Canadian Fusion Fuels
Technology Project

CFFTP

ITER - TORUS VACUUM PUMPING SYSTE
REMOTE HANDLING ISSUES
PHASE 4

CFFTP G-91116
November 1992

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Wardrop Engineering Inc.

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2.	Alsthom-Velan Dwg. No.	9104.SET01/1500/E

SUMMARY

This report describes further critical design issues concerning remote maintenance of Torus Vacuum Pumping System (TVPS) options for ITER. The key issues under investigation in this report are flask support systems for valve seal exchange operations for the compound cryopump scheme and remote maintenance of a proposed multiple turbomolecular pump (TMP) system, an alternative ITER torus exhaust pumping option.

Previous remote handling studies (CFFTP G-9162) show that when removing valve working parts the overhead support methods for seal exchange flask equipment could potentially malfunction due to valve/flask misalignment. A floor mounted support system is described in this report as a possible alternative flask support method. This scheme will provide a more rigid support system for seal exchange operations.

An alternative torus pumping system concept (proposed by ITER), based on the use of multiple TMPs, is studied from a remote maintenance standpoint. In this concept, centre distance spacing for pump/valve assemblies is excessively restrictive for remote maintenance operations. Recommendations are made for adequate spacing of these assemblies based on commercially available 0.8m and 1.0m diameter valves. These recommendations have serious implications for pumping system performance as fewer pumps must be used. This, in turn, implies a need for larger TMPs which are not commercially available.

Other concerns regarding the servicing and storage of remote handling equipment in the cells are also identified.

1.0 INTRODUCTION

Wardrop Engineering Inc. has prepared this report for Canadian Fusion Fuels Technology Project (CFFTP). This work discusses further critical design issues which have an impact on the torus vacuum pumping system (TVPS). This is a continuation of TVPS remote maintenance design studies focusing on, firstly, a more rigid flask support system using floor mounted means for regeneration-isolation valve seal replacement and, secondly, an assessment of remote maintenance of a proposed alternative vacuum pumping system, using multiple TMPs, currently under consideration for ITER.

2.0 VALVE SEAL EXCHANGE/FLOOR MOUNTED SUPPORT CONCEPT

2.1 Background

The primary exhaust system reference option for ITER consists of compound cryopumps for burn and dwell, together with turbomolecular pumps for initial conditioning and pumpdown.

In this system eight pump stations are located symmetrically around the base of the machine. Each pump station consists of a U-shaped pumping duct with 3-100m^3/sec compound cryopumps and 1-15m^3/sec turbomolecular pumps connected in parallel.

Every cryopump is equipped with a combined regeneration-isolation valve arranged horizontally at the pump inlet. The pumps are arranged vertically (bottom entry inlet). Remote maintenance of the valve seal and internal working parts, without disturbance to the rest of the system, with contamination control, is a requirement. Flask equipment concepts have been developed by CFFTP for valve seal replacement, based on European and North American valve designs, which comply with these requirements.

Overhead methods of supporting the flask show that during the seal exchange process, the compliance of the overhead bridge transportation system, which supports the flask, could potentially malfunction. A more rigid support system is therefore needed, which would minimize the misalignments which occur between the valve/flange interface during seal replacement operation.

2.2 Discussion

Previous remote handling studies[1] show that when the flask is supported by the overhead transporter equipment, considerable misalignment occurs between the valve and the flask during seal exchange operations . This situation could lead to malfunction of the valve moving parts during the transfer operation. In addition, during seal removal, large forces are developed in the flask clamps, which could tend to separate the valve/flask connection and lead to airborne contamination of the pump cells.

The valve/flask misalignment is due to the compliance of the overhead transporter bridge and the stretch of the crane cable when subject to the valve moving parts live load (seal/disc). Analysis has shown[1] that increasing the stiffness of the bridge produces no significant reduction in either flask clamp forces or valve/flask misalignment, and the conclusion reached is that this is not a cost effective way of alleviating the problem.

There is a need, therefore, to develop a concept that would provide a more rigid support system for seal exchange operations. The feasibility of a floor mounted support concept to meet these requirements is explored, and the results described in this report.

2.3 Requirements

Some preliminary requirements, outlined below, are used as criteria for developing the concept. A floor mounted support concept must:

- support valve moving parts weighing approximately 4.75 tonnes;
- support flask equipment weighing approximately 2.5 tonnes;

- provide a system for alignment and docking of the flask on the valve;
- minimize misalignments between the flask and the valve during the seal exchange operations;
- facilitate installation/removal of the equipment by the overhead polar crane;
- minimize loads in the flask clamps during the seal transfer operation.

Valve moving parts are based on Alsthom-Velan's valve design[2] .

