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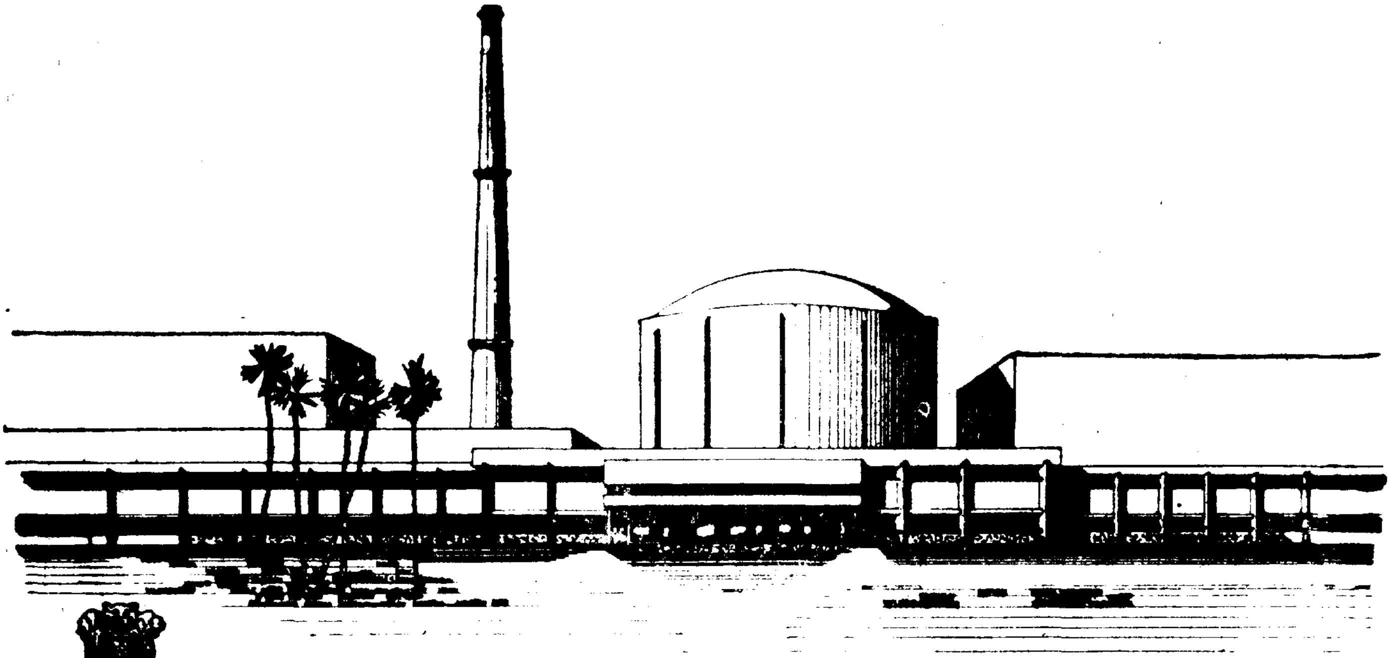

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DEVELOPMENT OF SPECIAL SEALS AND SYSTEMS FOR A LEAKTIGHT HOT CELL FACILITY

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ABSTRACT

A hot cell facility has been recently commissioned in the Radiochemistry Laboratory, IGCAR, Kalpakkam with the objective of carrying out post - irradiation studies on fast reactor fuels as well as PHWR fuels. The hot cell facility has several novel features such as a double containment system with high purity argon atmosphere in the containment box, low probabilities of contamination or radiation exposure to operating personnel and economy in both capital and operating costs. This report describes the different concepts used to achieve a high degree of leaktightness in the stainless steel containment boxes as well as in the cells and the development of special gaskets and O-rings like formed gaskets and co-seals.

CONTENTS

DEVELOPMENT OF SPECIAL SEALS AND SYSTEMS FOR A LEAKTIGHT HOT CELL FACILITY

M.P.Antony*, G.Ravishankar*. S.Subramanian*, R.Manivannan* and C.K.Mathews*

1.0 INTRODUCTION

The problems associated with the design and operation of hot cell facilities arise primarily from the need to ensure that both the external exposure as well as the internal exposure of the operating personnel are less than established maximum permissible levels. The control of internal exposure resulting from air-borne activity is achieved by providing containment enclosures, control of air flow and air cleaning. This becomes more critical when plutonium-rich fuels have to be handled in the cells. In addition, the mixed carbide fuel of FBTR is sensitive to air and moisture and therefore has to be handled in a high purity inert atmosphere.

The hot cells in the Radiochemistry Laboratory at IGCAR have incorporated several unique design features to meet the diverse, but demanding requirements (radiation shielding to an adequate degree as well as stringent control on radioactive contamination). In these hot cells, an outer concrete shell provides not only the shielding but also one level of containment. A set of removable boxes with high degree of leaktightness are housed in some of these concrete cells. These stainless steel boxes provide the second level of containment.

In this report, we briefly describe the design features of the cells, the development of special sealing techniques and materials like gaskets, formed gaskets and co-seal rings which have enabled us to achieve high degree of leaktightness in the stainless steel containment boxes and in the concrete cells. The details of the leak testing procedure and the test results are also included in this report.

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2.0 DESCRIPTION OF THE HOT CELL FACILITY

There are five concrete cells in a row. The cells at both the ends (1 & 5) are primarily meant for the examination of PHWR fuel and hence operated under air atmosphere. The middle cells 2, 3 and 4 are provided with stainless steel containment boxes. Purified argon gas will be recirculated in these boxes facilitating the examination of air sensitive carbide fuel. Provisions are made in cell 4 so that it can be operated under air atmosphere also. In order to control the air-borne activity, 30 to 40 air changes per hour are provided in the concrete cells. The cross section of a concrete cell with containment box in it is shown in fig.1. The different operations planned in individual cells include visual examination of the fuel bundles, disassembly of the bundle, sipping of the fuel pins to locate any leaks, cutting of the pins and subsequent chemical operations.

3.0 CONCRETE CELLS

Cell no. 1 is double the size of other four cells. Cells 1 and 5 are lined with stainless steel (AISI 304 L) and Cells 2, 3 and 4, wherein SS boxes are housed , are lined with mild steel.

The integrity of the cells are ensured by sealing all the openings in the cell wall. The major openings and embedments in the cells and the method of sealing them are described below.

3.1 Roof plugs

Each cell is covered at the top with two stepped roof plugs as shown in fig.2 . Roof plugs are removable type. Gaskets are provided at the steps of the roof plug for getting the sealing. A special type of gasket made out of ethylene propylene was designed and developed for this purpose .The details of the gasket are shown in fig.3. The gasket has been designed with a hollow core, and the shape and size of the gasket are such that the dead weight compressive load of the roof plug (approx. 8 tonne) will not significantly deform the gasket. The hollow cross section facilitates the flowing of the gasket into the defects / abnormalities which are unavoidable in the fabrication of heavy structures like roof plug.

3.2 Cell doors

Doors (fig.4) are provided behind all the cells to provide access to the cell from the isolation area. The doors are motorised and they run on rails. A gasket similar to the one described in the previous section is fixed on the door. When the door is closed, this gasket makes a leak-tight seal with the stainless steel frame on the cell wall. The design of the gasket is such that no bolting arrangement is required for sealing.The details of the gasket are shown in fig. 5.

