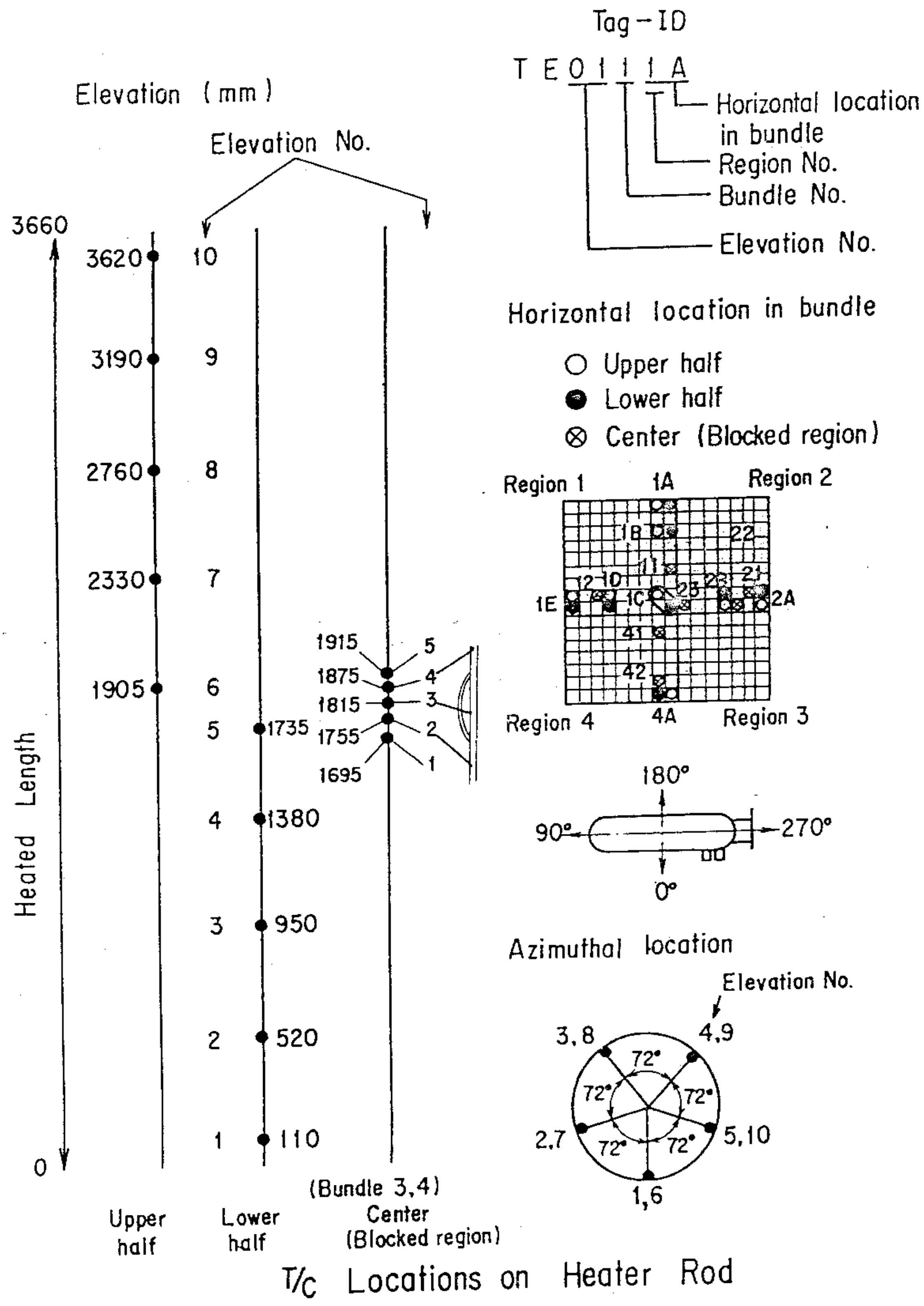


Fig.4-3 Thermocouple Locations of Heater Rod Surface Temperature Measurements

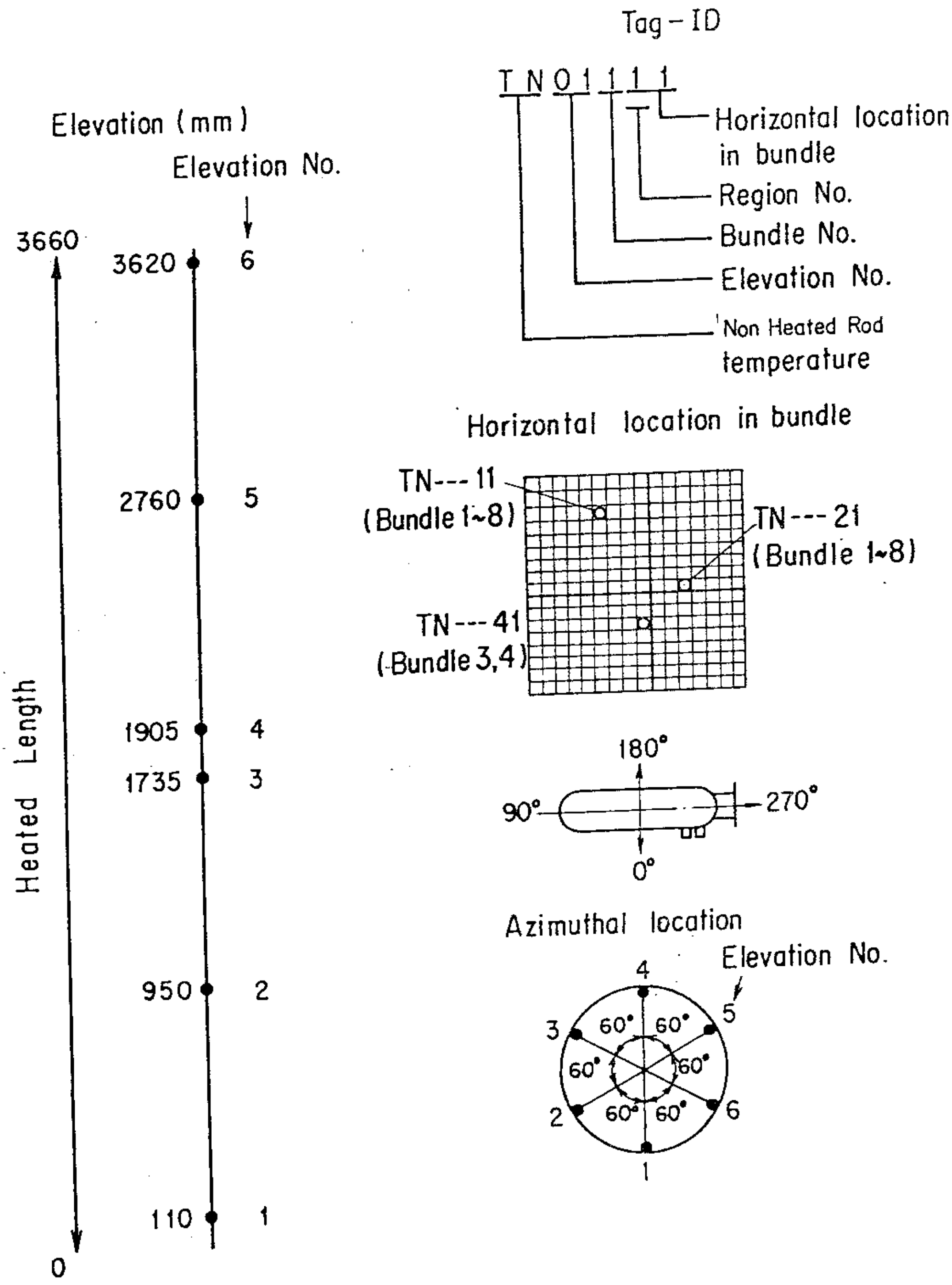


Fig.4-4 Thermocouple Locations of Non-Heated Rod Surface Temperature Measurements

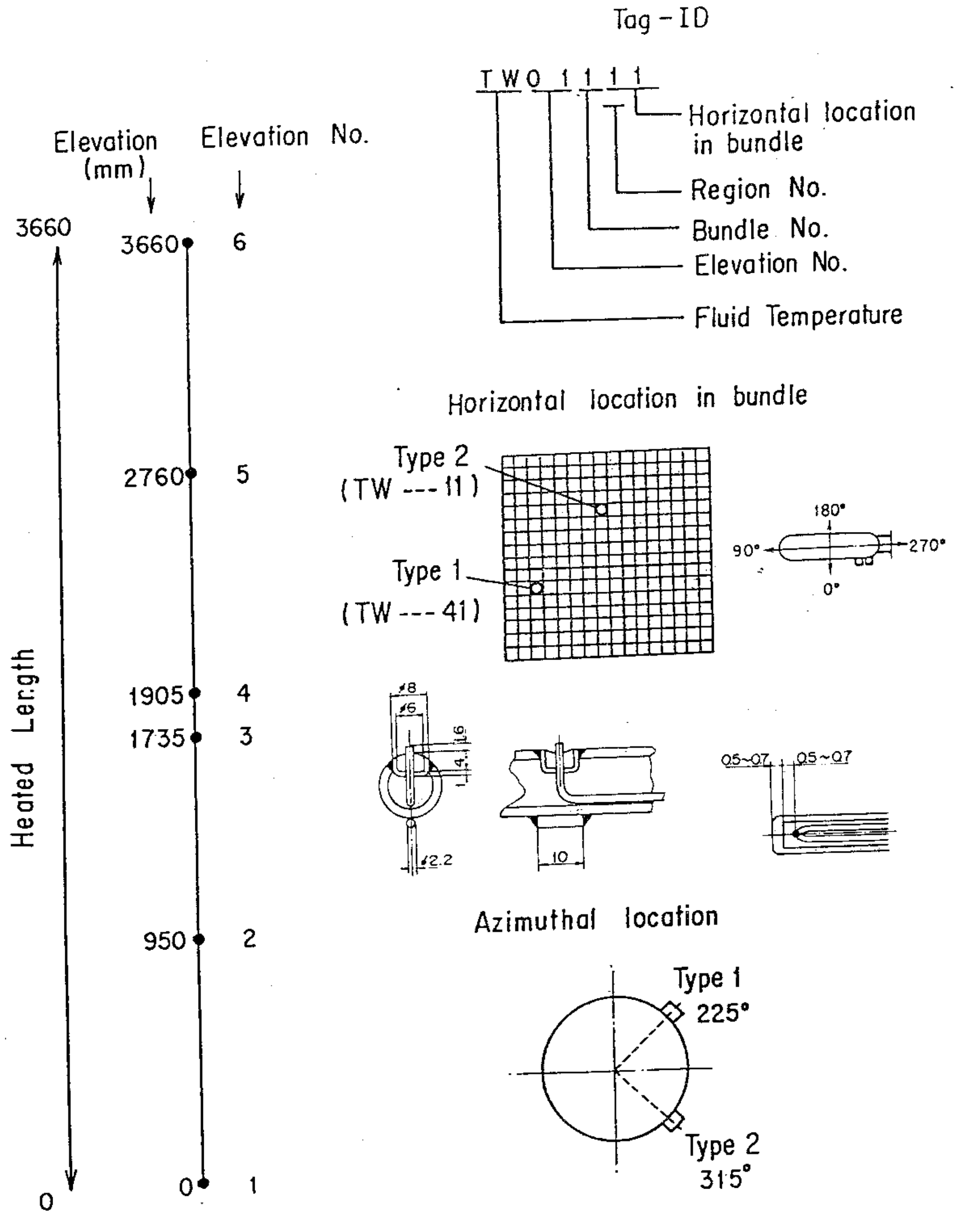


Fig.4-5 Thermocouple Locations of Fluid Temperature Measurements in Core

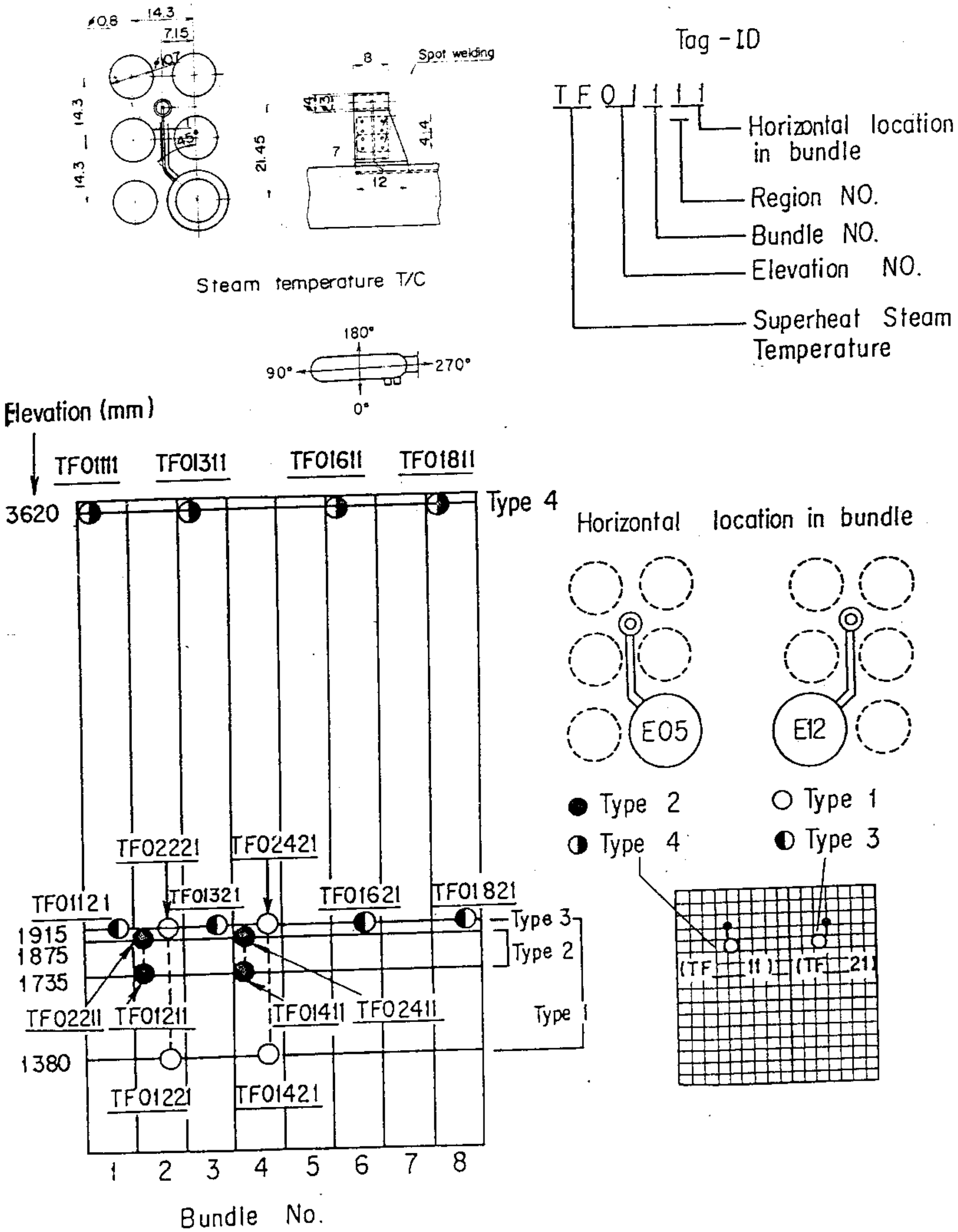


Fig.4-6 Thermocouple Locations of Steam Temperature Measurements in Core

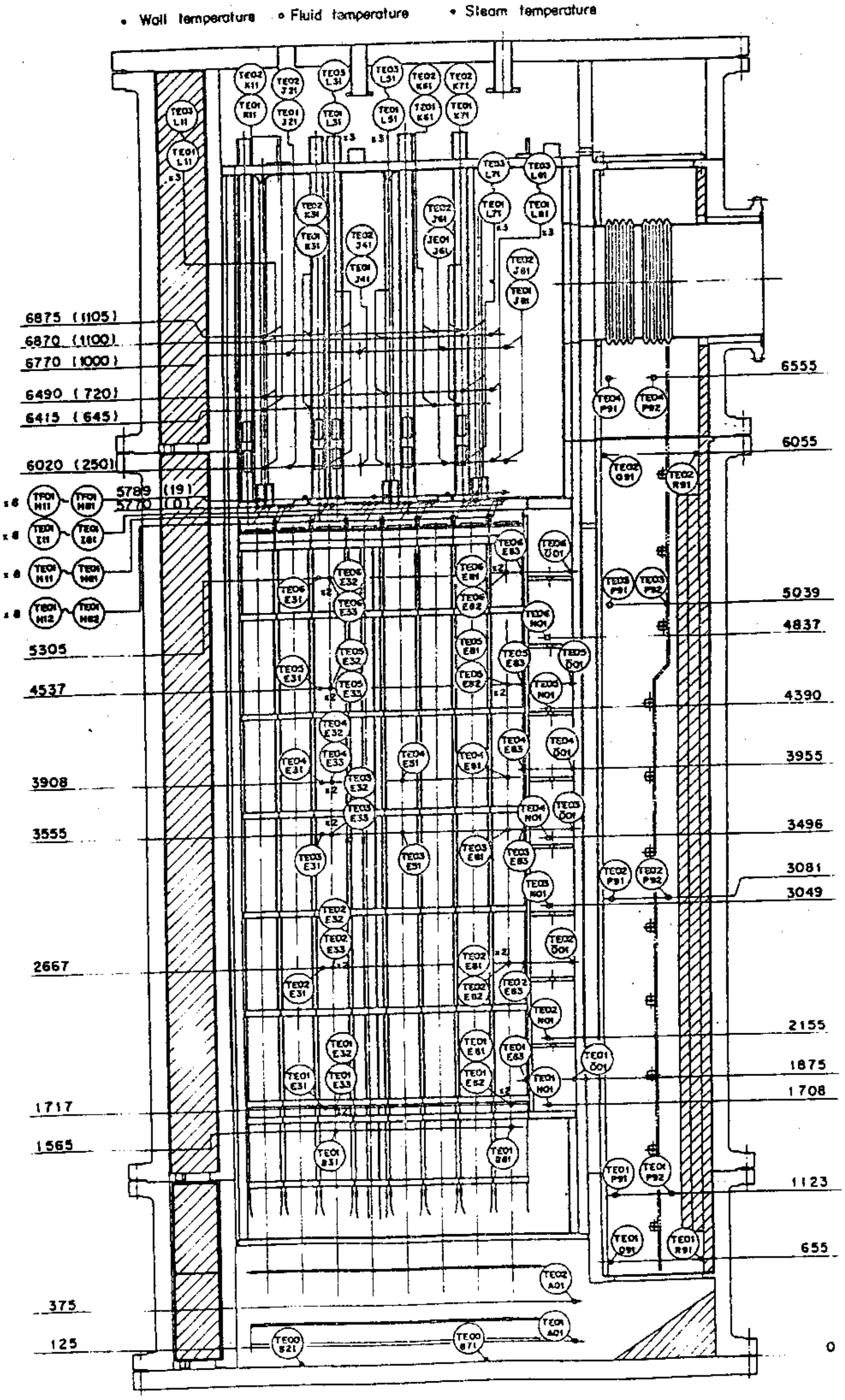


Fig.4-7 Thermocouple Locations of Temperature Measurements in Pressure Vessel except Core Region (Vertical View)