Stainless steel panels with 16 mm thickness are provided behind cells 1 & 5 to prevent spread of contamination from the cells to the isolation area even when the doors are opened. These panels have a man entry port, a viewing panel, and glove ports. The size of the panel opening is so large that maintaining a perfect planar mating surface is very difficult. So formed gaskets with low shore hardness were developed to achieve leaktightness between the cell wall and the stainless steel panel even when the differences in planarity is large. A cross section of the gasket used for sealing is shown in fig.6 .

3.3 Windows

Radiation resistant lead glass windows are used for viewing purposes in all the cells. A 50 mm thick protective lead glass panel is fixed on the hot side of the cell wall in cells 1 & 5. Silicone rubber gaskets are used to get the sealing . In Cells 2, 3 and 4 , 20 mm thick radiation resistant glass frames are fixed on the leaktight containment boxes by using silicone rubber gaskets.

3.4 Service sleeves

Ten service sleeves with plugs are embedded in the concrete cell wall around window liner for taking various instrument loads, control cables and other services from the operating area into the cell. Neoprene O-rings are provided between the service sleeve and the plugs to ensure leaktightness.

3.5 Master slave manipulator sleeves

Master slave manipulators are introduced through two seamless mild steel tubes embedded in the wall above each window. The sealing is provided by means of a booting made out of polyvinyl chloride. The booting is connected to the La Calhene flange fixed on the cell/ containment box by means of a double action flexible lip joint. This arrangement provides a hermetic seal on the hot side of the cell.

3.6 Emergency lamp sleeve

One emergency lamp is fitted to a service plug and the plug is inserted in the wall between the two manipulator sleeves in each cell . A flanged radiation resistant glass panel is fixed on the hot side of the cell wall by using a silicone rubber gasket to provide leaktight sealing.

3.7 Periscope sleeve

Cell 1 has an additional sleeve for a periscope. A flanged glass dome assembly is fixed on the hot side of the cell wall by using a silicone rubber gasket to provide leaktight sealing.

3.8 External transfer system

External transfer ports are provided in cells 1 & 5 for receiving and sending out radioactive materials by using shielded casks. These transfer ports consist of a SS tunnel of 340 mm diameter. A La Calhene door assembly is fixed on the hot side of the cell wall. The door assembly consists of one ring and a door made out of PVC . A lip seal is fixed on the PVC door to provide leaktightness. A pneumatically operated air cylinder is connected to the cell door structure for opening the door. The material will be transferred by using a La Calhene container[1]. During the transfer operation there is no breach of containment, because of the unique design of the La Calhene system.

3.9 Intercell transfer system

For transferring materials from one cell to the other cell, intercell transfer ports are provided. Since such ports connect cells operated in air atmosphere with cells operated in inert atmosphere, the ports have been designed for very good leaktightness, with provision for purging the volume. The transfer ports contain a stainless steel bellow and a flange assembly as shown in fig. 7. A shielding cum sealing door is provided on each side of the transfer port. The doors are designed for remote operation with manipulators. The unique design feature of these doors is the incorporation of specially designed co-seals. The co-seal assembly consists of an ethylene propylene elastomer seal sandwiched between two stainless steel rings . One of the SS rings is provided with a holder to facilitate remote removal of the co-seal by using master slave manipulators. The details are shown in fig.8 & 9. This co-seal was leak tested by pressurising the transfer port with helium gas to a pressure of 20 kPa and the leak rate was found to be less than $1x10^{-6}$ cc / s.

4.0 CONTAINMENT BOXES

The containment boxes which form the inner container in cells 2, 3 & 4 are designed for a much higher degree of leaktightness. The boxes are meant for handling fuels such as the carbides, which are pyrophoric in nature. The oxygen and moisture levels in the argon gas should be maintained at low levels.

The problem of maintaining an air free atmosphere is complicated by impurities in the flushing gas, impurities occurring during the transfer of equipments, leakage through seams and joints and diffusion through containment box materials such as rubber and plastic. The seals should be reliable, long lasting and easily demountable.

The major openings in the boxes and the method of sealing them are described below.

4.1 Radiation resistant glass panel

A radiation resistant glass panel is fixed on to a stainless steel frame on the front side of the containment box for viewing purpose. Due to the large size of the glass panel (1220x1355 mm), it was necessary to design and fabricate the stainless steel frame with great care in order to achieve good leaktightness as well as ensure the safety of the delicate glass panel. This meant that the deviation from the flatness of the frame had to be less than 0.2 mm/meter of its longest side and the torque applied on the mounting screws of the frame had to be limited to about 3000 to 4000 N mm in order to avoid breakage of the glass panel.

The steel frame was fabricated and machined on a planer in the Central Workshop at IGCAR, and the flatness achieved was better than 0.2 mm/meter. Precautions were taken during the welding of the frame with the containment box to avoid any distortion. An 8mm thick silicone gasket was used for tightening the glass panel to the stainless steel frame. The details of the assembly are shown in fig 10. These design features have ensured that the leak-tightness of the containment box is better than 0.05 vol %/hr (see section 5).

4.2 Service panel

The containment box has a service panel to facilitate in-situ maintenance of cell equipment and for manual intervention for maintenance if necessary. The service panel consists of one glass frame for viewing and two glove ports. The glove ports are normally closed, but can be fitted with gauntlets for minor repairs such as changing of bulbs, gaskets etc. The service panel is fixed on the containment box using formed gaskets similar to that shown in fig. 6. By the provision of formed gaskets the torque required for tightening the screws has been reduced and hence the panel can be quickly removed for man entry and refitted.

4.3 Service lines

All the service lines in the stainless box are sealed with O-rings. All the pipe lines associated with the recirculation system are connected to the box through HANSEN type quick release couplings. Electrical lines are taken inside through leaktight multicore connectors.

5.0 LEAK TESTING

Individual components of the cell systems were leak checked by employing localised leak testing methods. An absolute method was used to find out the leak rate of the cells and the containment boxes.

Preliminary leak tests were carried out by applying soap solution on the lining while keeping the cell space in a negative atmosphere. Bubble formation was noticed wherever minor leaks existed. These leaks were then arrested. Subsequently, localised vacuum tests were carried out for the metal lining in all the cells. The vacuum test employs a vacuum box that can be placed over an area to be tested and evacuated to atleast 5 psi pressure differential with respect to the atmospheric pressure. Air leak through the area tested will be revealed by changes in the readings of a manometer fixed in the vacuum box. All the leaks in the cell linings were detected and arrested.

Localised pressure tests were employed to detect leaks in the stainless steel pipe lines required for the argon recirculation system and other components used in the containment boxes. Before doing this the weld joints were subjected to Dye Penetrant Test. All the valves were checked at a pressure one and half times more than the rated pressure. After testing individual components an integrated pneumatic leak-detection test was carried out for the entire pipe line . This was done by pressurising the pipe lines pneumatically and applying soap solution on exterior surfaces of the entire pipe line to provide air bubble indications.

After making all the components leaktight, the containment structure (cell and containment box) was evacuated to 150 mm water gauge and leaks were identified by soap bubble tests and arrested . Finally, the leak rate in the concrete cells and in the containment boxes were determined by the absolute method. The absolute method of leak rate testing constitutes the determination of direct pressure and temperature and calculation of air losses over a period of time. Temperatures were monitored by using platinum resistance temperature detectors . Manometers were used for monitoring the changes in the absolute pressures.