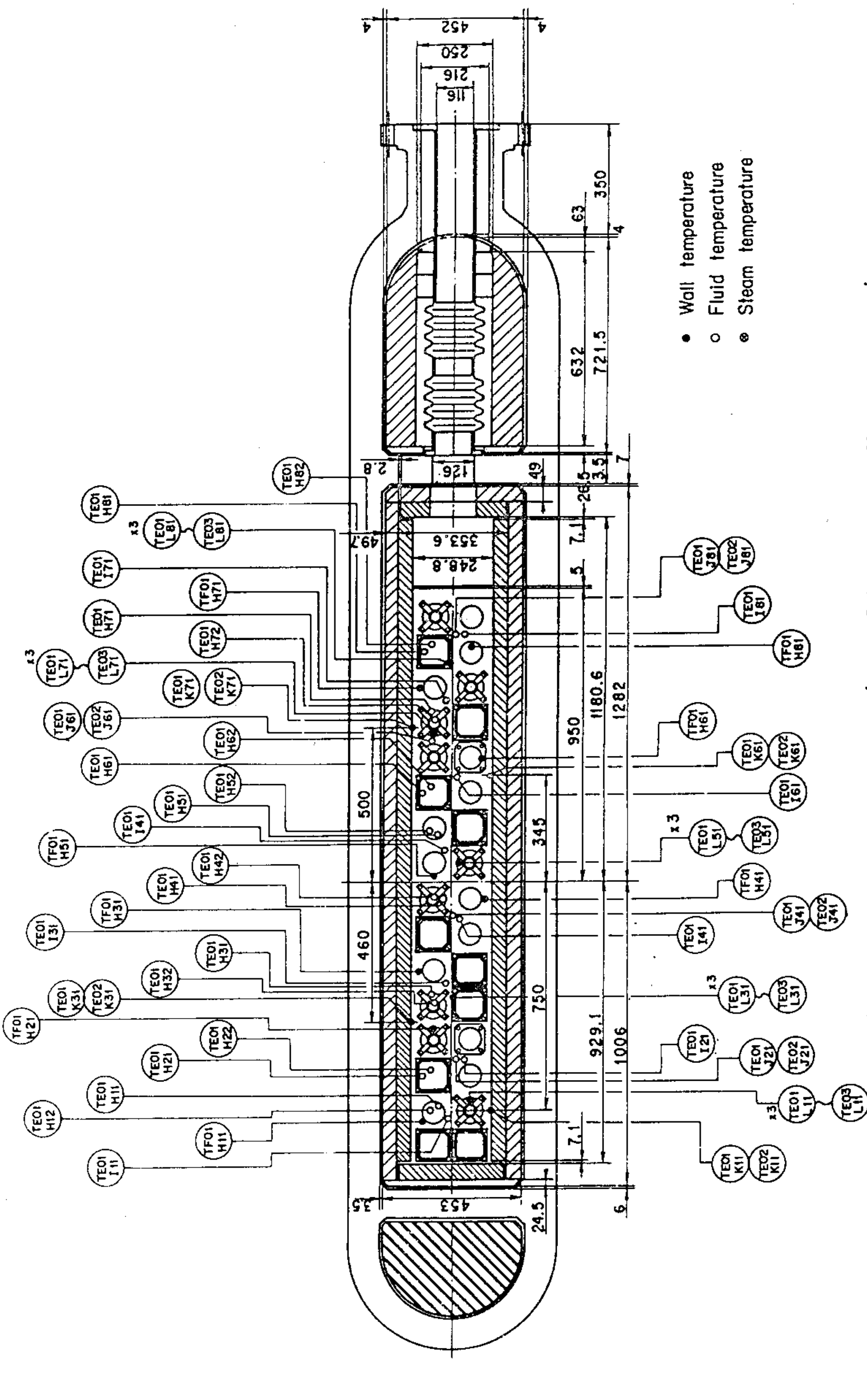


Fig.4-8 Thermocouple Locations of Temperature Measurements in Upper Plenum (Horizontal View)

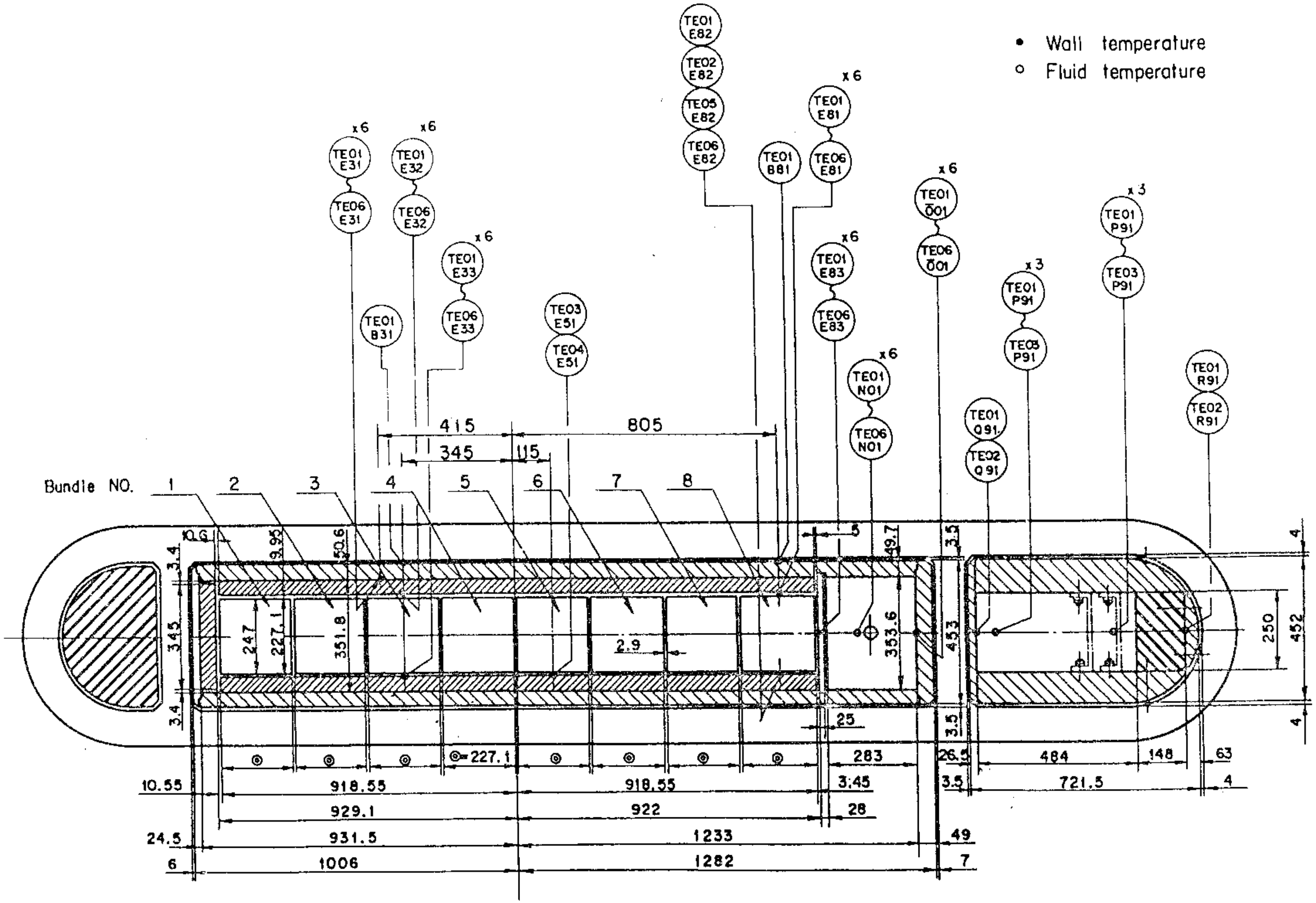


Fig.4-9 Thermocouple Locations of Temperature Measurements in Pressure Vessel except Upper Plenum (Horizontal View)

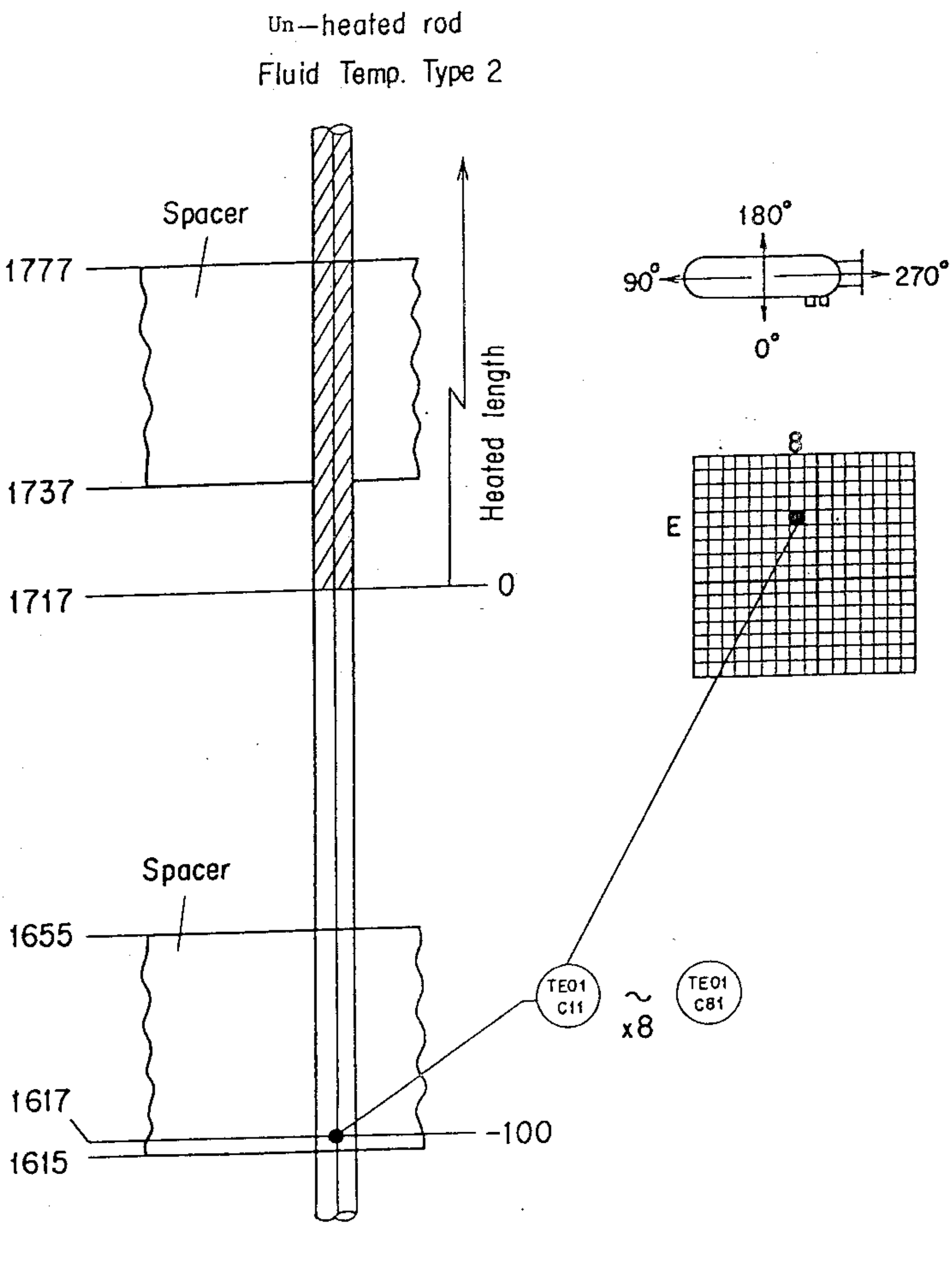


Fig.4-10 Thermocouple Locations of Fluid Temperature Measurements at Core Inlet

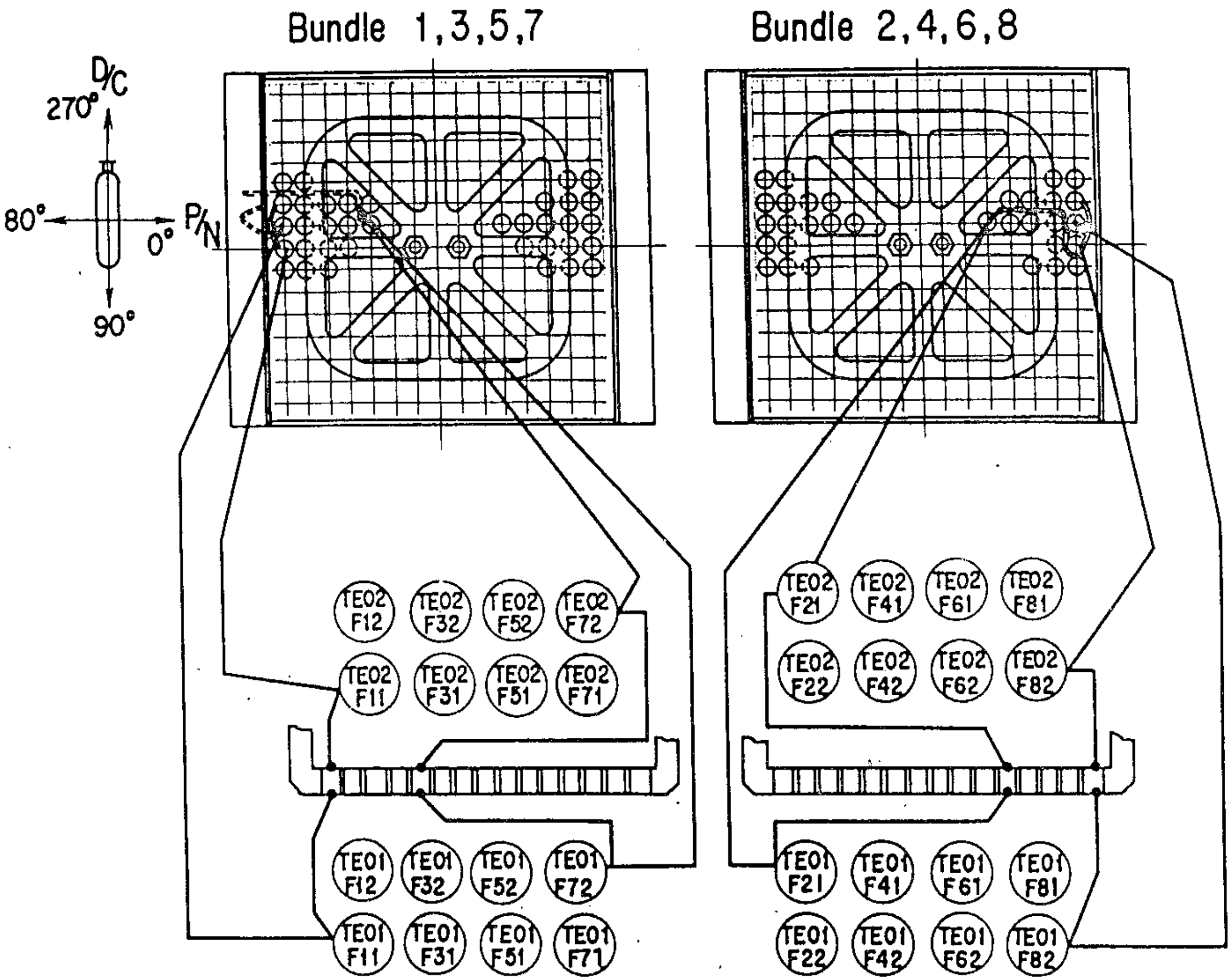


Fig.4-11 Thermocouple Locations of Fluid Temperature Measurements just above and below End Box Tie Plates

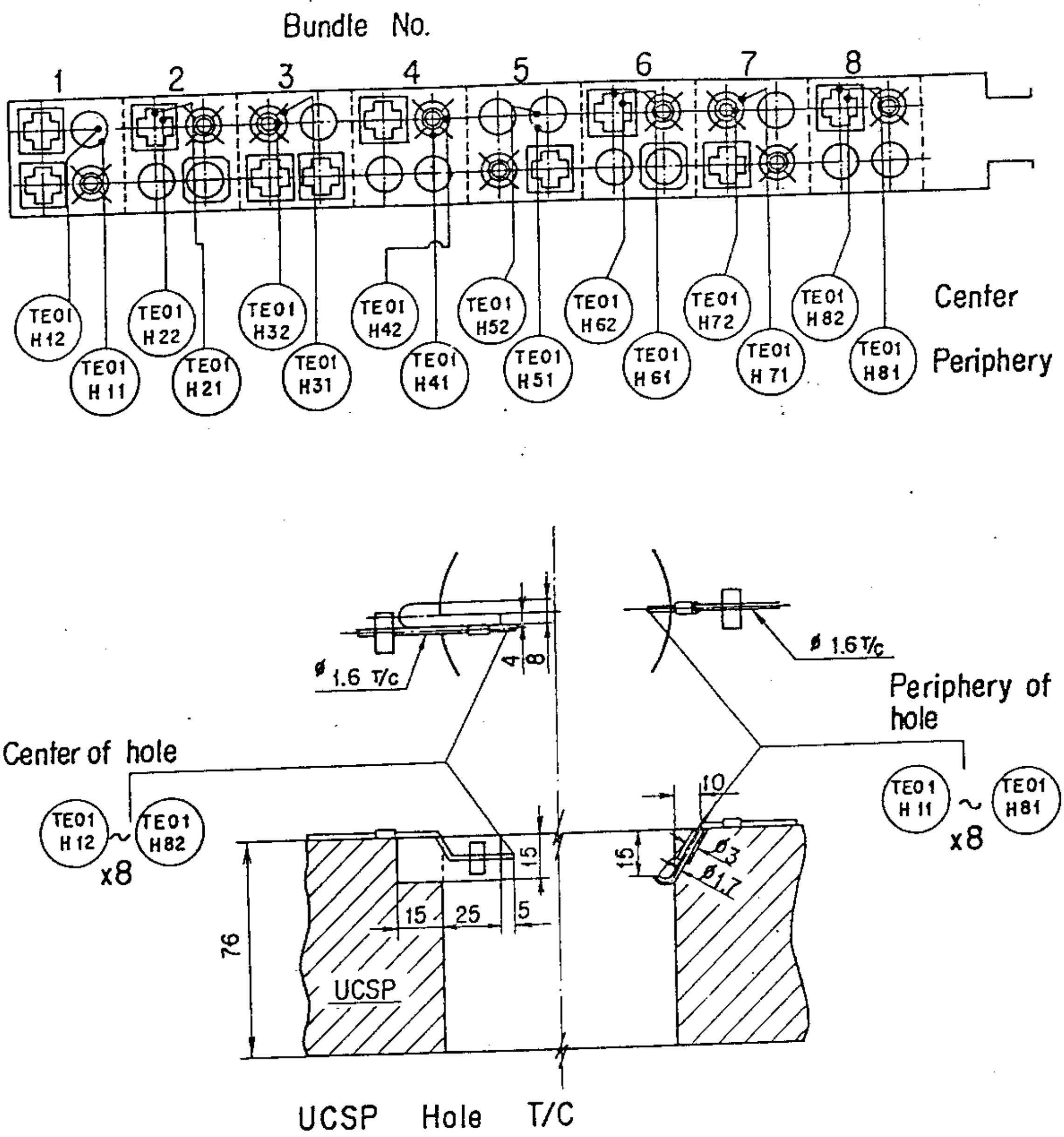


Fig.4-12 Thermocouple Locations of Fluid Temperature Measurements at Center and Periphery of UCSP Holes