The concrete cells were leak tested by pressurising the cells to 100 mm of water column and monitoring the pressures and temperatures on an hourly basis over a period of time. The containment boxes have been leak tested both by pressurising and evacuating the boxes to 100 mm of water column and monitoring the pressures and temperatures.

The cells and containment boxes were pressurised under atmospheric conditions by using dry air to avoid moisture condensation within the containment structure. Fans were used for air circulation in order to maintain uniform temperature inside the containment during the period of testing. The leak rate test period extended for three weeks. Pressure and temperature observations were made within the containment structure and recorded during the course of the leak rate test at hourly intervals. The pressure and temperature measurements of the outside atmosphere were also made and recorded at corresponding intervals.

The procedure adopted for the computation of leak rates is given in the Appendix.

5.1 Leak rate

All the concrete cells except cell 5 have a leak rate less than 1 % of the cell volume per hour. Cell 5 has a leakage rate less than 0.5 % of the cell volume per hour. Containment boxes have leak rates less than 0.05 % of the box volume per hour.

6.0 CONCLUSION

It was found from our experience that usage of standard rubber gaskets between flanges and panels of large dimensions does not give high degree of leaktightness. We have designed special formed gaskets of various shapes and sizes made out of ethylene propylene elastomer for sealing large openings in the cells where the cell door and roof plugs are located. Special seals like co-seals are used to provide sealing at the inter cell transfer port doors inside the cells . These co-seals can be easily replaced remotely by using master slave manipulator. We could achieve very high degree of leaktightness in the stainless steel containment boxes and in the concrete cells by using indigenously made gaskets and other sealing methods described in this report.

7.0 ACKNOWLEDGEMENT

The moral support and encouragement of Dr. P.R.Vasudeva Rao in preparing this report is gratefully acknowledged. The suggestions made by him after a critical reading of the draft have helped to enrich this report.

The authors express their sincere thanks to the staff of Central Work Shop ,IGCAR for precise machining , fabrication and welding support rendered by them which has contributed to the achievement of leaktightness in the containment boxes. On-sight fabrication , machining and welding support rendered by staff of hot cell group as well as Technical Services Section of Chemical Group is also thankfully acknowledged.

REFERENCE

1.G.LEFORT, J.VERTUT, JEAN PIERRE CAZALIS " New interchangeable seals for parts in alpha,beta cells", Proceedings of the 11 th conference on " Hot laboratories and Equipment ", American Nuclear Society , Ill. USA,P-353, 1963.

8.0 APPENDIX

Computation of Leak Rates

Leak rates were calculated on an hourly basis.

In the absolute method

$P1.V = (W1/n).R.T1$ and $P2.V = (W2/n).R.T2$

Where

P1 = total absolute pressure in the containment structure at the start of each hourly test period.

P2 = total absolute pressure in the containment structure at the end of each hourly test period.

W1 = weight of contained air at the start of test interval

W2 = weight of contained air at the end of test interval

T1 = mean absolute temperature of the containment structure air at the start of each hourly test period.

T2 = mean absolute temperature of the containment structure air at the end of each hourly test period.

V = internal volume of containment structure

n = mean molecular weight of air.