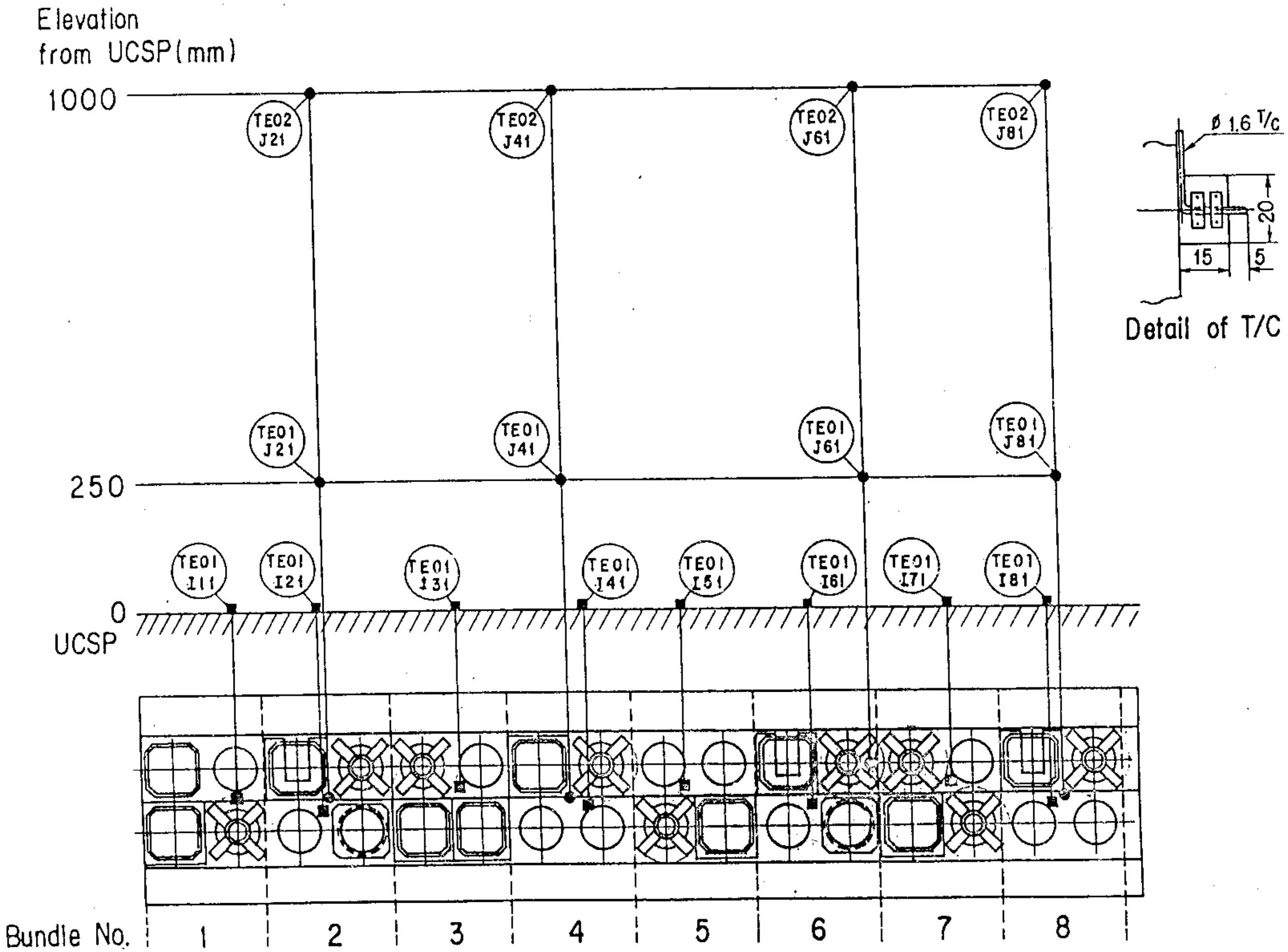


Fig.4-13 Thermocouple Locations of Fluid Temperature Measurements on and above USCP

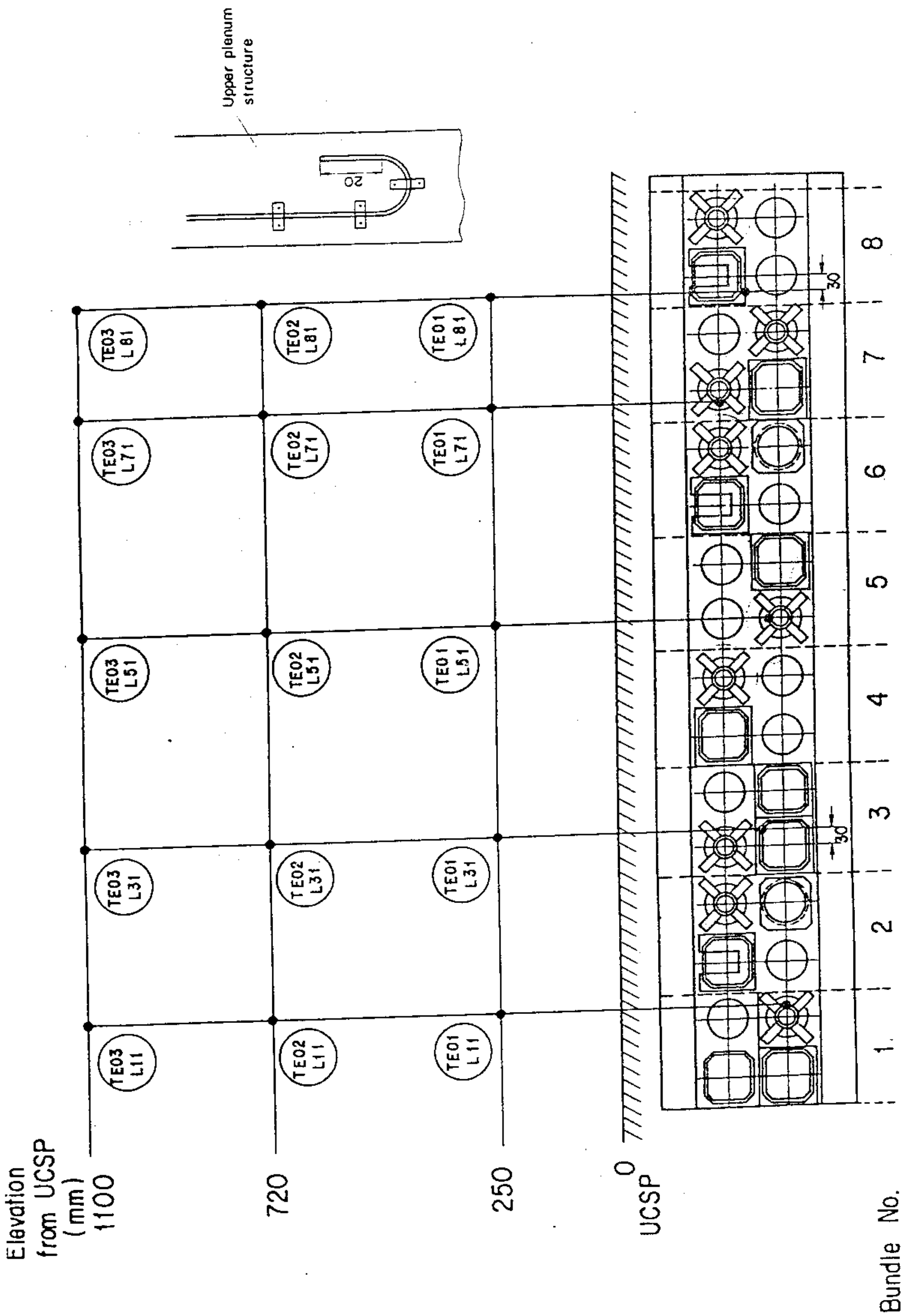


Fig.4-14 Thermocouple Locations of Surface Temperature Measurements of Upper Plenum Structures

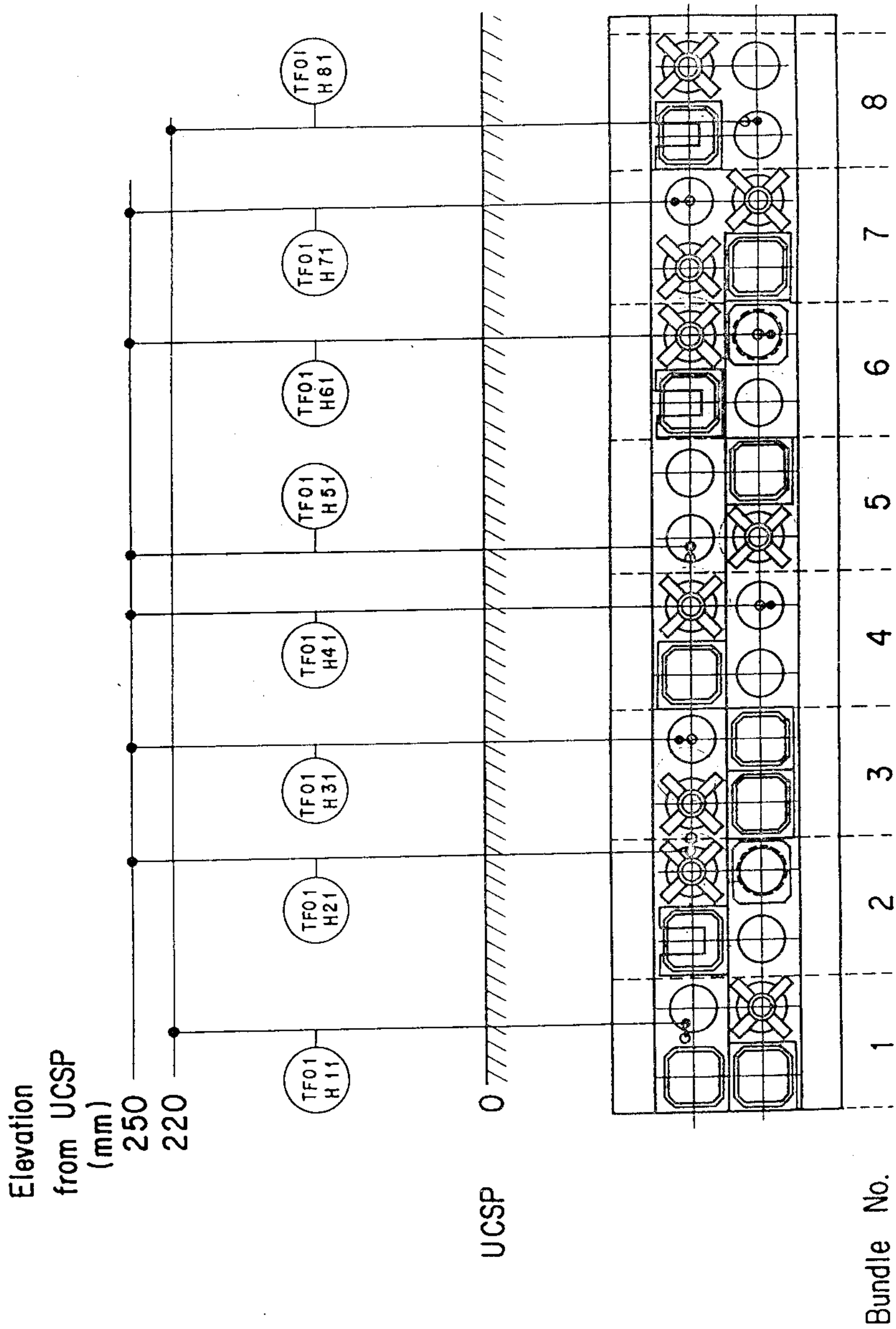
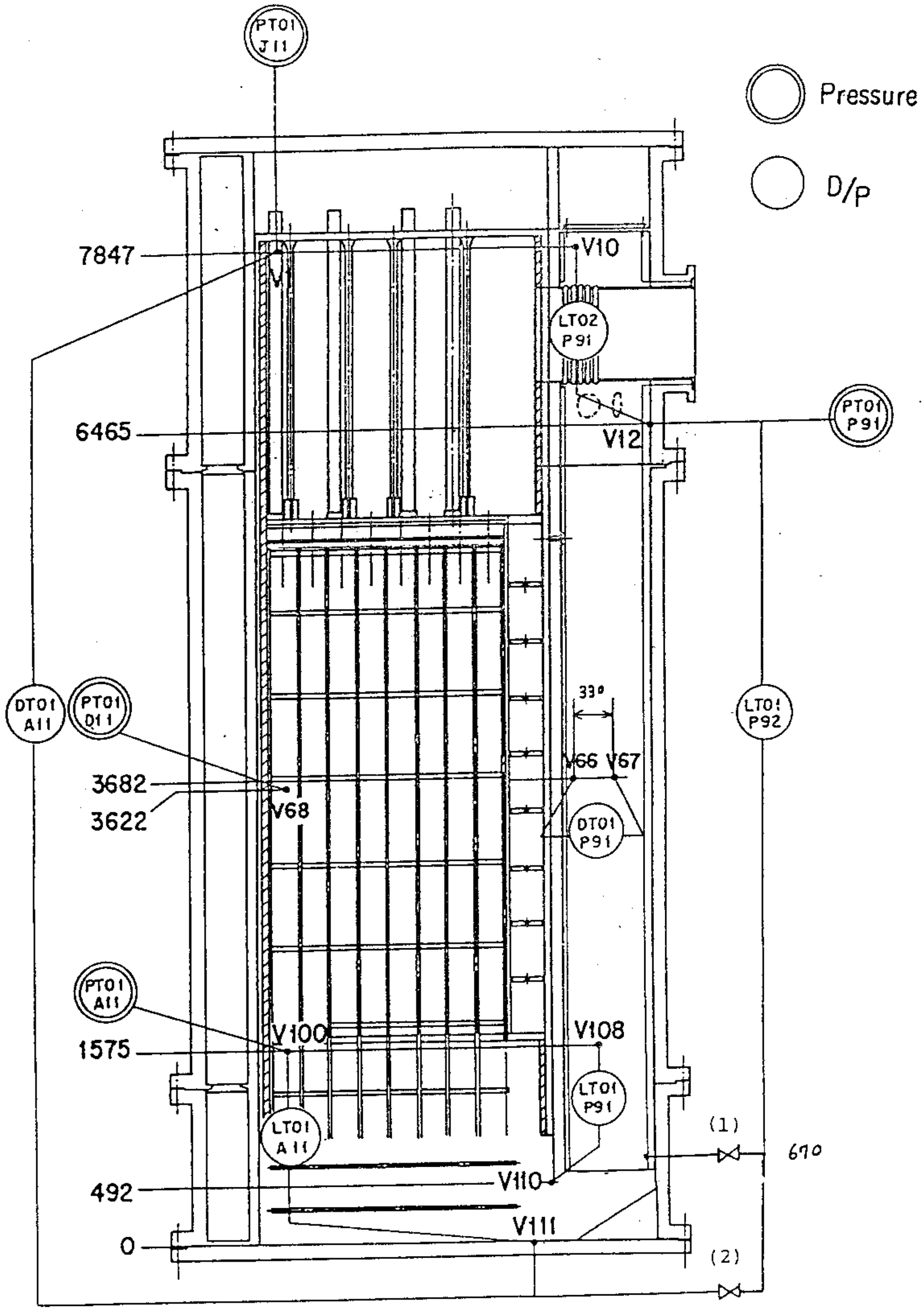


Fig.4-15 Thermocouple Locations of Steam Temperature Measurements above UCSP Holes



(1) used for lower plenum injection tests
(the bottom of downcomer is blocked)

(2) used for the other tests

Fig.4-16 Locations of Pressure Measurements in Pressure Vessel, Differential Pressure Measurements between Upper and Lower Plenums and Liquid Level Measurements in Downcomer and Lower Plenum

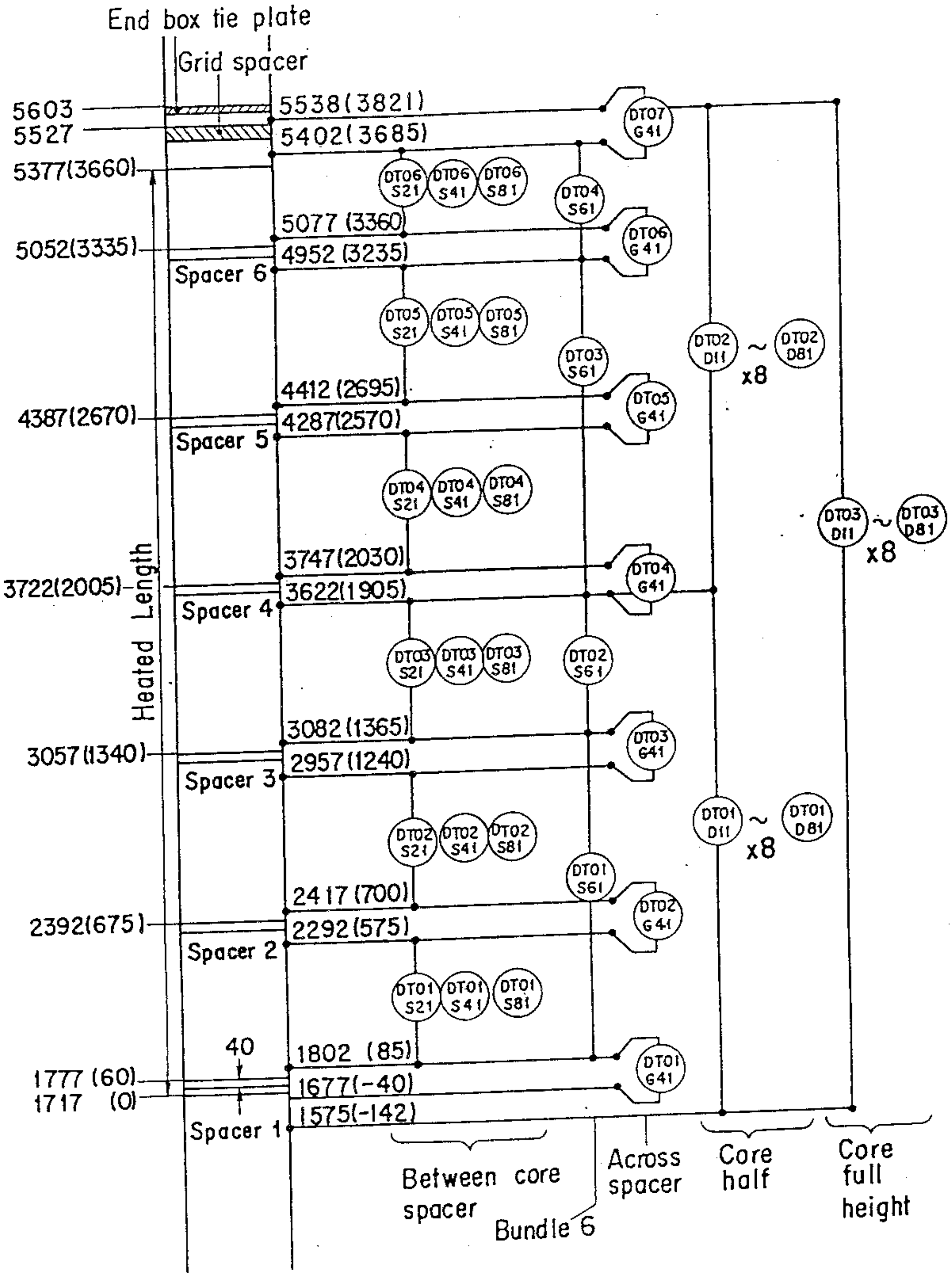


Fig.4-17 Locations of Vertical Differential Pressure Measurements in Core

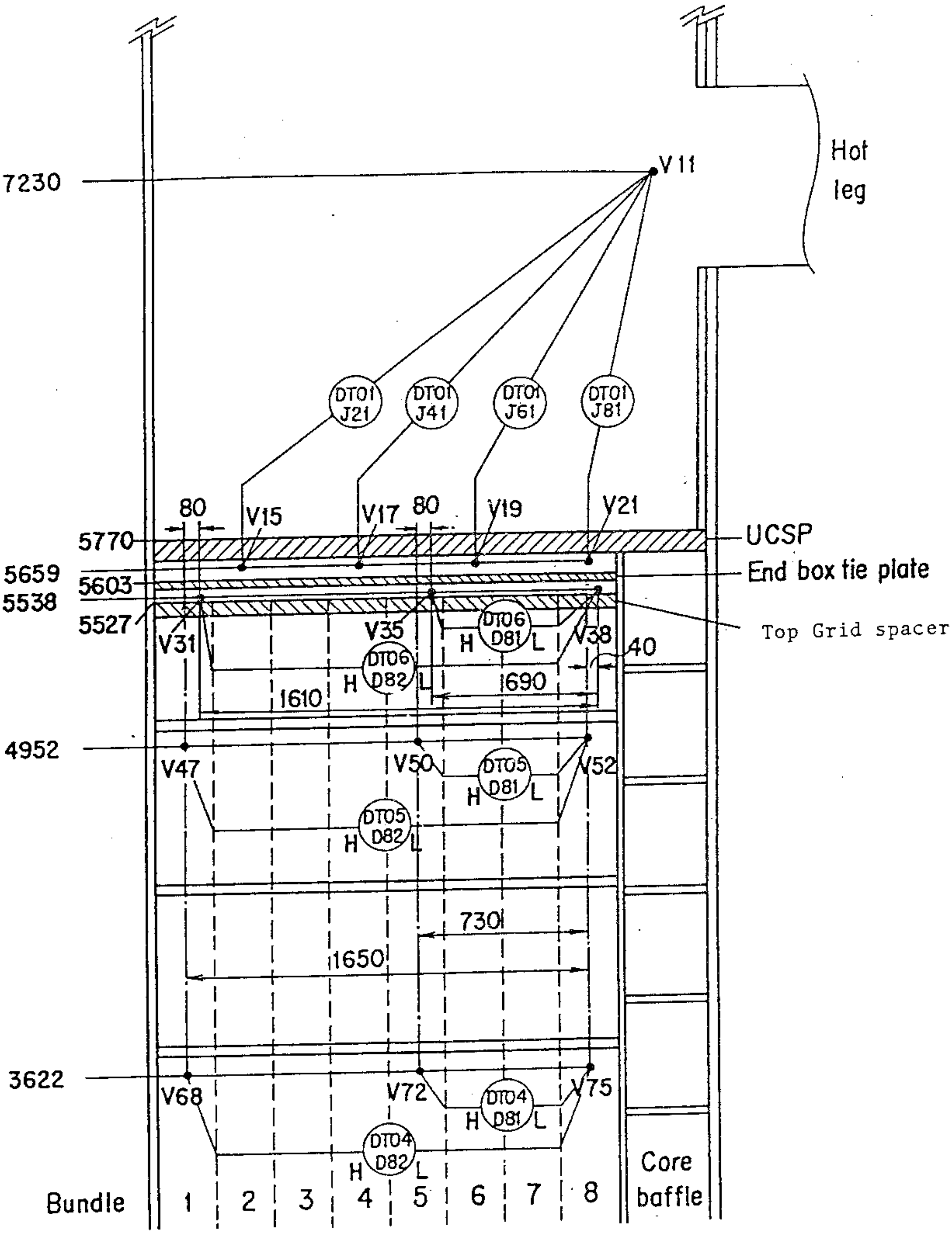


Fig.4-18 Locations of Horizontal Differential Pressure Measurements in Core and Differential Pressure Measurements between End Boxes and Inlet of Hot Leg