Rewriting the above equations we get,

$W1.T1/P1 = n.V/R$ and $W2.T2/P2 = n.V/R$

therefore, $W1.T1/P1 = W2.T2/P2$

whereby, $W1 = W2.T2.P1/T1.P2$ and $W2 = W1.T1.P2/T2.P1$

accordingly,

$$\text{Leak} = (W1-W2)/W1 = W2(T2.P1/T1.P2 - 1)/ W2(T2.P1/T1.P2)$$

$$= 1- (T1.P2/T2.P1)$$

and

$$\text{Percent leak rate} = (1-T1.P2/T2.P1)\ 100$$

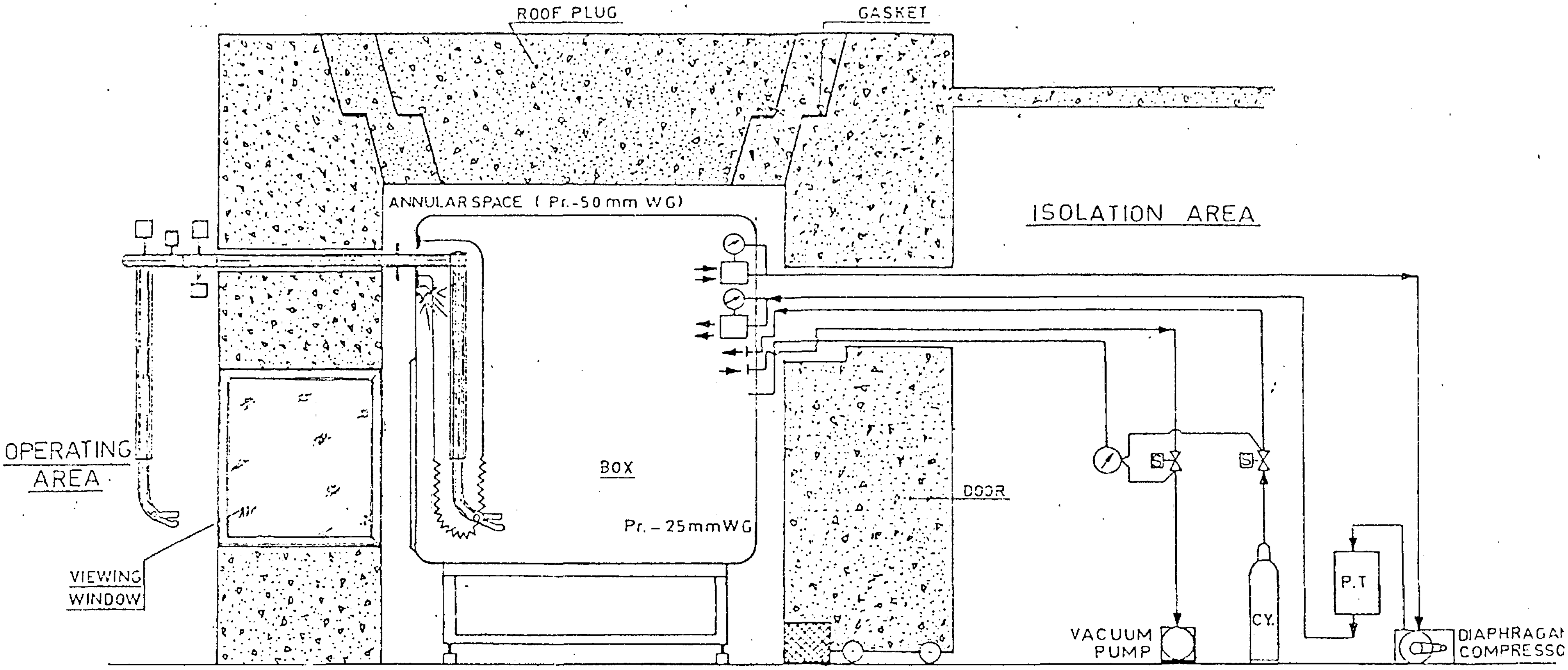


FIG. 1 CROSS SECTIONAL VIEW OF HOT CELLS

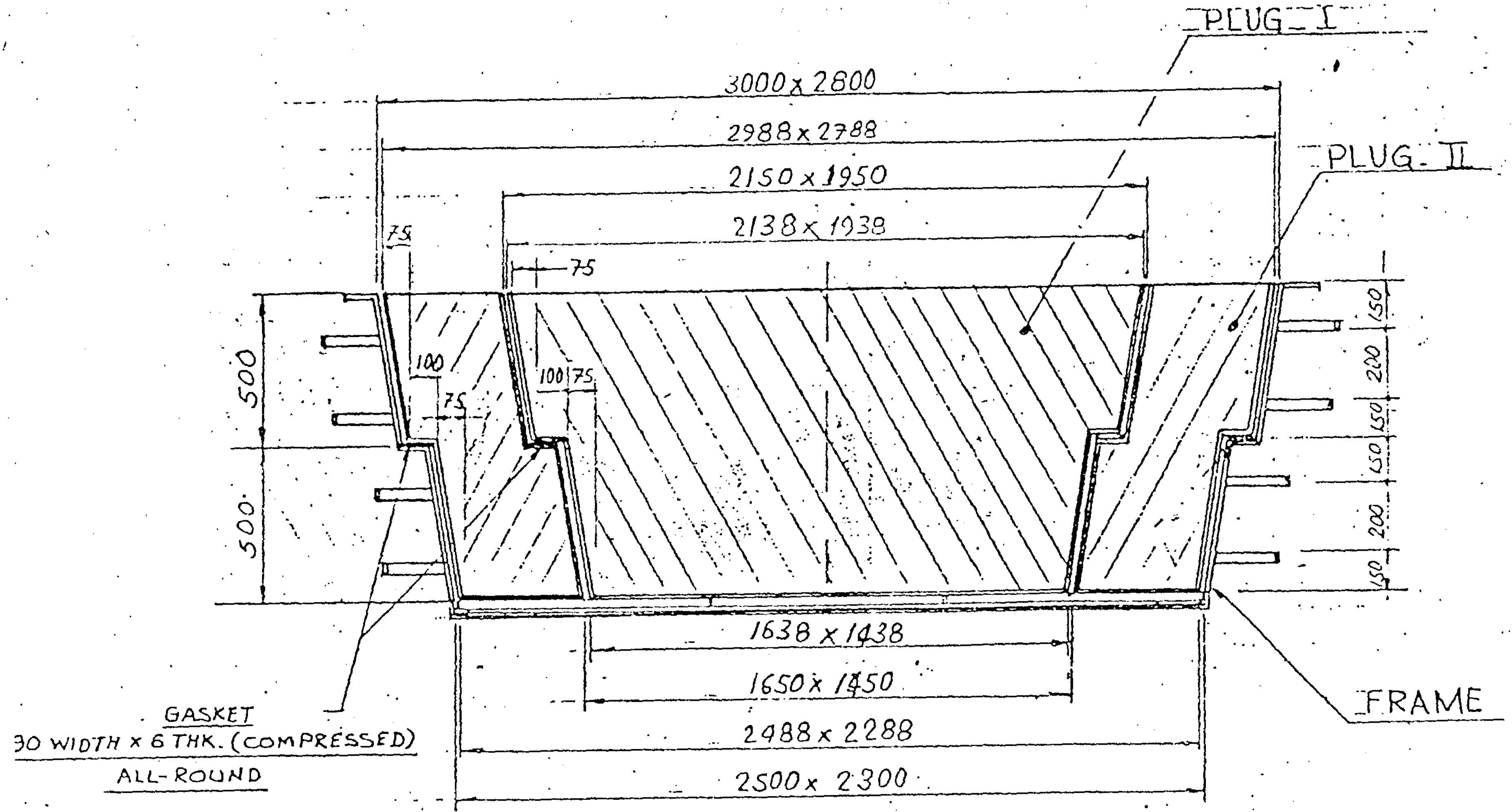


FIG:2 R.C.C. ROOF PLUG FOR HOT CELL

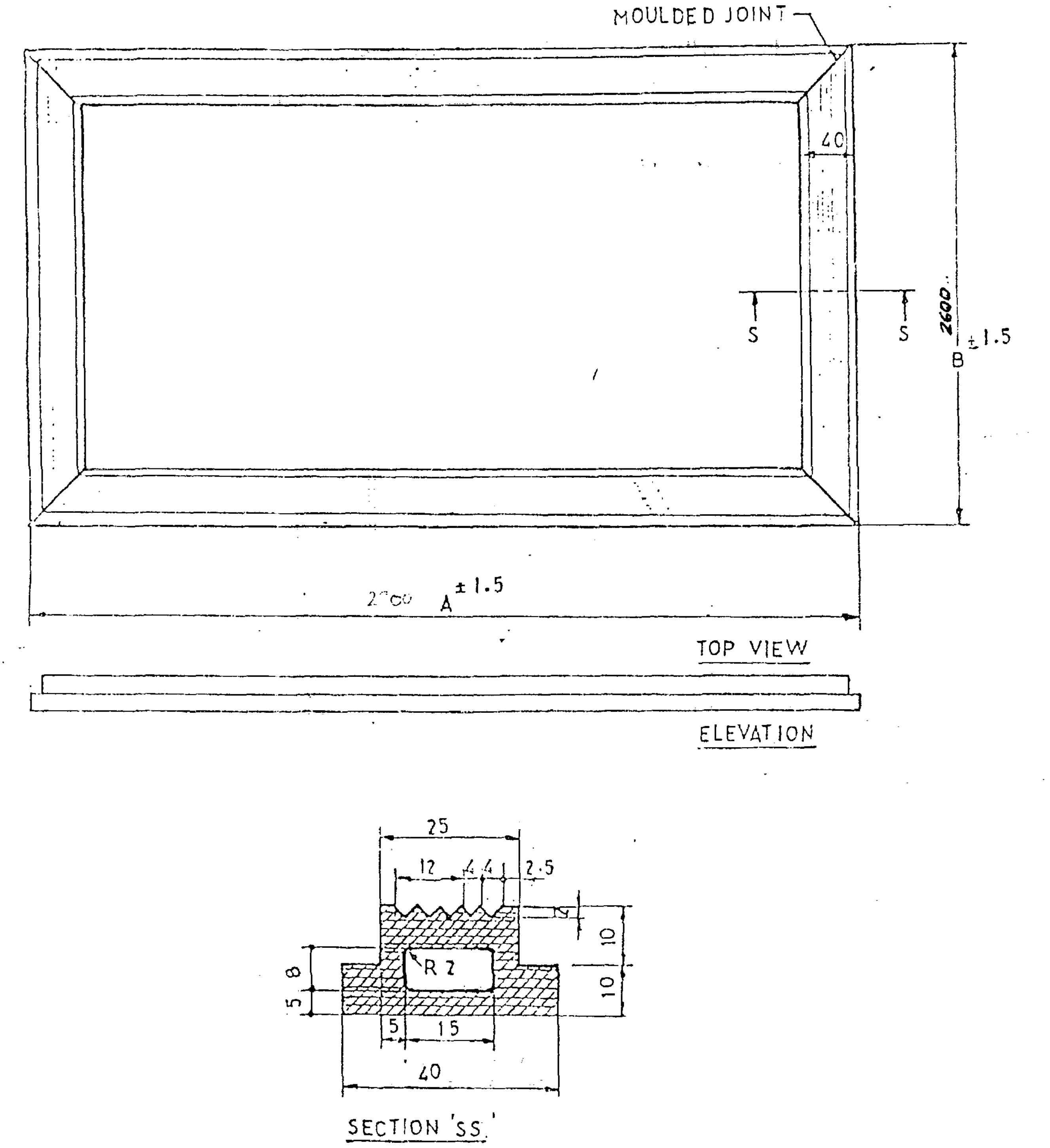


FIG. 3 GASKET FOR ROOF PLUG

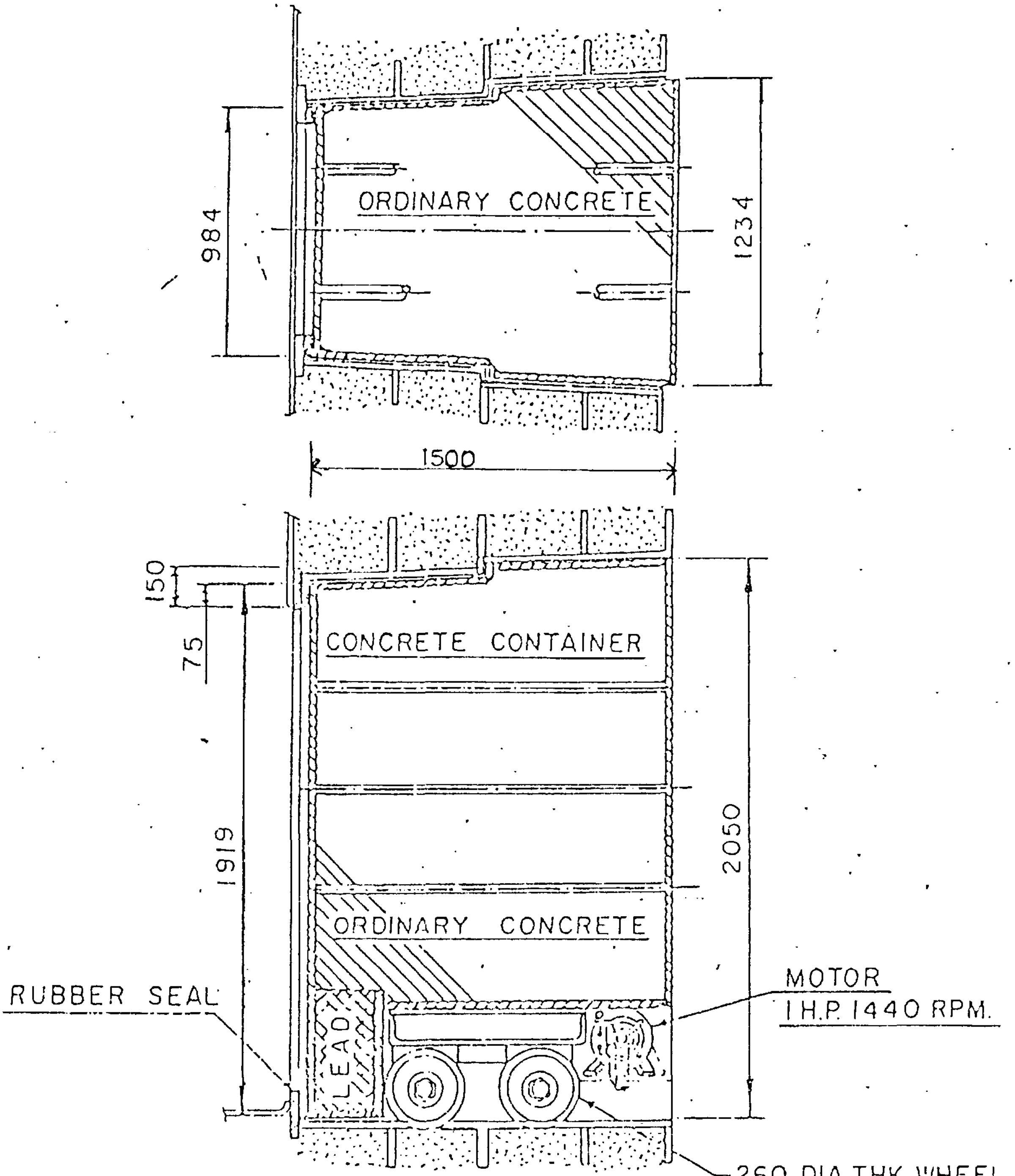
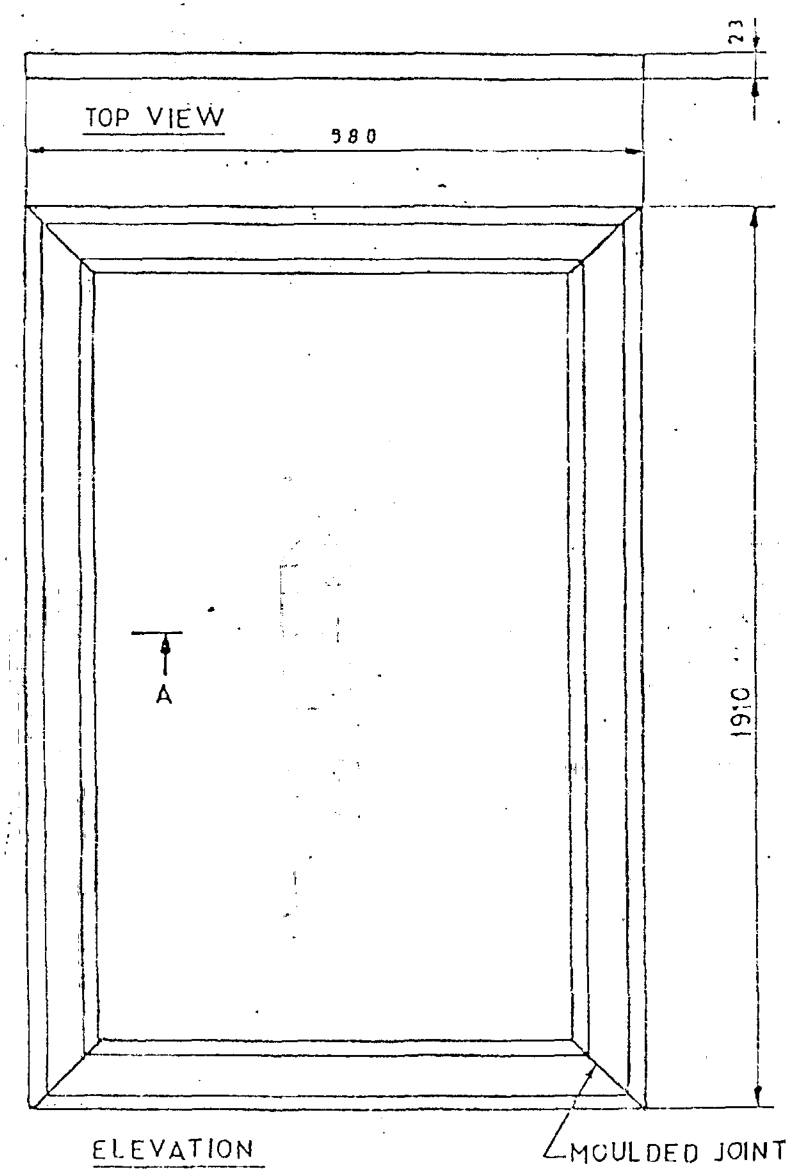
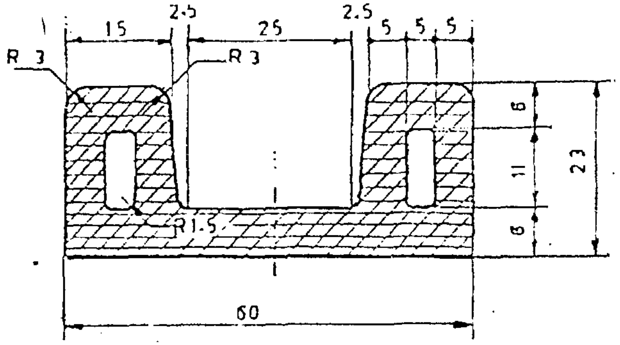


FIG. 4

PERSONNEL DOOR FOR HOT CELLS



ELEVATION



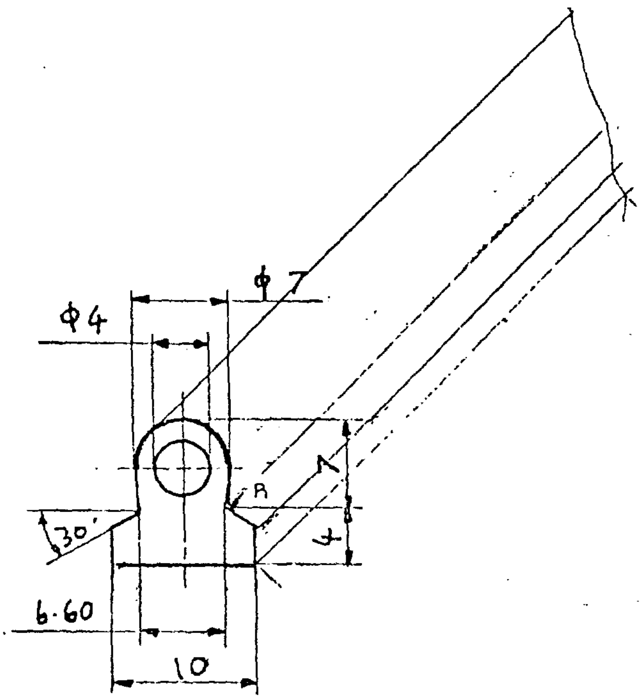
SECTION AA

GENERAL NOTES

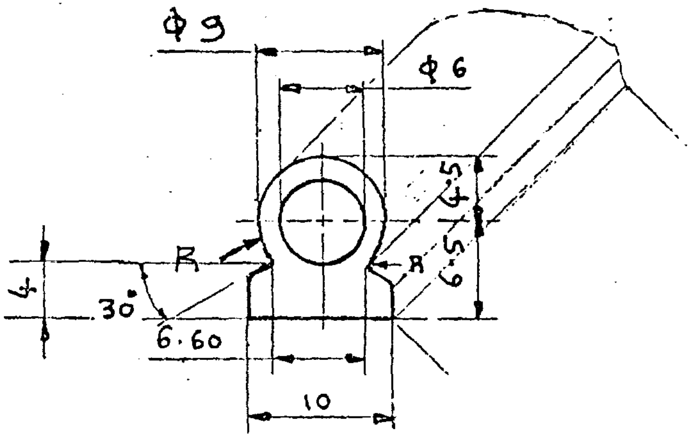
- ALL DIMENSIONS IN mm
- MATERIAL NEOPRENE
- QUANTITY REQUIRED : 7 NOS
- SHORE HARDNESS : 45/50°