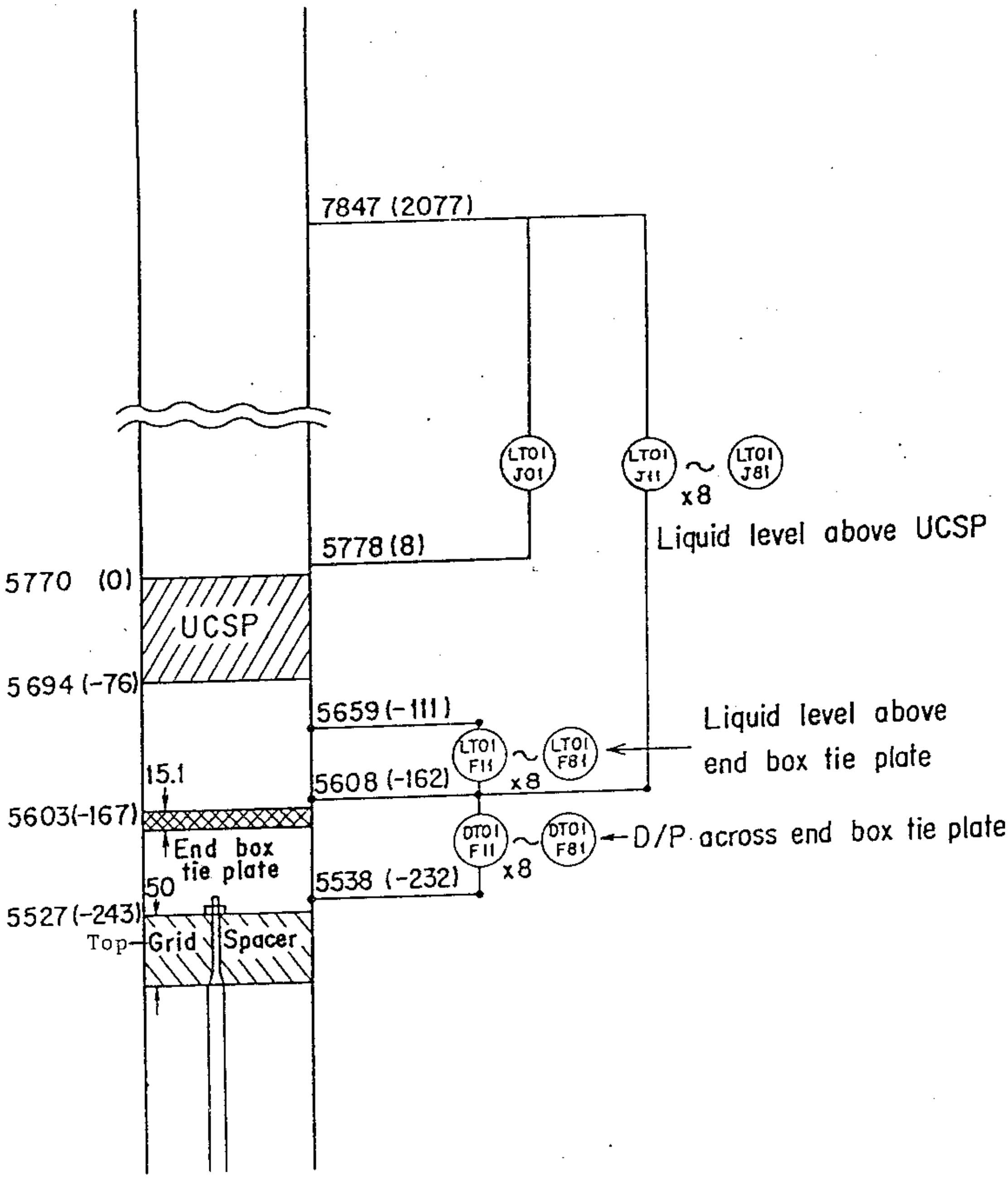


Fig.4-19 Locations of Differential Pressure Measurements across End Box Tie Plate and Liquid Level Measurements above UCSP and End Box Tie Plate

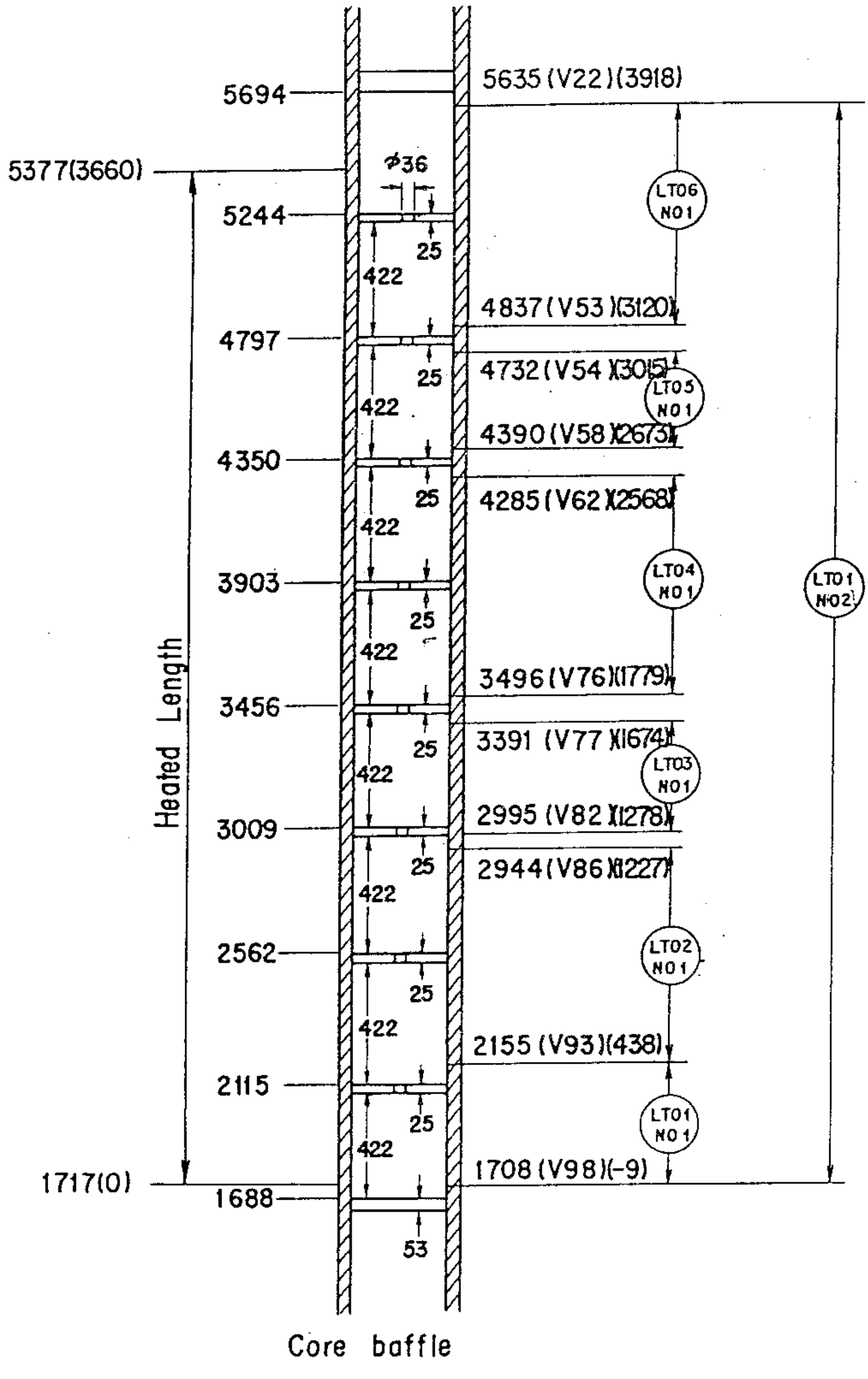


Fig.4-20 Locations of Liquid Level Measurements in Core Baffle

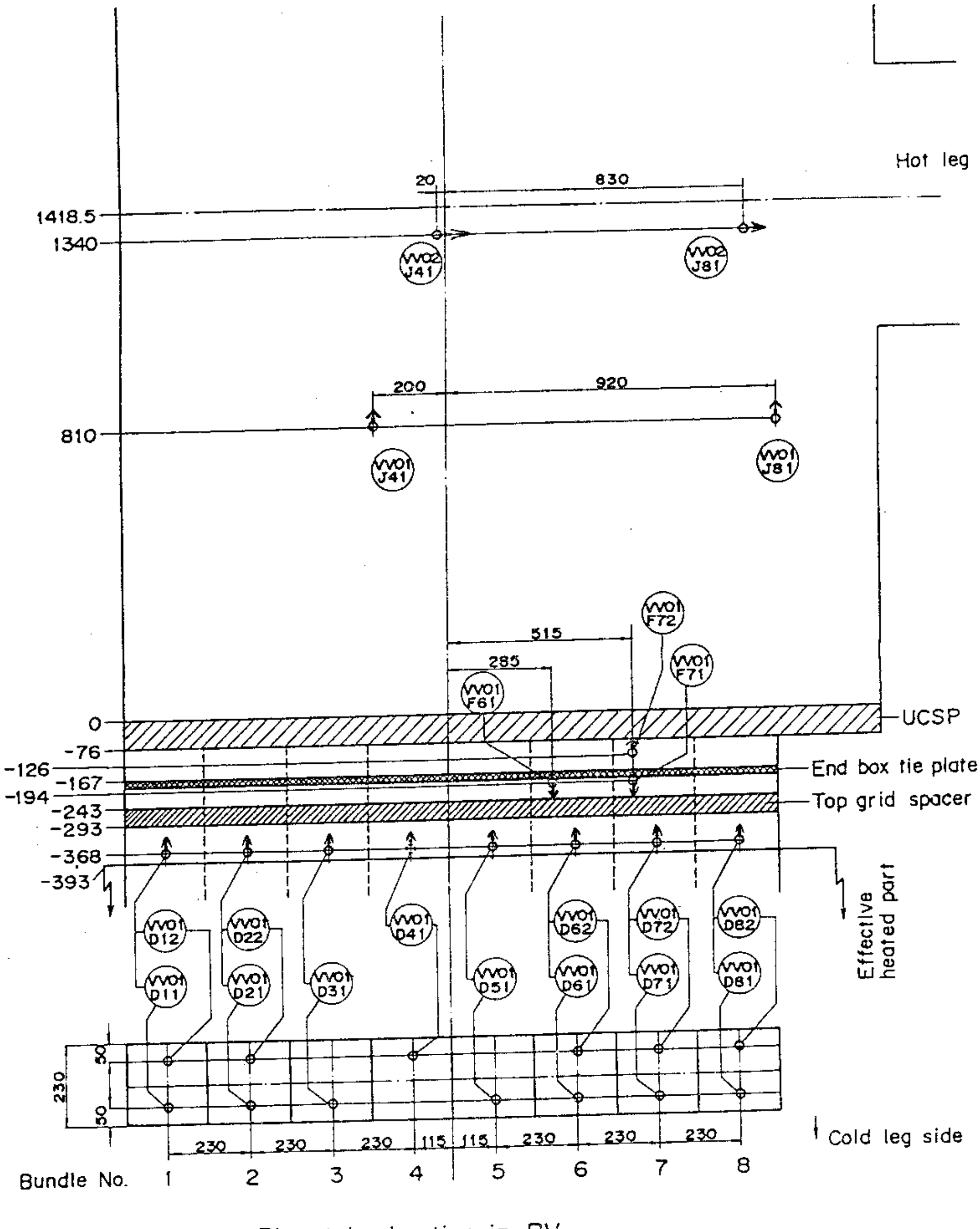


Fig.4-21 Locations of Steam Velocity Measurements with Pitot Tubes

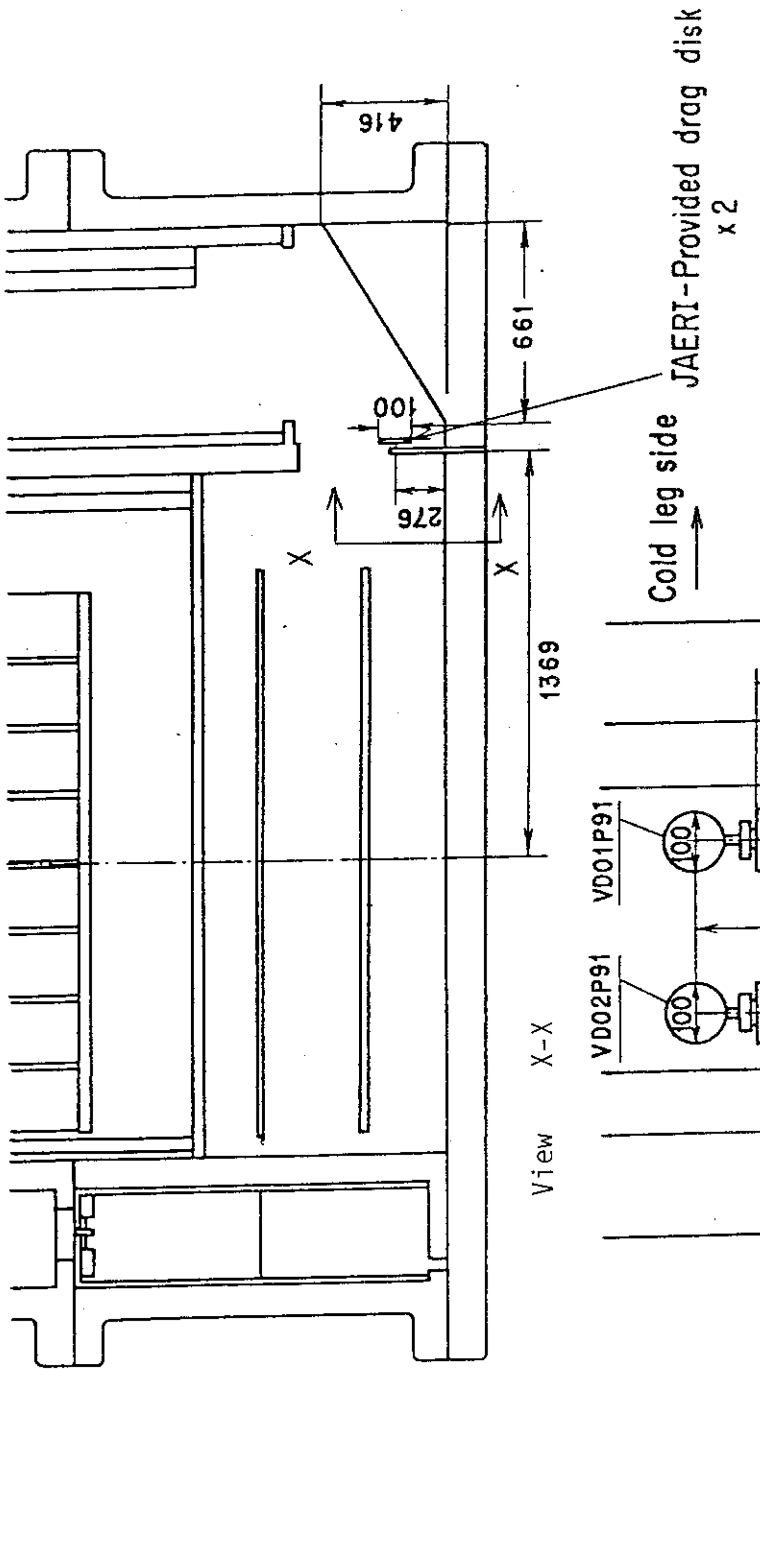


Fig.4-22 Locations of JAERI-Provided Drag Disks

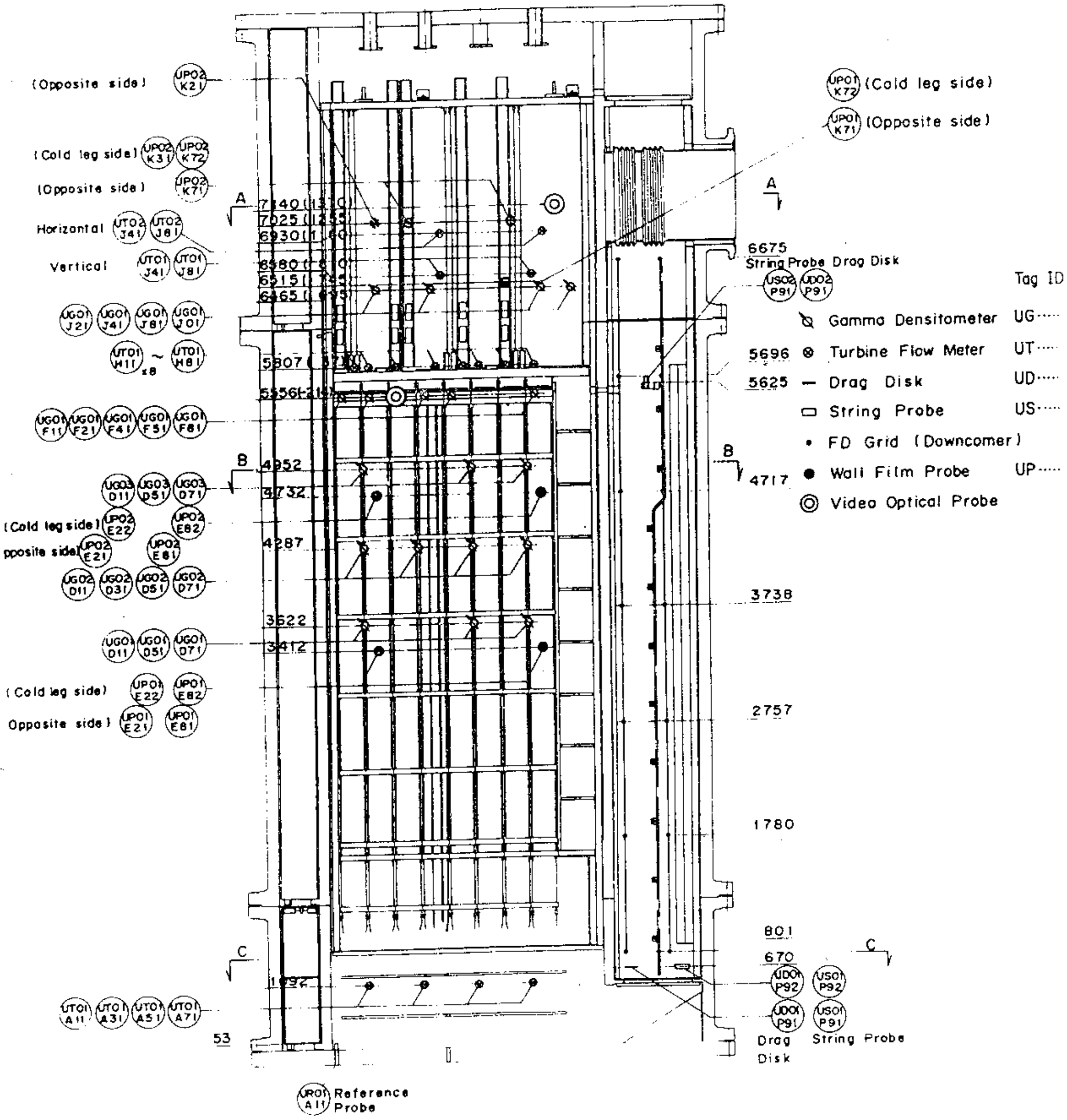


Fig.4-23 Vertical Locations of USNRC-Provided Instruments in Pressure Vessel

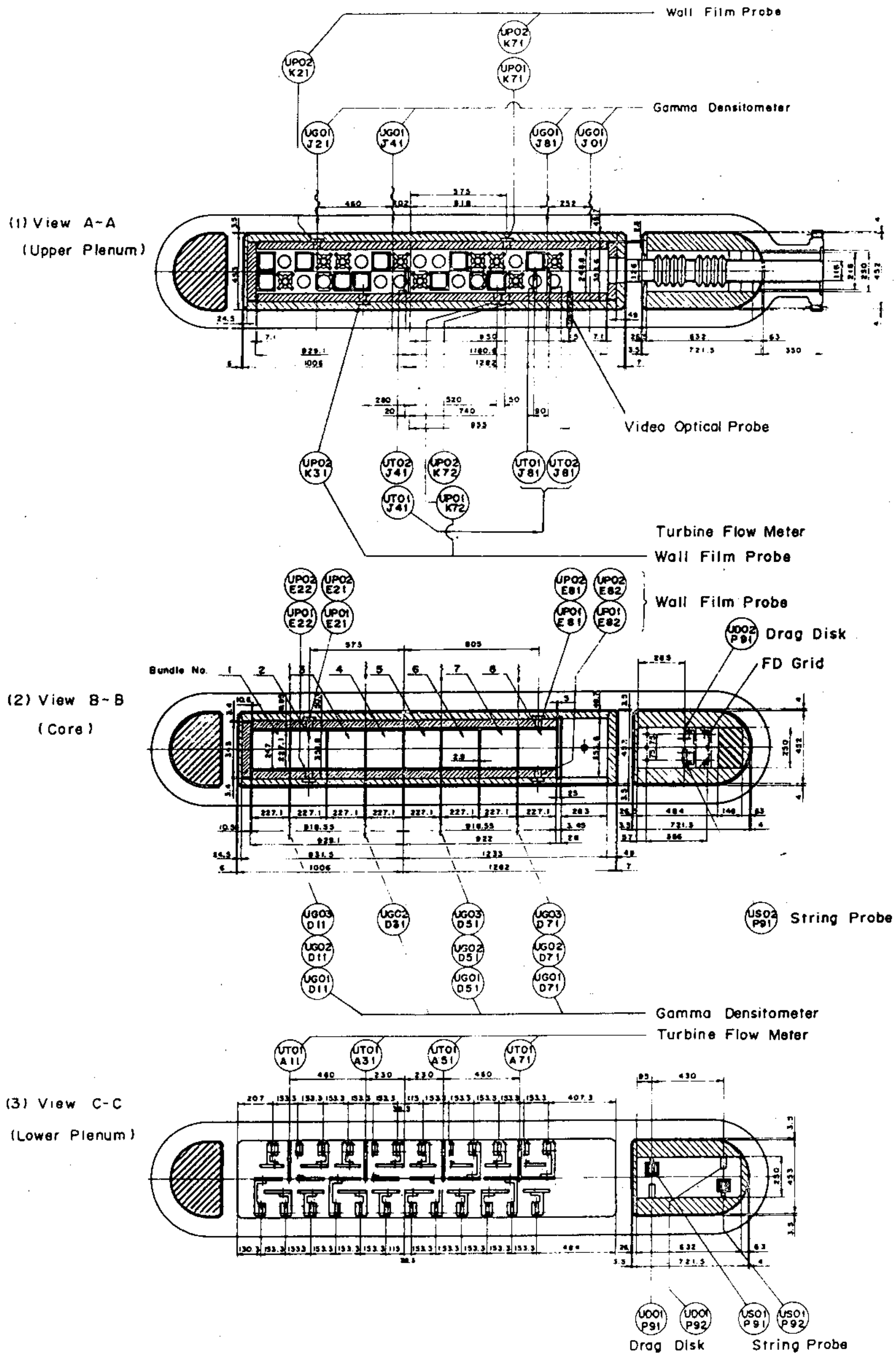


Fig.4-24 Horizontal Locations of USNRC-Provided Instrumentation in Pressure Vessel