GASKET

FIG.5 GASKET FOR DOORS

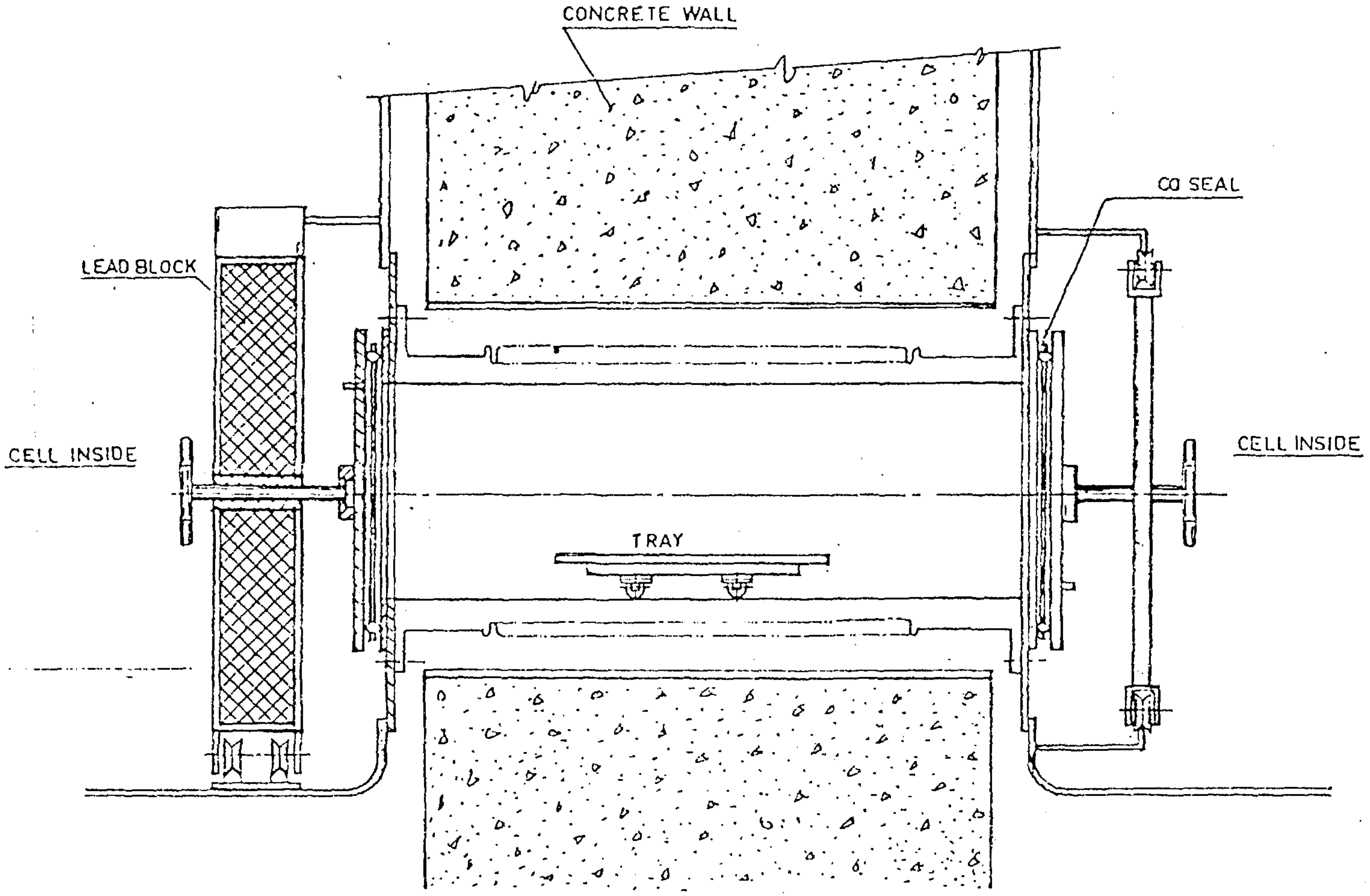


TYPE -I



TYPE -II

FIG. 6 CROSS SECTION OF GASKET FOR S.S PANELS



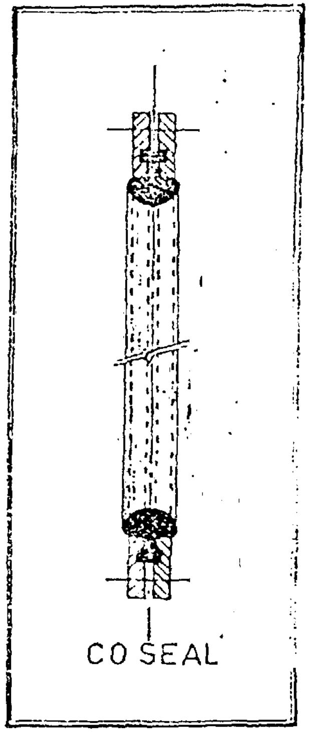
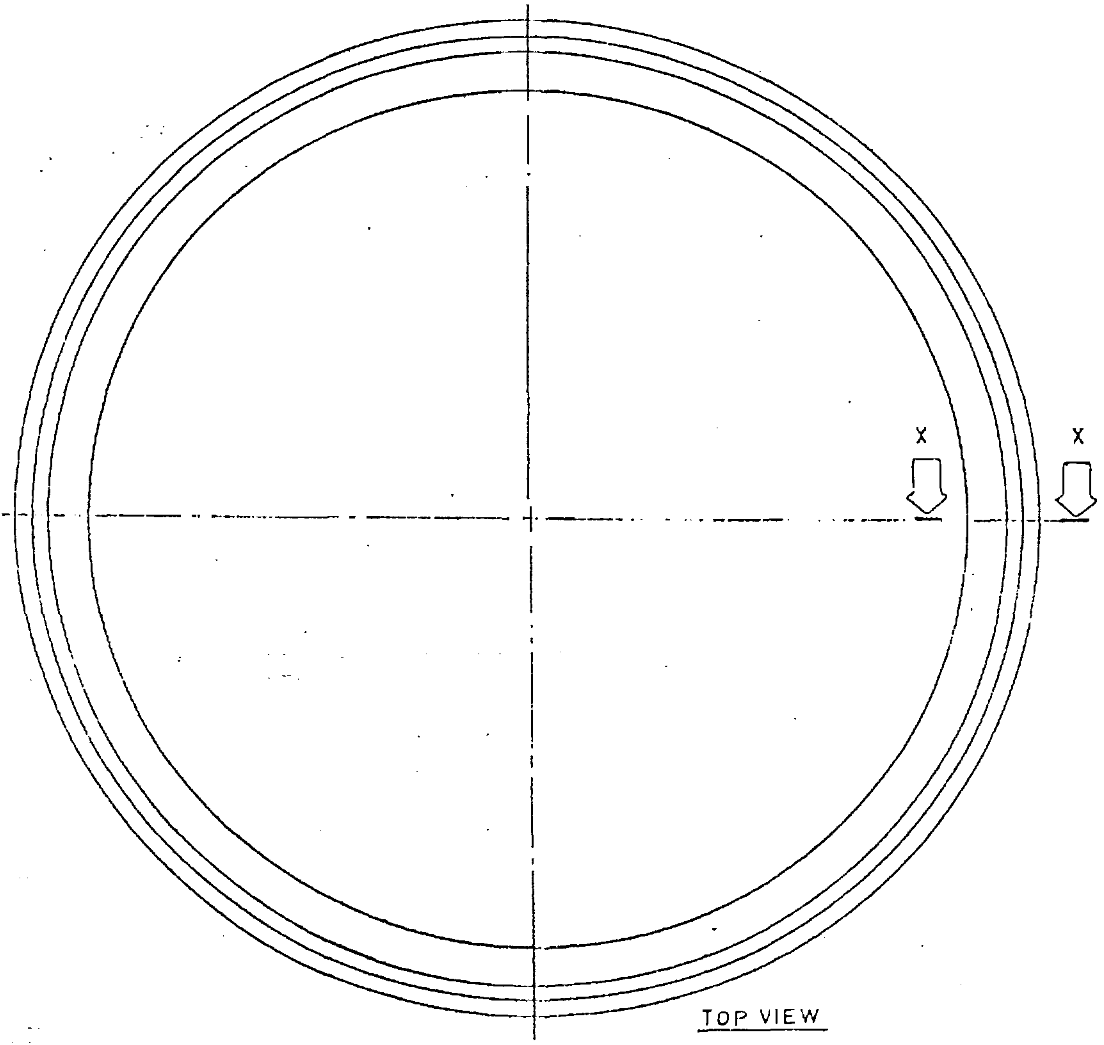
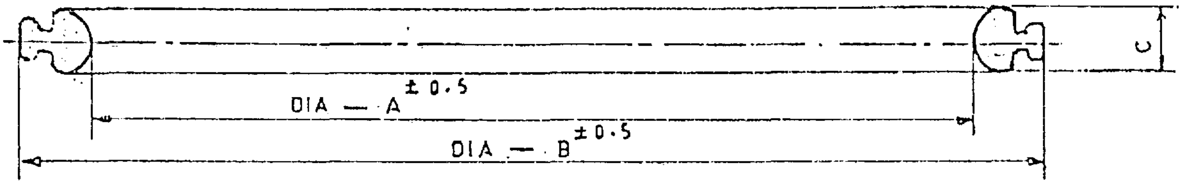