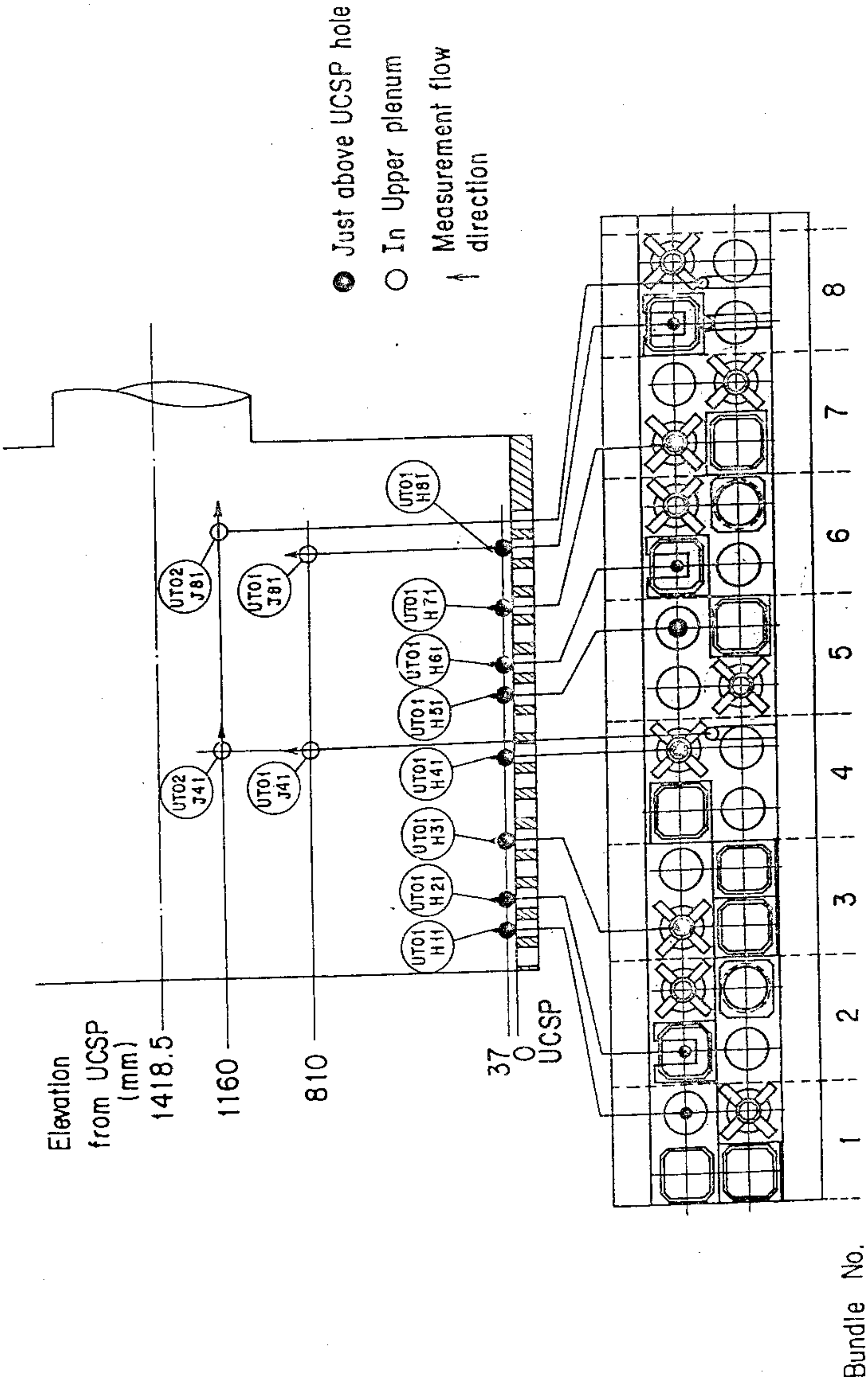


Fig.4-25 Locations of Turbine Flow Meters in Upper Plenum

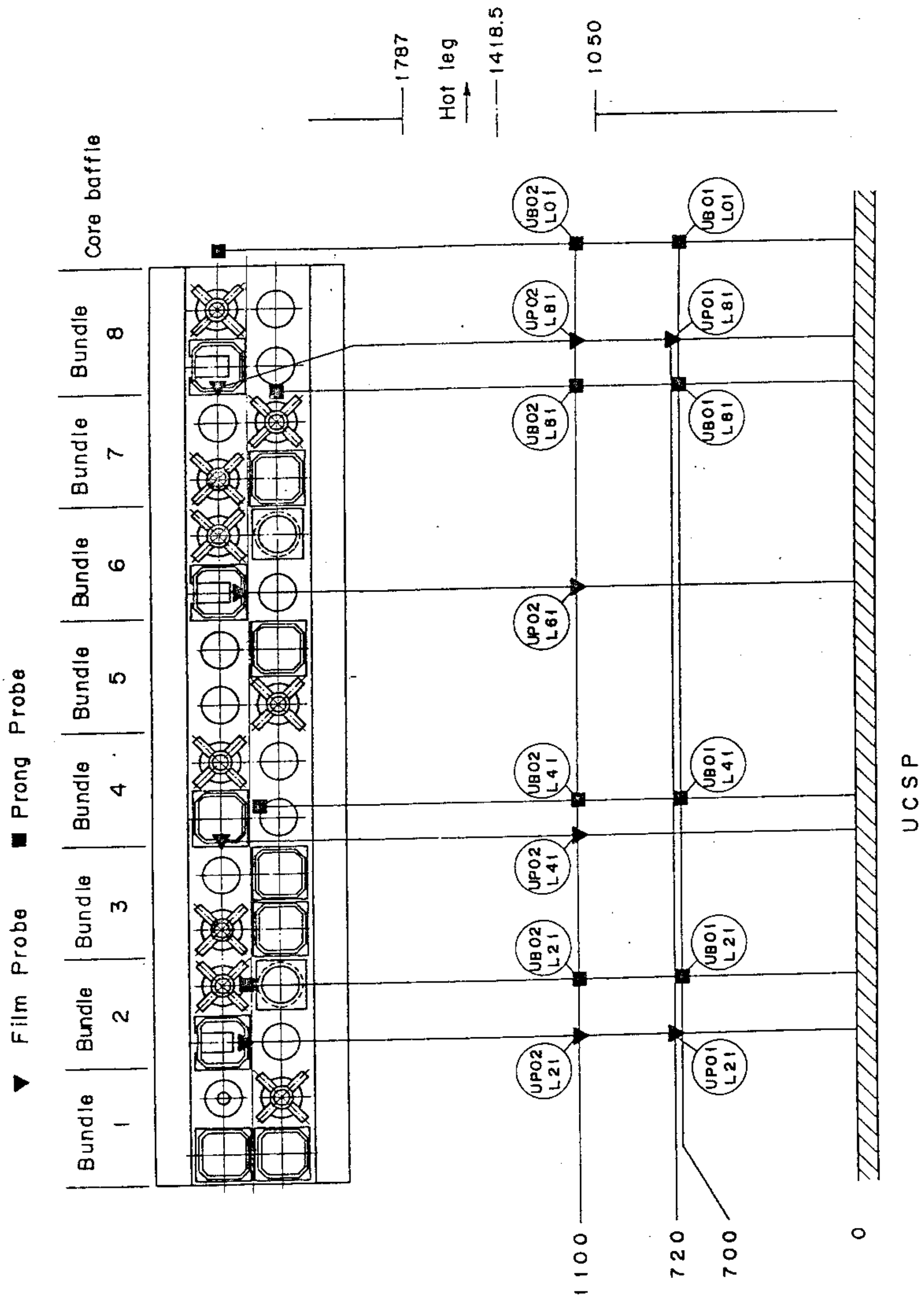


Fig.4-26 Locations of Film and Prong Probes in Upper Plenum

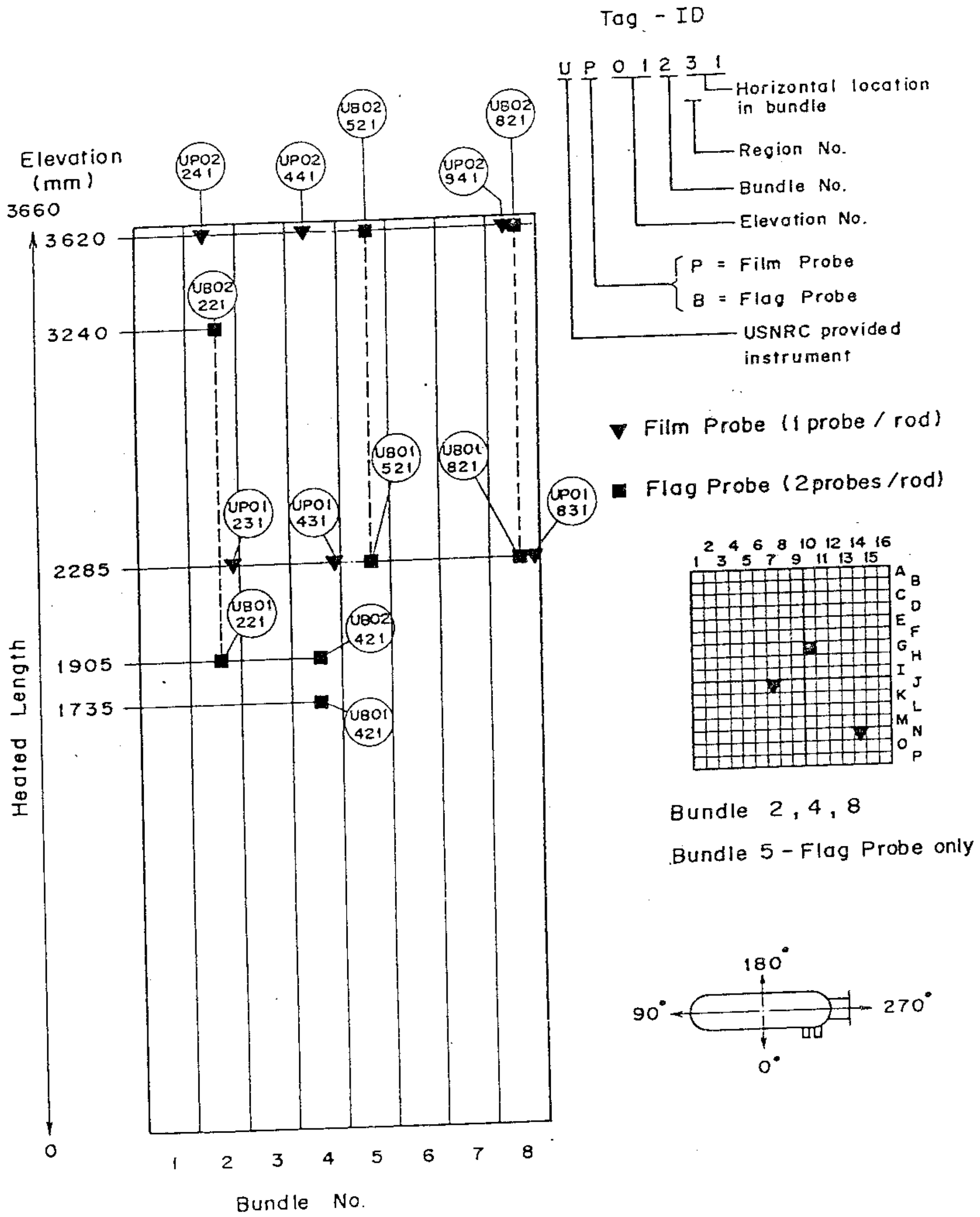


Fig.4-27 Locations of Film and Flag Probes in Core

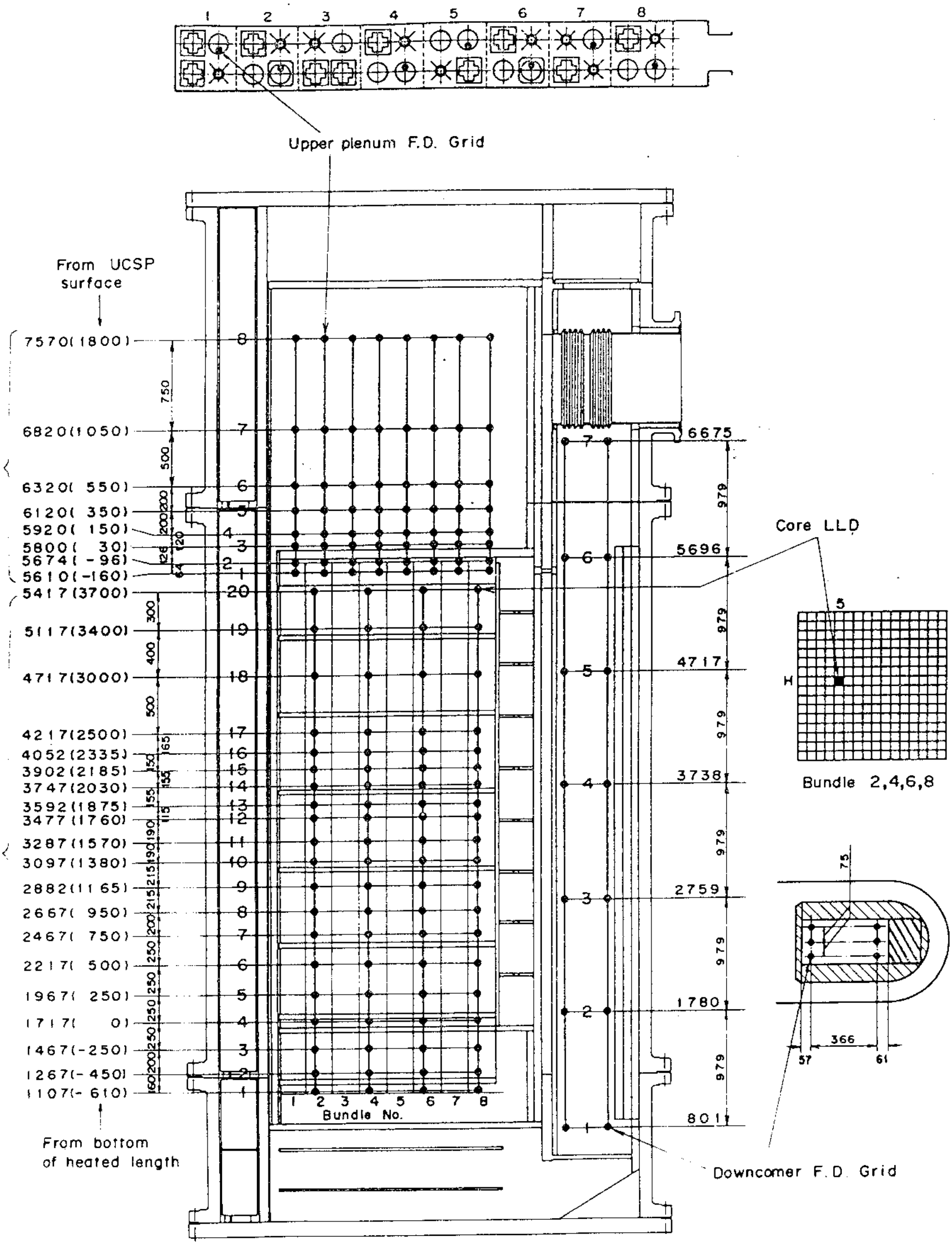
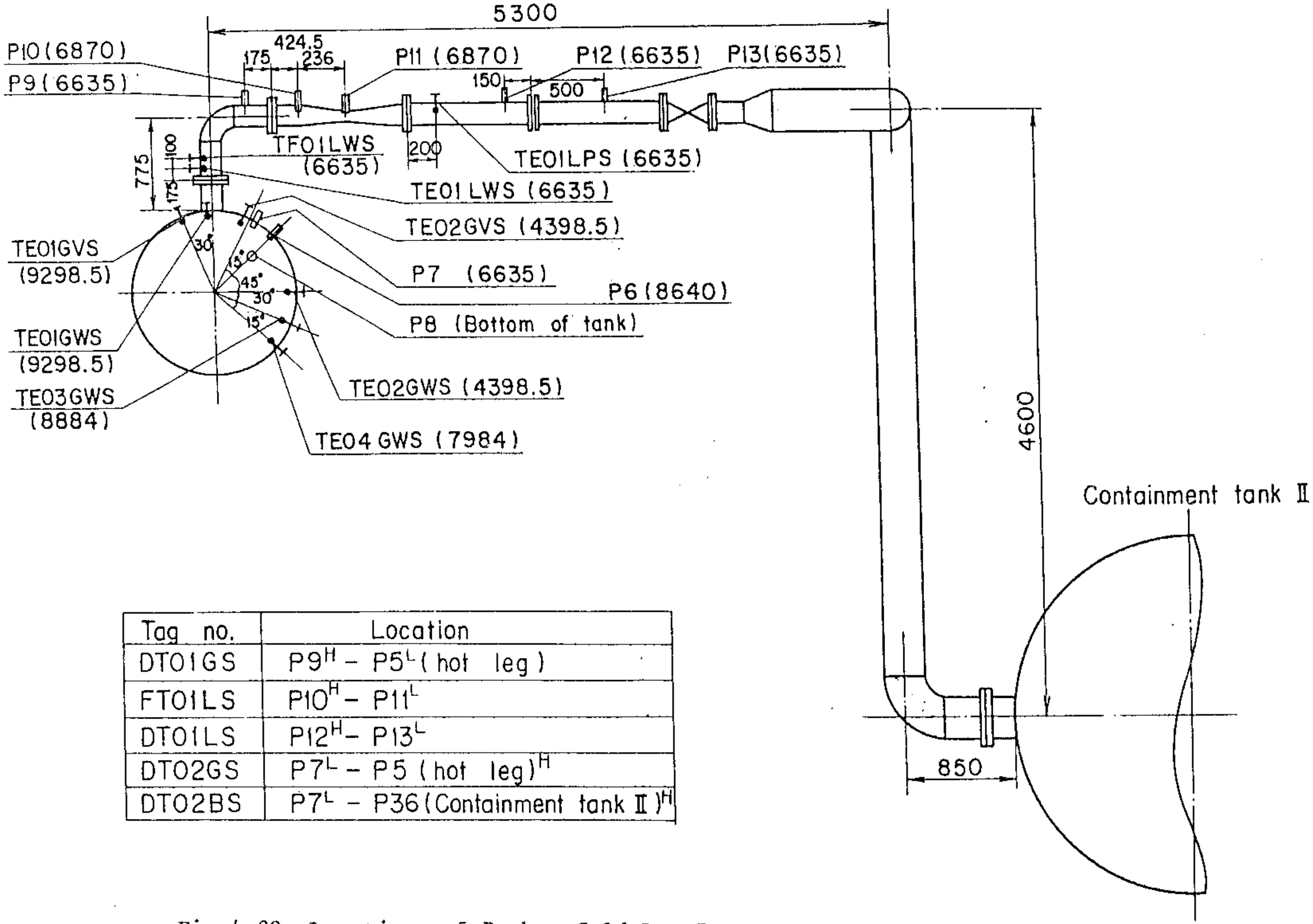


Fig.4-28 Locations of LLDs and FDGs in Pressure Vessel



Tag no.	Location
DT01GS	$P9^H - P5^L$ (hot leg)
FT01LS	$P10^H - P11^L$
DT01LS	$P12^H - P13^L$
DT02GS	$P7^L - P5$ (hot leg)^H
DT02BS	$P7^L - P36$ (Containment tank II)^H

Fig.4-29 Locations of Broken Cold Leg Instruments (Steam-Water Separator Side)

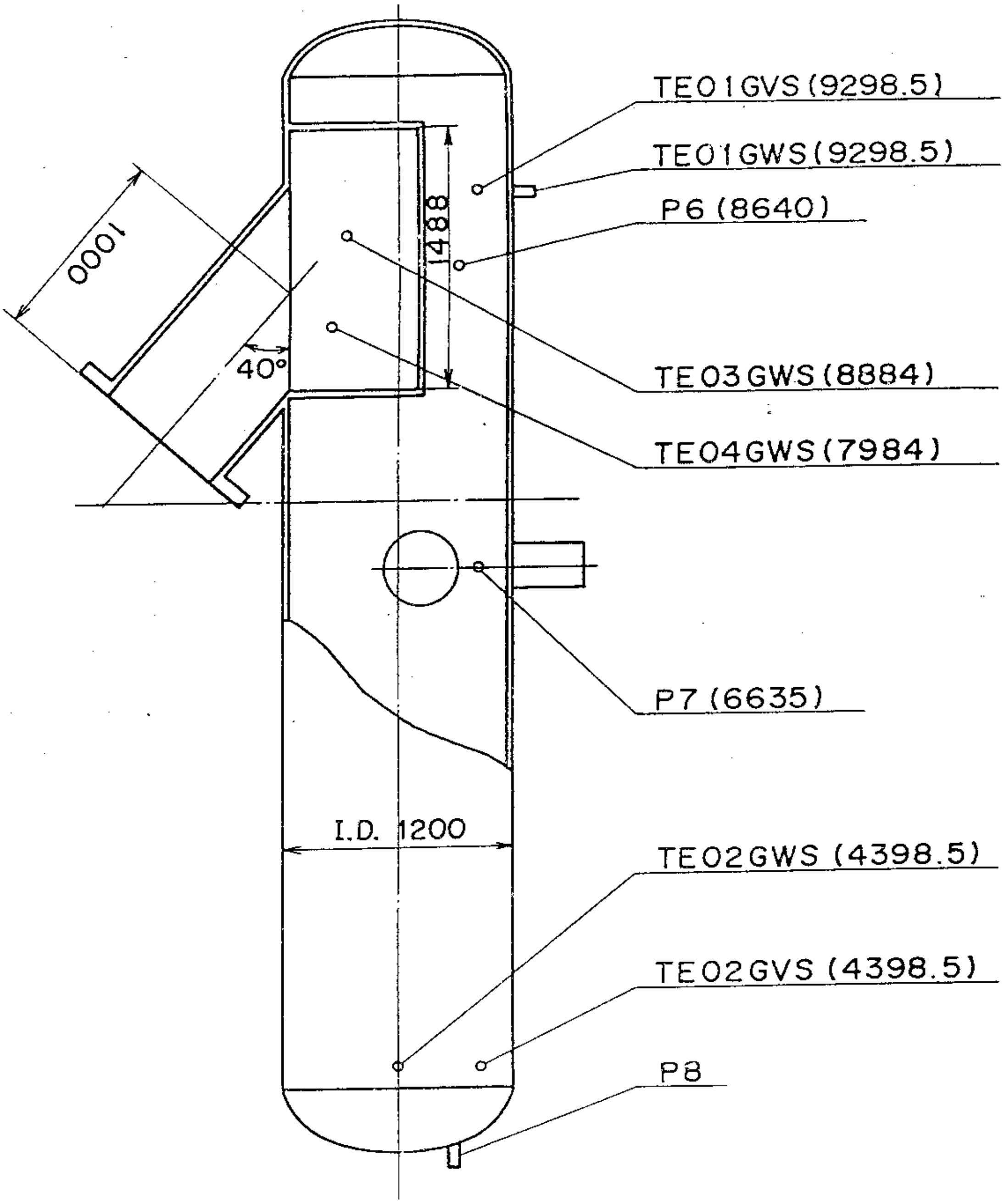
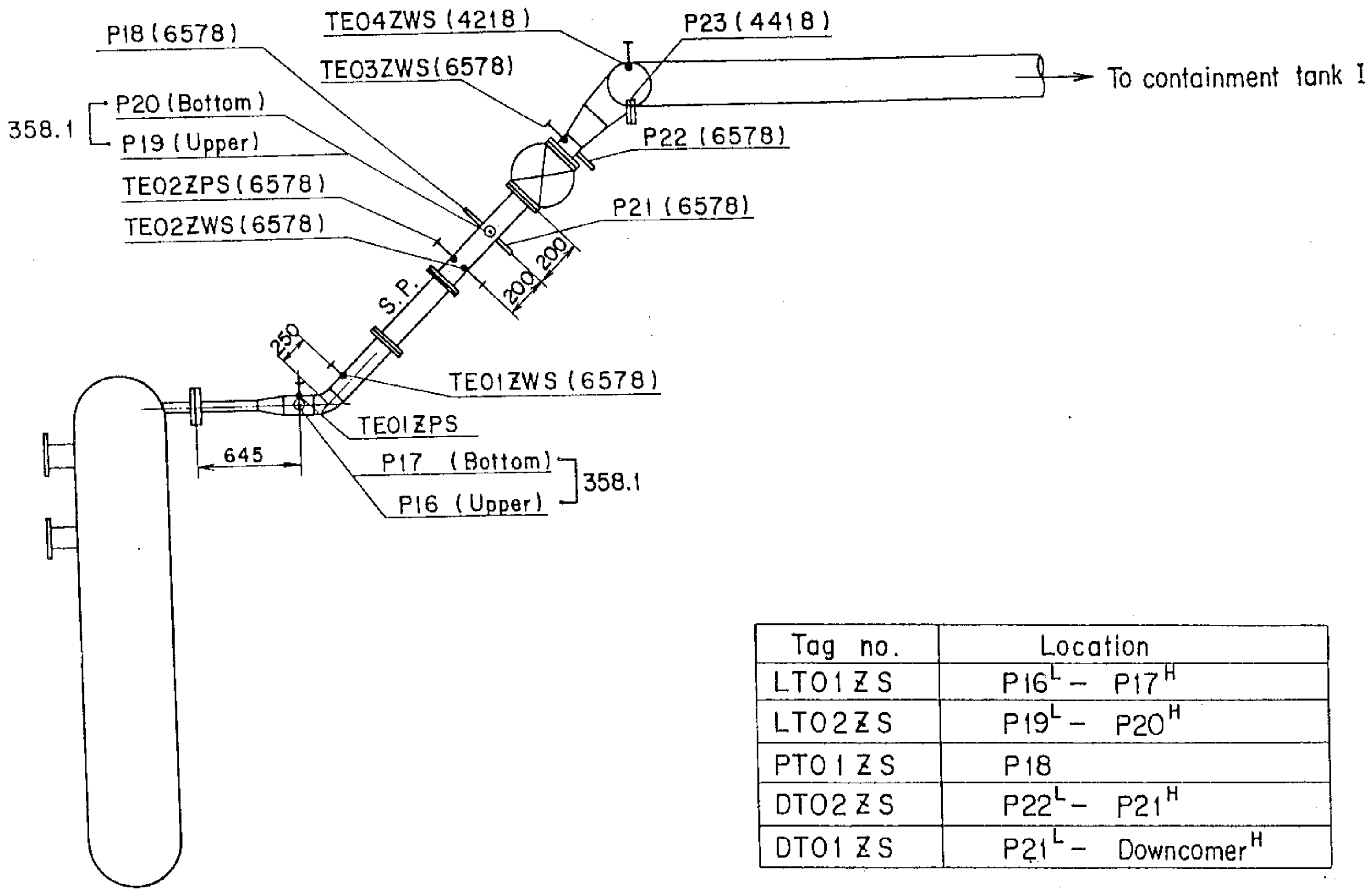
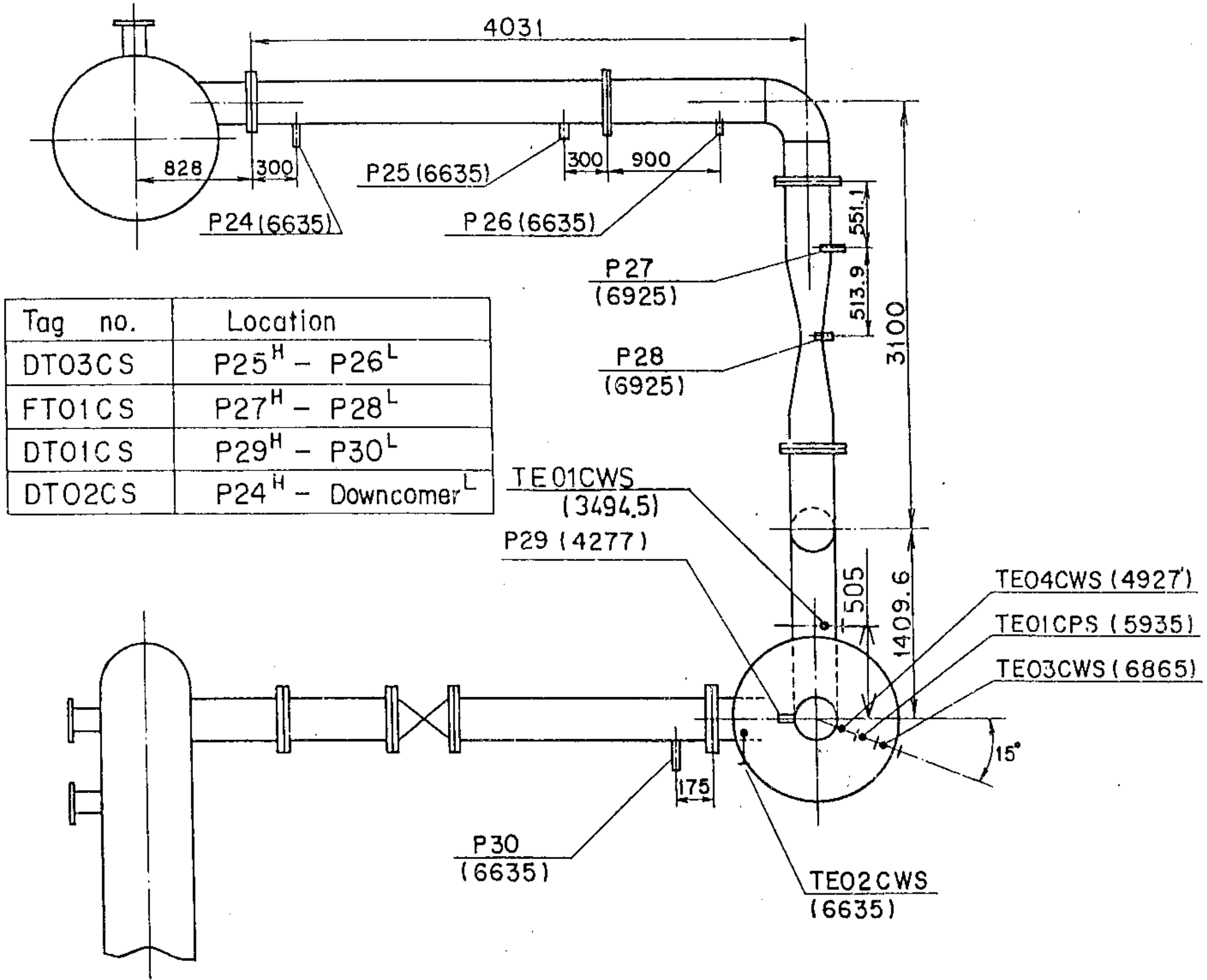


Fig.4-30 Locations of Steam-Water Separator Instruments



Tag no.	Location
LT01ZS	$P16^L$ – $P17^H$
LT02ZS	$P19^L$ – $P20^H$
PT01ZS	P18
DT02ZS	$P22^L$ – $P21^H$
DT01ZS	$P21^L$ – $Downcomer^H$

Fig.4-31 Locations of Broken Cold Leg Instruments (Pressure Vessel Side)



Tag no.	Location
DT03CS	$P25^H$ - $P26^L$
FT01CS	$P27^H$ - $P28^L$
DT01CS	$P29^H$ - $P30^L$
DT02CS	$P24^H$ - $Downcomer^L$

Fig.4-32 Locations of Intact Cold Leg Instruments

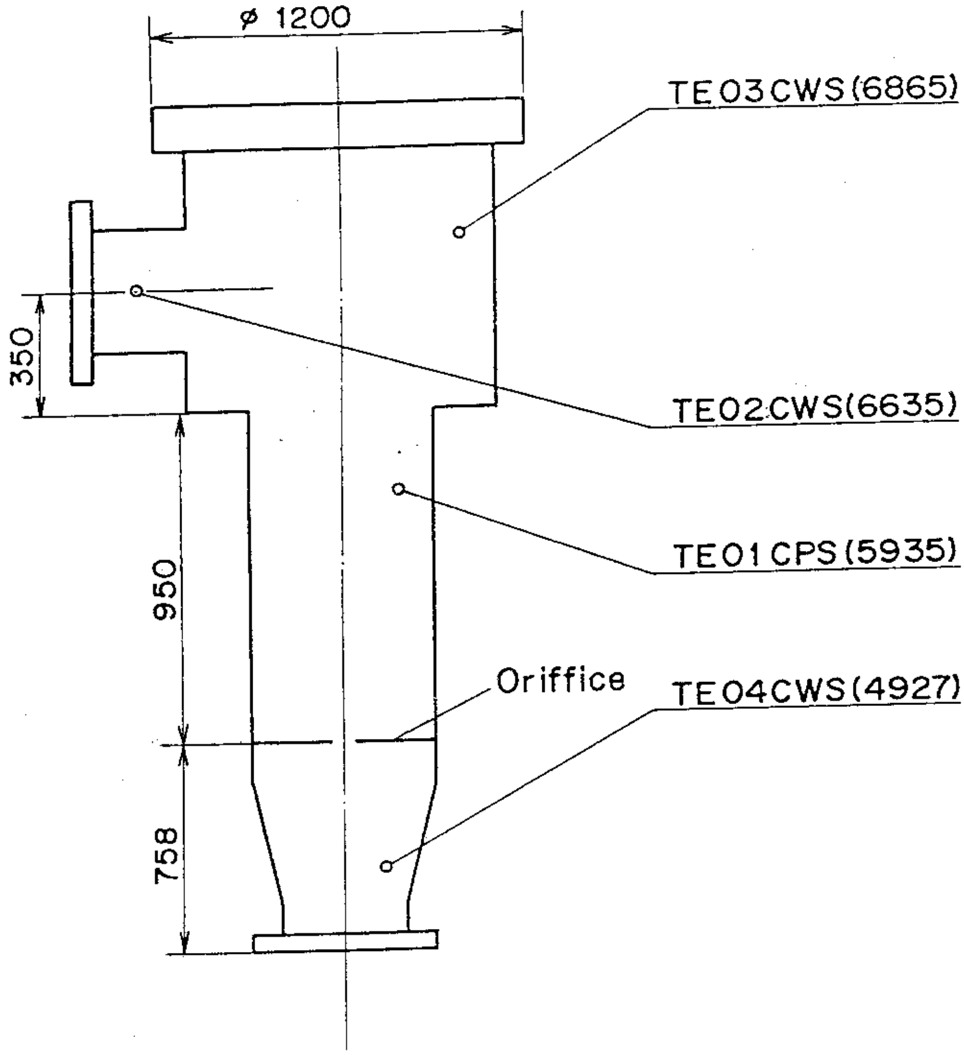
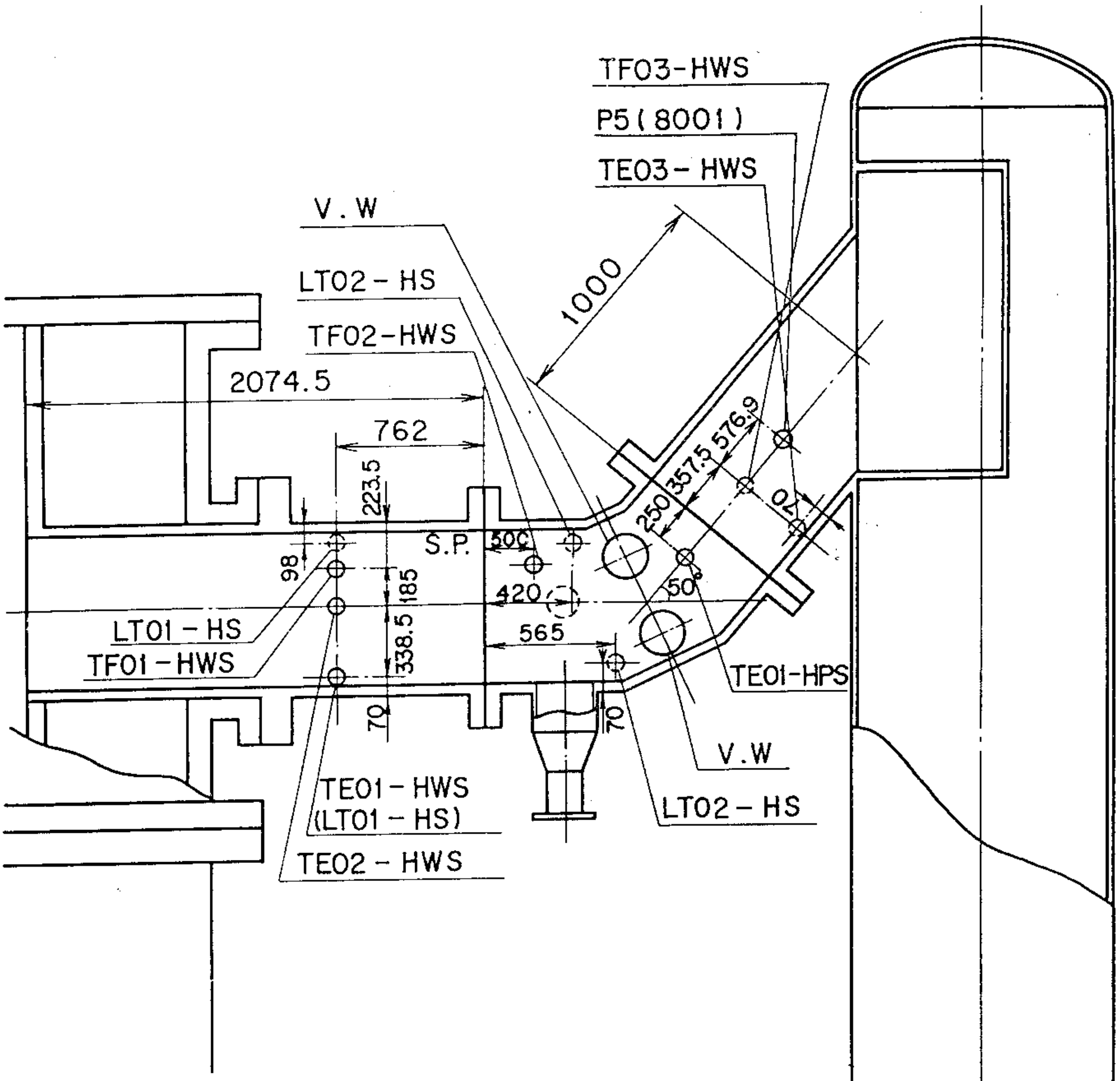
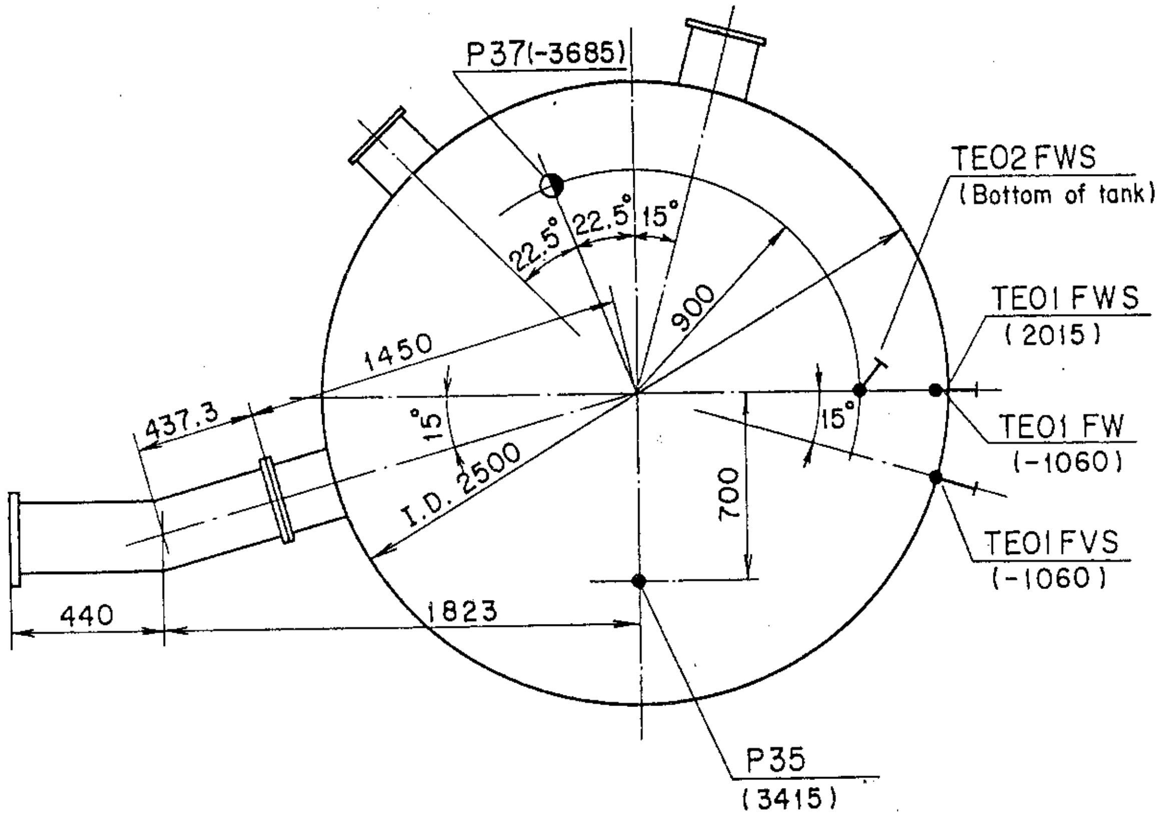


Fig.4-33 Locations of Pump Simulator Instruments



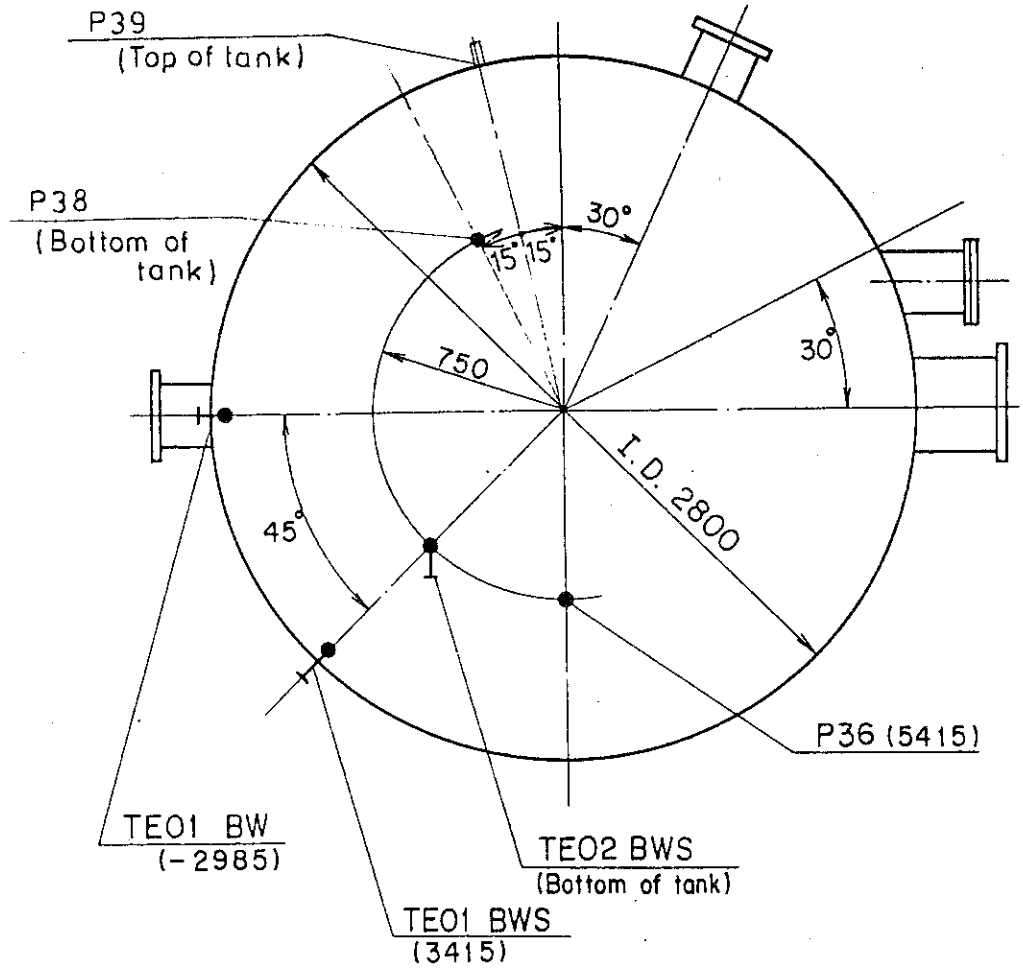
Tag no.	Location
DT01 HS	P5ᴸ– Inlet of hot legᴴ
DT01 GS	P5ᴸ– Broken cold leg (S-W separator side)ᴴ
DT02GS	P5ᴴ– S-W separator tankᴸ

Fig.4-34 Locations of Hot Leg Instruments



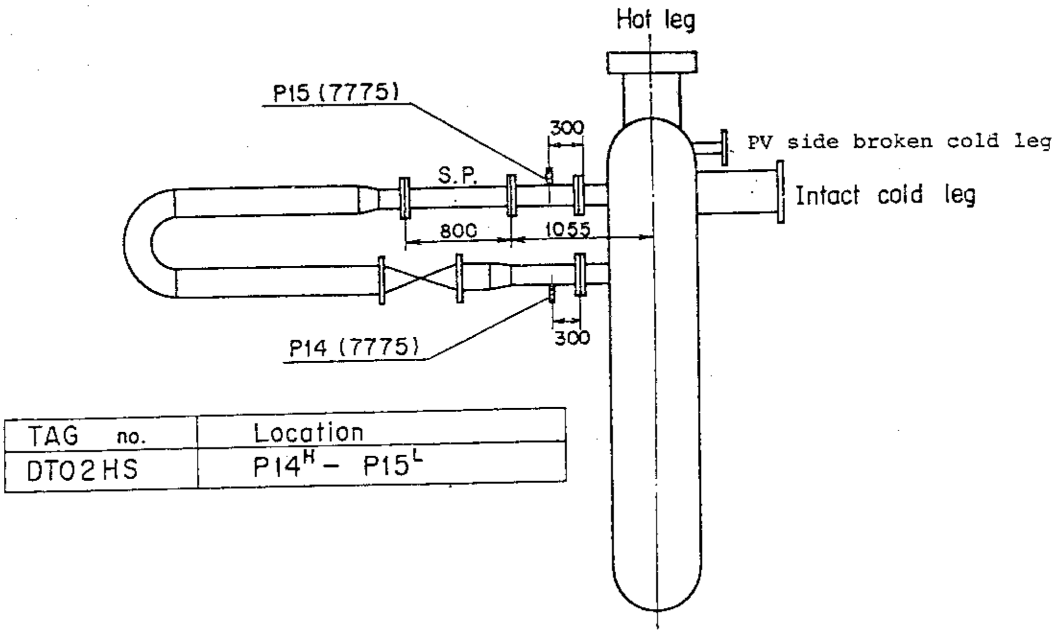
Tag. no.	Location
LT01 FS	$P35^{L}$– $P37^{H}$
DT01 FS	$P35^{H}$– Downcomer^{L}
DT01 E	$P35^{L}$– $P36(\text{C.T. II})^{H}$
PT01 F	P35

Fig.4-35 Locations of Containment Tank-I Instruments



Tag no.	Location
DT01 BS	P36^H– Upper plenum^L
DT02 BS	P36^H– S-W Separator^L
DT01 E	P36^H– P35 (C.T.I)^L
PT01 B	P36
LT01 1B	P38^H– P39^L

Fig.4-36 Locations of Containment Tank-II Instruments



TAG no.	Location
DT02HS	P14^H − P15^L

Fig.4-37 Locations of Vent Valve Simulation Line Instruments

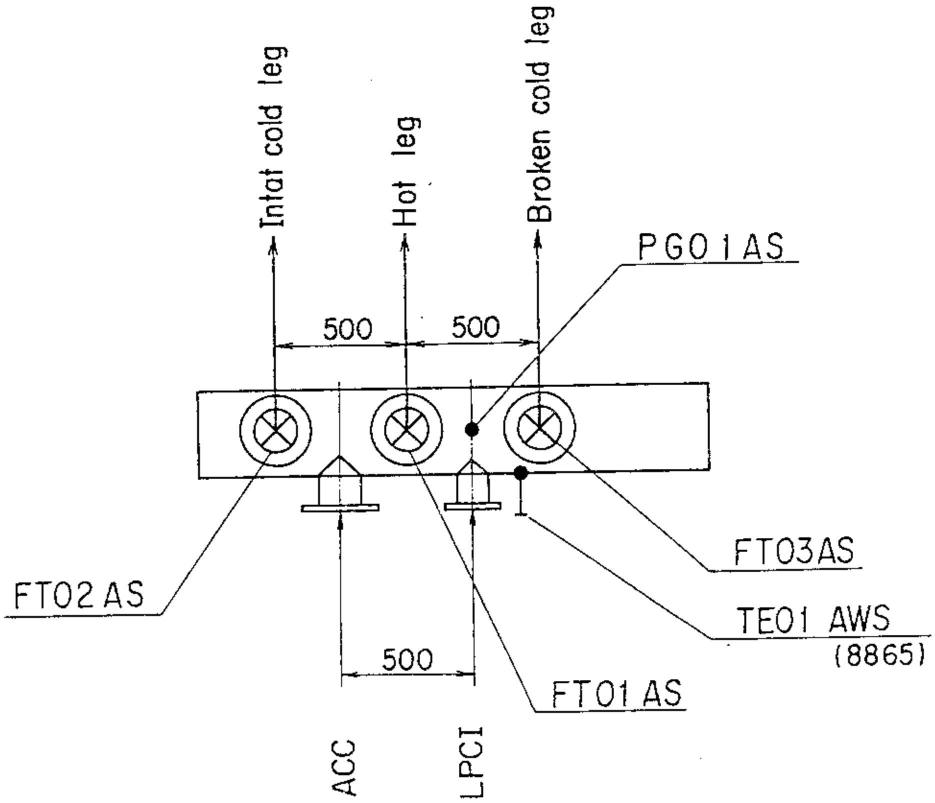


Fig.4-38 Locations of ECC Header Instruments

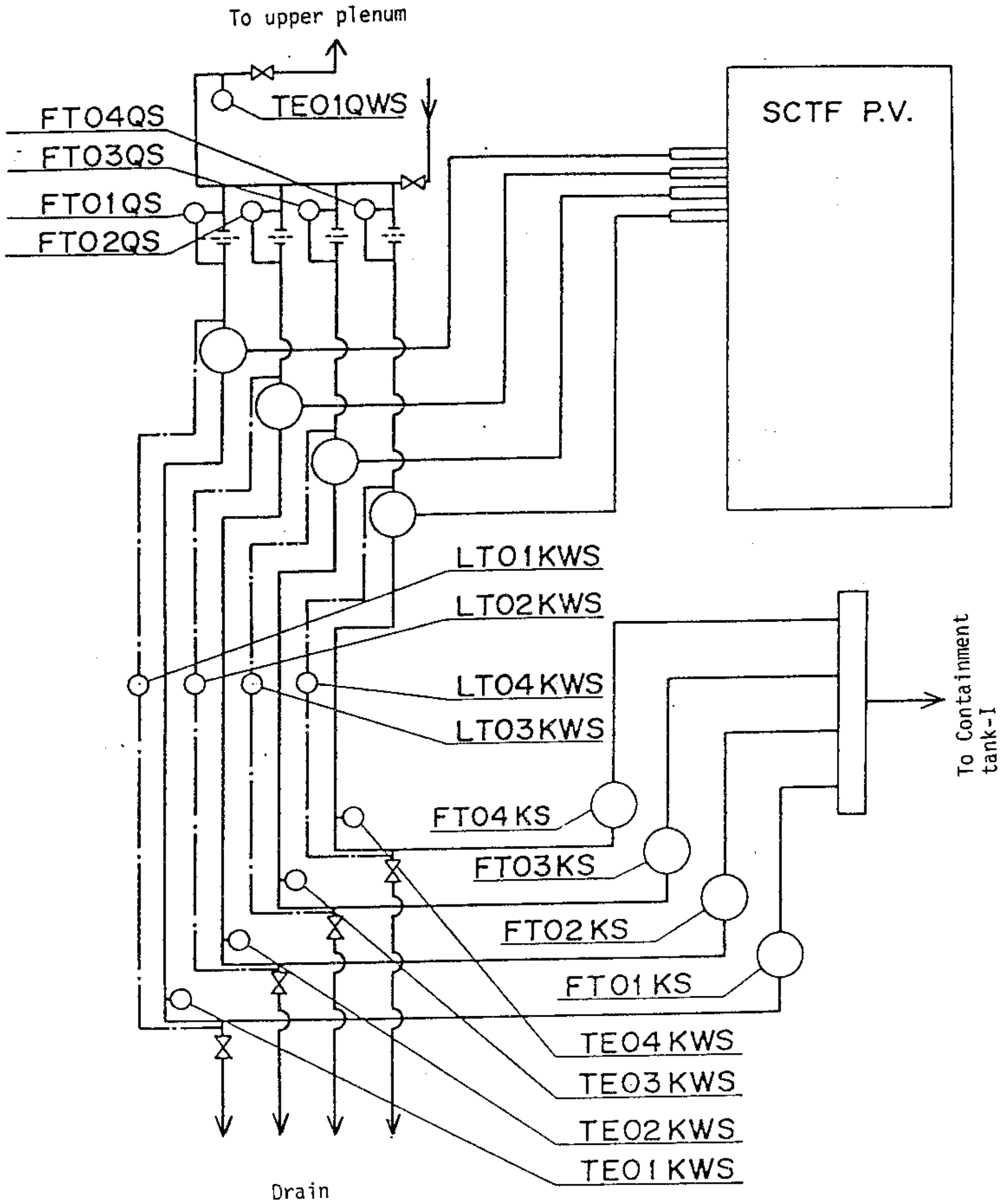
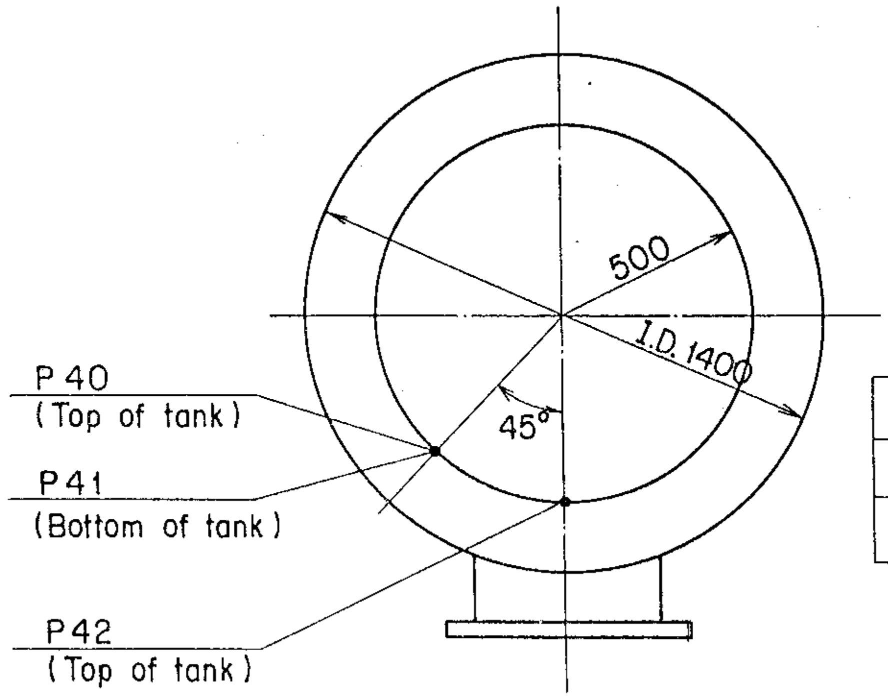