FIG 7

INTER CELL TRANSFER SYSTEM

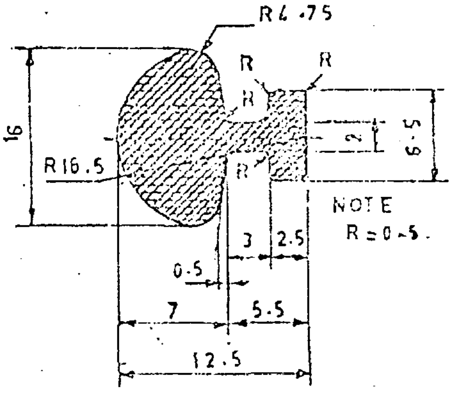


TOP VIEW



SECTIONAL ELEVATION

SECTION - X X



SECTION ENLARGED VIEW

FIG: 8 CO.SEAL 'O'RING

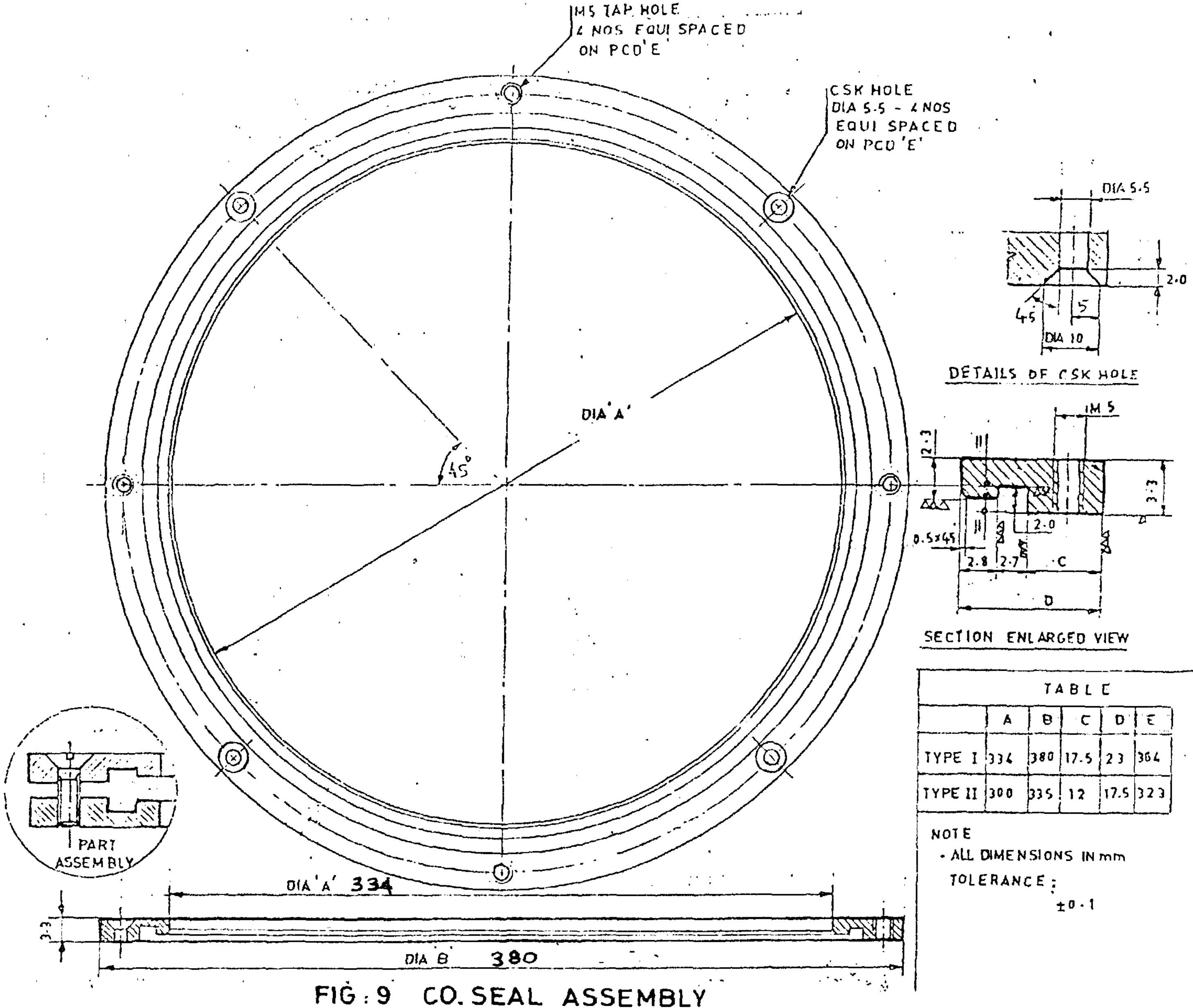


FIG : 9 CO. SEAL ASSEMBLY

TABLE E

	A	B	C	D	E
TYPE I	334	380	17.5	23	364
TYPE II	300	335	12	17.5	323

NOTE
- ALL DIMENSIONS IN mm

TOLERANCE : ±0·1

Radiation Resistant Glass Panel

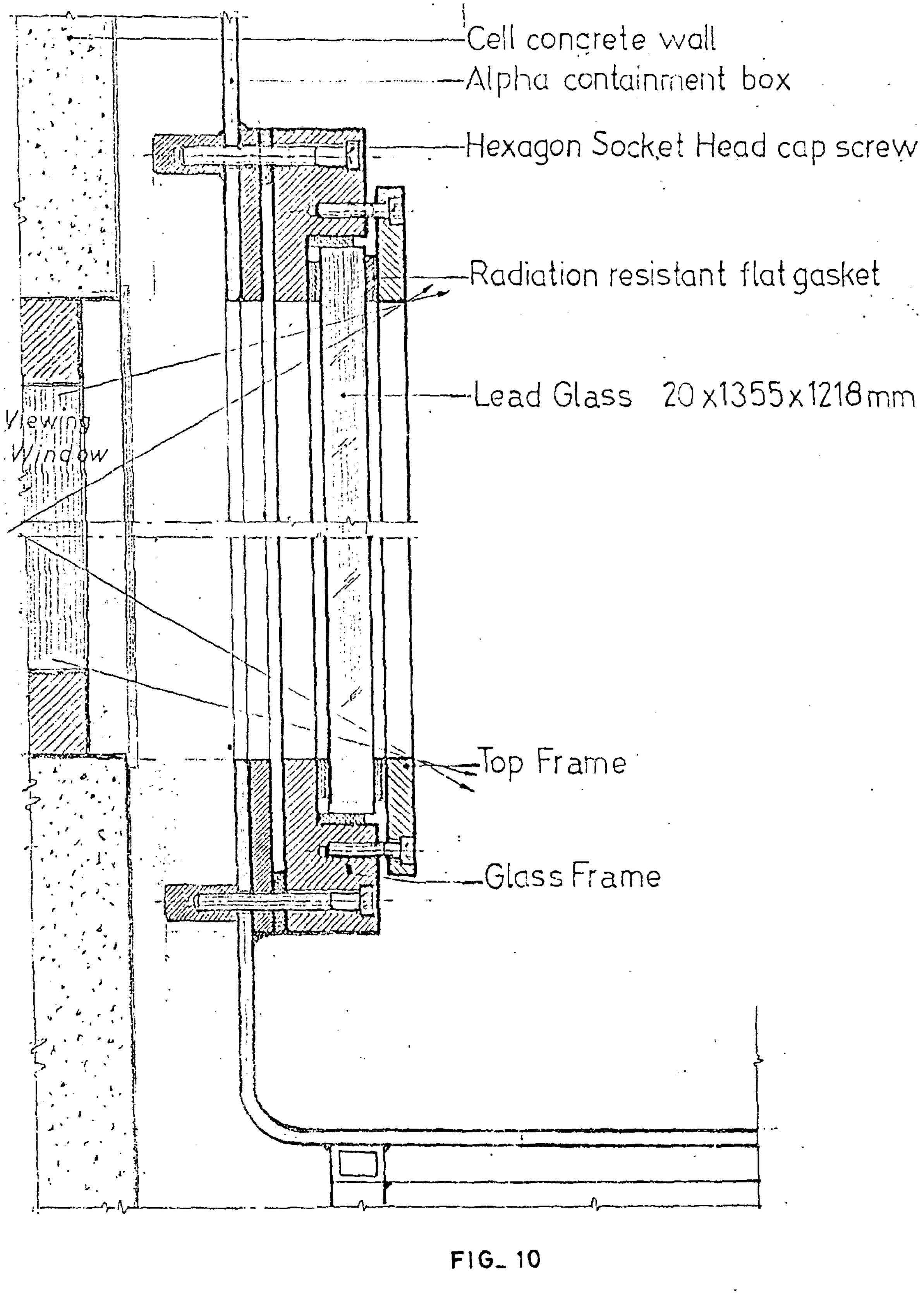


FIG. 10