Fig.4-39 Locations of UCSP Water Extraction System Instruments



Tag no.	Location
PT01 I	P42
LT01 I	$P40^{L} - P41^{H}$

Fig.4-40 Locations of Acc Tank Instruments

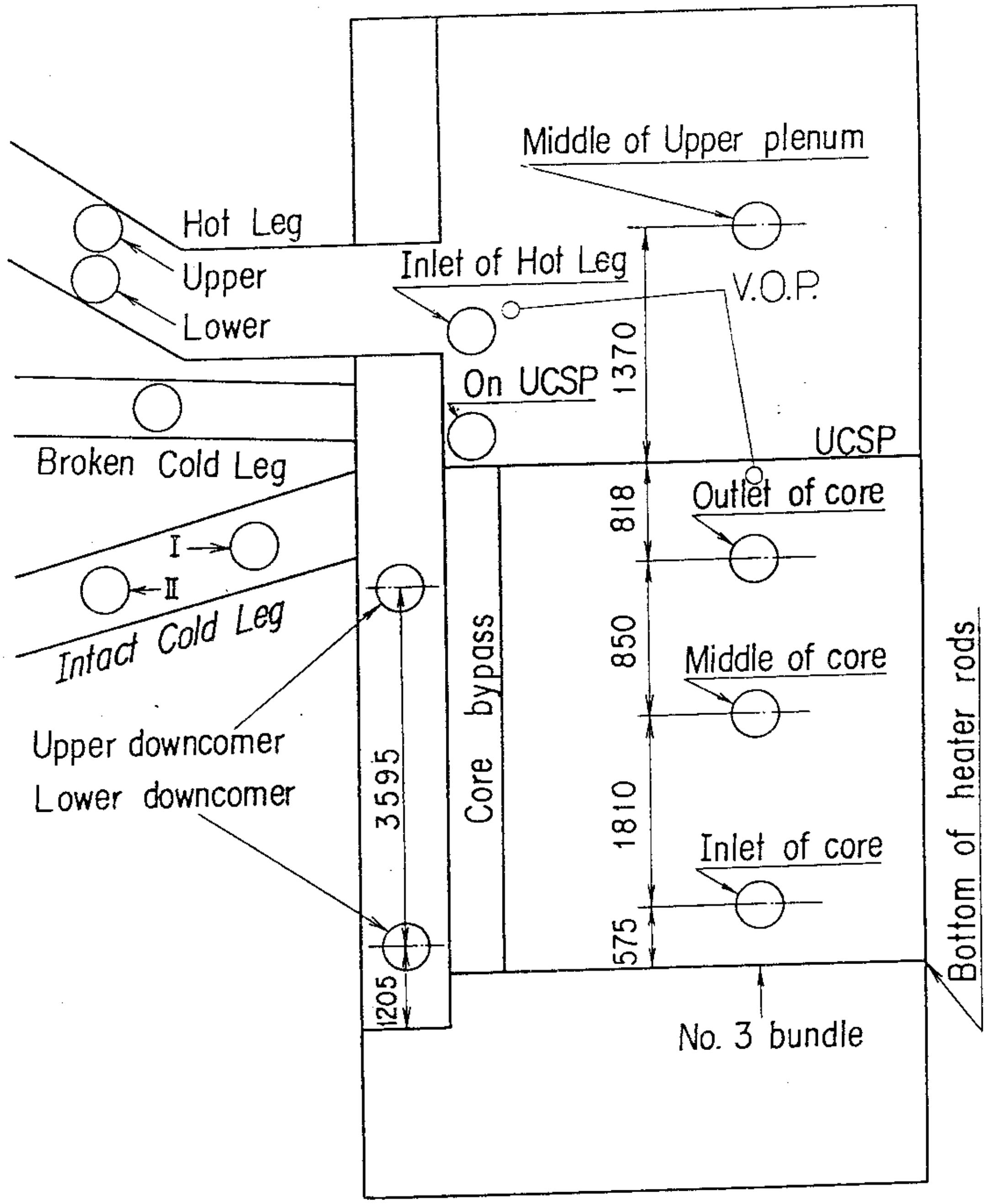


Fig.4-41 Locations of View-Windows

5. Test Procedure

The SCTF tests are performed with the following test procedure.

(1) The pressure vessel including core, steam-water separator, pump simulator, containment tanks-I and -II and the pipings connecting these components with each other are heated up and pressurized by external heating with electric heaters and by steam heating with the saturation steam up to the specified temperature and pressure conditions. It takes two working days for this process.

(2) Initial core temperature is adjusted by a small rate of core heating so as to set at the certain value of the maximum cladding temperature. Due to non-uniform heat flux of the core, wall effect and cooling effect by fall back water from the upper plenum, initial core temperature has a distribution.

(3) Cold water initially filled in the accumulator injection piping is replaced with hot water by repeating four times to supply the water into the lower plenum and to drain it. This process became not necessary after the completion of a circulation system for Acc injection system in the later test period for the Core-I.

(4) Water temperature in LPCI injection piping is kept at aproximately the same value as in the LPCI tank by water circulation through the tank.

(5) Usually, some amount of saturation water is filled in the lower plenum for preventing from sudden disturbance due to condensation effect of the following ECC water injection and from exposure of ceramic terminals of heater rods to superheated steam.

(6) After these preparations, the test starts. Four kinds of test sequence pattern, H1 ~ H4, can be chosen. Each sequence pattern is shown in Figs.5-1 through 5-4. All the initial and boundary conditions are controlled by using the computer.
In the pattern H1, core power for preheating is tripped and core power for test is turned on at 10 sec after data sampling is switched on. This time of core power "on" is defined as "0 sec" in the regular computer-drawn graphes. When a certain number (usually, four) of cladding temperature signals exceeded specified value "Fs", power supply to the heater rods starts to be controlled based on the preset power decay curve.
Simultaneously, break valves are opened and accumulator injection

initiates. Break valves can be kept open from before the test as an option. Usually, Acc water is injected first into the lower plenum and then switched to the other injection ports after the bottom of core recovery (BOCREC), for preventing from a sudden decompression in the system due to condensation. Durations of the lower plenum injection and of the following injection to the other injection ports are specified by the times "TLP" and "TA" in Fig.5-1, respectively. Nitrogen gas can be injected into the downcomer as an option following the accumulator injection. The injection duration of N_2 gas is given by the time "TN" in Fig.5-1.

Initiation and duration of LPCI are specified by the times "TSL" and "TL" in Fig.5-1, respectively, based on the power decay initiation time. In addition, pressure in the containment tank-II can be controlled based on the preset curve from the time of the power decay initiation as an option. If not specified, the pressure is kept at constant.

In the pattern H2, Acc injection initiation is specified by the time "TS1" in Fig.5-2 independently of the cladding temperatures. LPCI injection, nitrogen gas injection and the containment tank-II pressure start to be controlled based on the time of the Acc injection initiation. The other terms are similar to the pattern H1. In the pattern H3, the break valves are opened by the time TS2 in Fig.5-3. The other terms are similar to the pattern H2. In the pattern H4, the power control based on the preset power decay curve is started by the time TS3 in Fig.5-4 independently of the cladding temperatures. The other terms are similar to the pattern H3.

(7) All output from the instruments are stored in the data aquisition systems during the test period and some specified time after the test. Observation is also done at the various locations of the test facility using video cameras, cine cameras and video optical probes.

(8) The power supply to the heater rods is turned off for preventing from core damage when a certain number of surface temperature signals of heater rods exceed the predetermined maximum allowable temperature or the temperatures of the ceramic terminals at the bottom of the heater rod exceed 523 K (250°C).

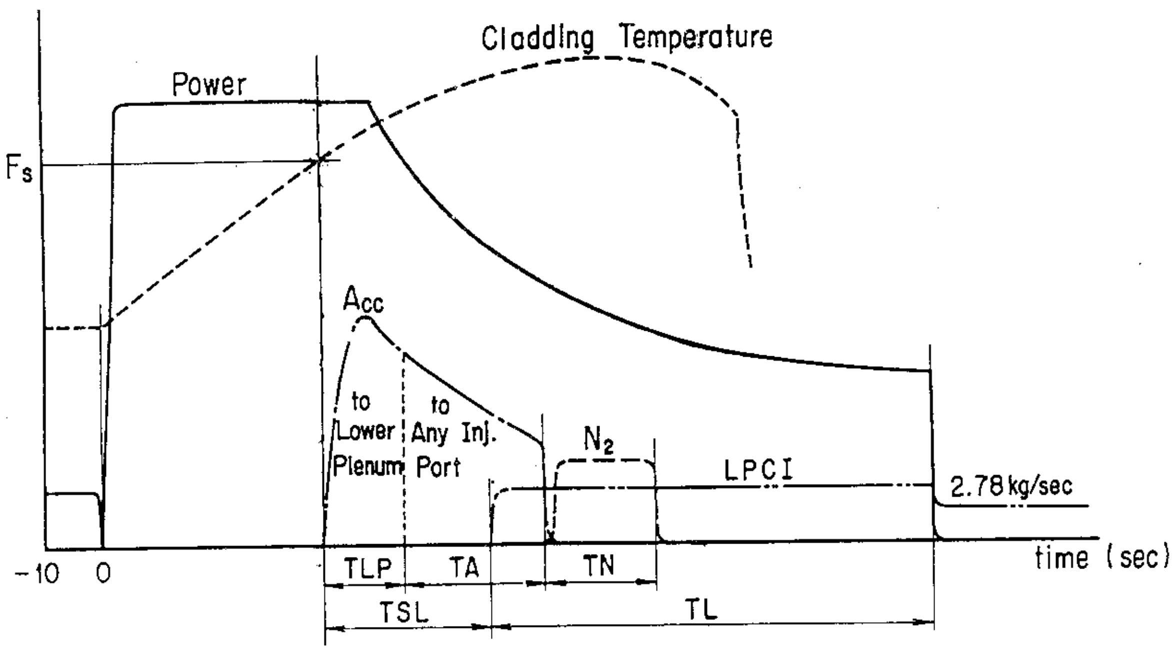


Fig.5-1 Test Sequence Pattern "H1"

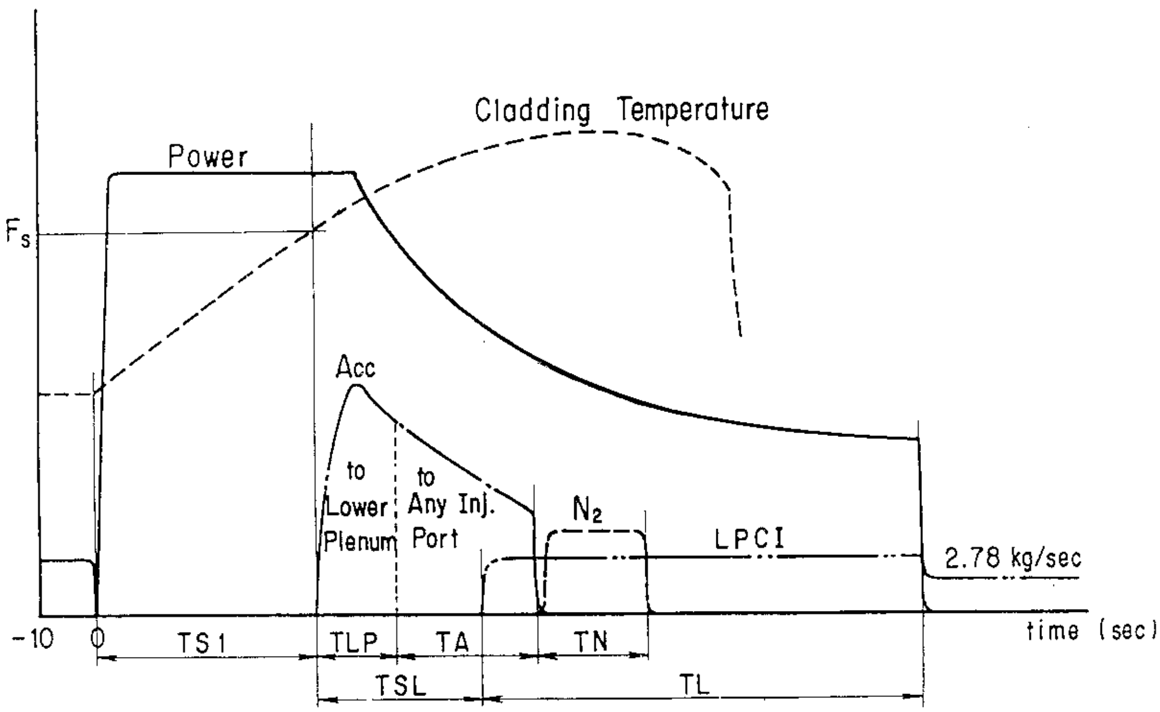


Fig.5-2 Test Sequence Pattern "H2"

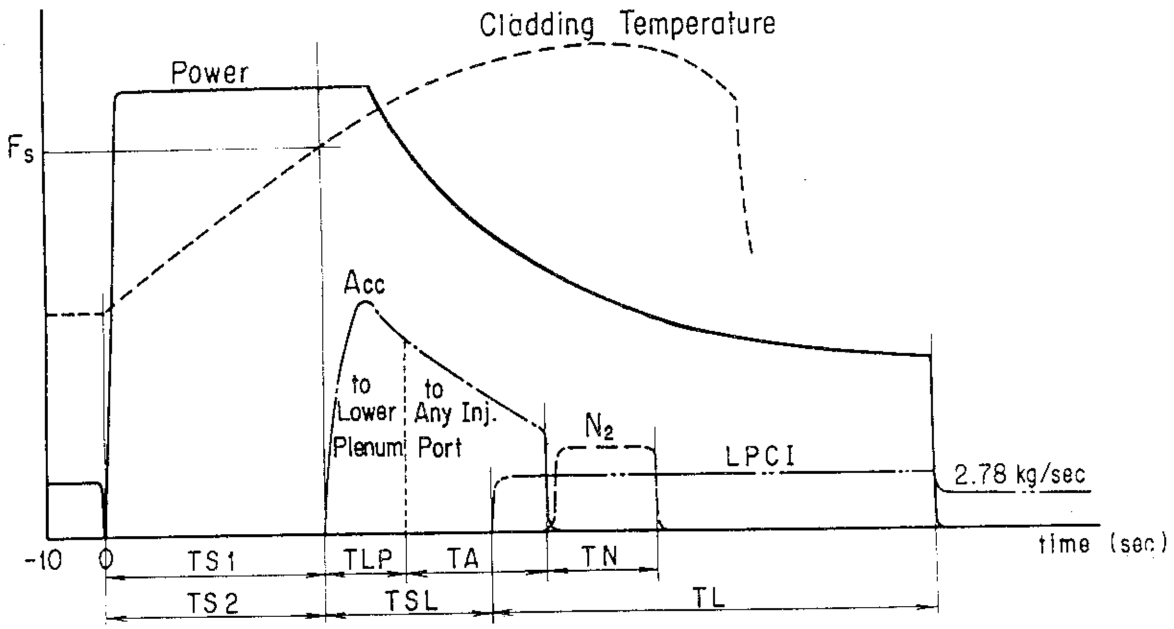


Fig.5-3 Test Sequence Pattern "H3"

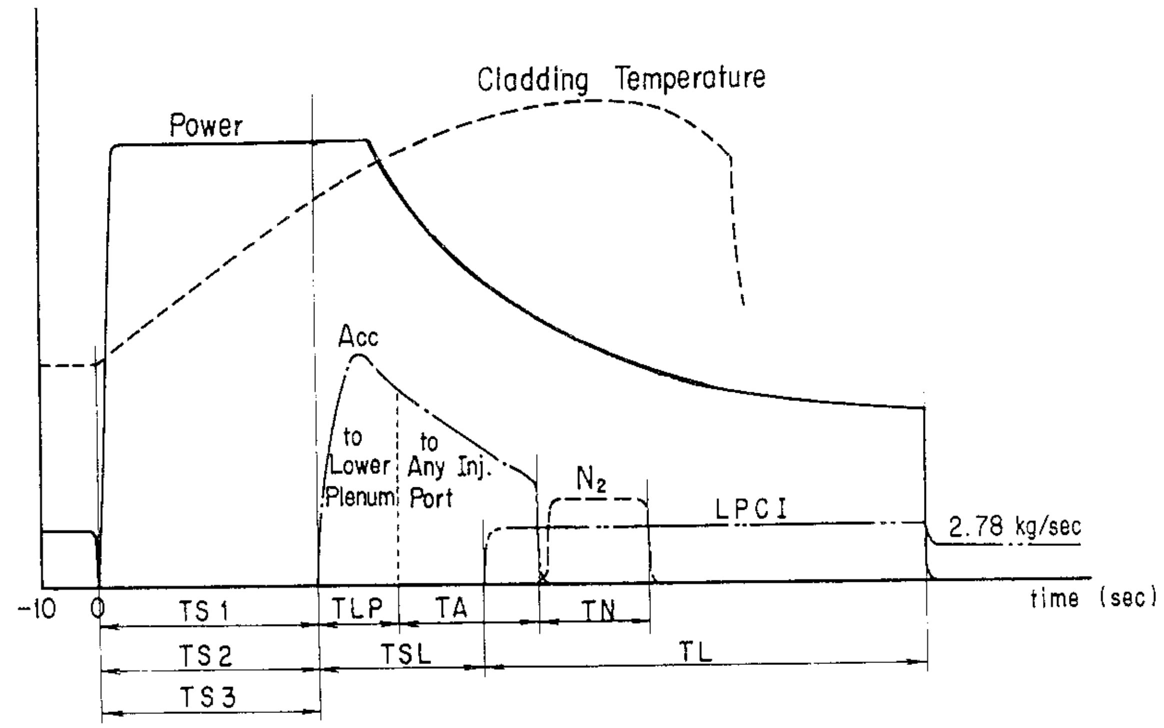


Fig.5-4 Test Sequence Pattern "H4"

6. Concluding Remarks

In this design report, design principle and detailed design of each part of the SCTF are described. Information on each instrumentation and identification method of measurements are introduced. In addition, short description of test procedure is also given. This various information may be considered enough not only for good understanding of the SCTF test data to be given in quick look reports but also for further analytical usage of the data.

Acknowledgement

The authors are much indebted to Dr. M. Nozawa and Dr. S. Katsuragi, the former and present Center Directors of the Nuclear Safety Research Center, JAERI, respectively, and Dr. M. Ishikawa and Dr. K. Hirano, the former and present Deputy Heads of Dep. of Nuclear Safety Research, respectively, for their guidance and encouragement for this program. They would like to express their appreciation to the numbers of the Safety Facility Engineering Service Section, Messrs. J. Matsumoto, T. Nishikizawa, K. Momori and H. Sonobe.

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References

(1) K. Hirano and Y. Murao: Large Scale Reflood Test (in Japanese), J. Atom. Engg. Soc. Japan, Vol.22, No.10, p.680-686 (1980)

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