2.4 Concept Description

A floor mounted remotely controlled scissors hoist and alignment system is proposed as a flask support method for seal exchange operations (Fig. 1). The concept consists of a scissors hoist, flask alignment system mounted on the upper surface of the hoist, and a remote control system. The systems are described in more detail below:

Hoist

A remotely controlled floor mounted scissors hoist and alignment system is used to support the flask and moving parts during the seal exchange operation. The system supports the combined weight of the flask, valve moving parts, and alignment system as well as its own structure. The hoist is designed to support a total weight of 10 tonnes, and will elevate the flask from a stored (lowered) position of .47m, to an elevated position of 1.97m (1.5m stroke) to align the flask with a valve requiring seal replacement. The lowered position on the hoist permits installation and removal through the cell airlock.

The hoist is raised and lowered by a hoist drive system consisting of a pair of lead screws, driven by an a/c servomotor via a double reduction gearbox, all mounted horizontally in the hoist baseframe. The hoist, which is equipped with 2 pairs of wheels, is mounted by the polar crane on pins in the floor during seal exchange operations. The hoist wheel drive motor is used as a traction drive for installation of the equipment in the cell. Scissors hoists of this size and load capacity are available commercially. The hoist dimensions are: 3m long x .47m high (closed) x 2.0m wide.

The remotely controlled pump cell overhead transporter bridge crane (polar crane) is only used to assemble the hoist equipment on pins mounted in the floor opposite any specific valve requiring seal replacement. The overhead bridge is not used to support the flask during seal exchange procedures as the hoist is used for this purpose.

Alignment System

The hoist alignment system, mounted on the upper surface of the hoist, is designed to support the flask during all handling operations, and to align the flask on the valve during initial alignment and docking.

The alignment system consists of two trunnion shafts, bearing assemblies and vertical posts to support the flask, vertical and horizontal jacking systems to align the flask on the valve, and a support carriage.

The alignment system consists of a 3-axis drive: A jacking system (Y-drive) is used to provide vertical adjustment of the flask in the vertical direction. A sub-carriage and roller support system is driven by a jacking screw (X-drive) to provide lateral adjustment of the flask in the horizontal (lateral) direction. The carriage drive (Z-drive) is used for coarse/fine docking of the flask on the valve in the axial direction (forward/back).

Each trunnion shaft incorporates two bearings. One bearing permits angular alignment of the flask in the vertical plane, Y-Z plane (pitch), while the second bearing permits flask angular alignment in the horizontal plane, the X-Z plane (yaw).

The flask is aligned and docked on the valve by independent control of each of these drives, from a remote control centre (not shown).

Control System

The drives, which control initial installation, vertical elevation of the hoist and the alignment of the flask on the valve, are controlled by the positioning control system, shown schematically in Fig. 2. This system consists of the following: a multi-axis controller (MAC) and power supply (PS1), an amplifier (A) and power system (PS2), and A/C brushless servomotor drives (M1-M5) and resolvers.

The control system which provides simple, advanced cost effective motion control uses A/C brushless technology. The controller provides fast operation, communication capacity and facilities for programming.

Direct Numerical Processing (DNP) digital brushless servo control technology is used to control speed, acceleration, position and motor torque on all 5 drive axis, all from a single compact control unit. Using DNP, advanced software commands provide simple motion control. Digital, reliable, direct control of servo parameters is feasible and system parameters can be changed through software.

Built-in diagnostics help to trouble shoot the system, axis drives and I/O problems. Software automatically diagnoses faults and relays error messages.

Using brushless servo technology, the multi-axis controller is matched with a drive amplifier and power supply. The controller provides complete control, through software, of the A/C brushless motors. The use of resolvers (rotary transformers) provides high accuracy, and avoids the use of environmentally sensitive electronic devices. Reliability is greatly improved due to the reduced number of components.

The multi-axis controller offers easy system programming. In this particular system the controller accepts program modules that use the multi-axis programming language 'Cybercalc'. The performance of the system can be modified by changing the programming modules.

2.5 Analysis

Two important considerations governing the design of the flask system are the hoist deflections and the forces that develop in the flask clamps during the seal replacement operation.

When the valve moving parts are transferred to the flask, the hoist will deflect under load causing some misalignment between the valve and the flask. The hoist deflection also influences the bending moment at the valve/flask interface and thus the forces acting on the clamps. It is therefore essential to minimize the hoist deflection and any mismatch between the valve and the flask.

The hoist concept was analyzed for a total load of 10 tonnes, and a live load of 4.75 tonnes (valve moving parts). The results of the analysis show that when supporting the live load the hoist structure deflects approximately

0.5mm. The small spans and relatively stiff members of the hoist structure help to minimize structural deflections.

To determine the forces in the clamps, the flask bending moment is plotted against the flask beam length for initial and final flask docked positions. The results of the analysis show that for an initial alignment of the flask on the valve (no mismatch) the interface bending moment is 2500 N-m, which results in a clamp force of 5000 N. During transfer of the valve moving parts, based on a hoist deflection of 0.5mm, the flange bending moment reduces to approximately 500 N-m, which results in a clamp force of 1000 N. The moment distribution for these cases is shown in Fig. 4. These results show that flask deflections and clamp forces are approximately 20% of those based on overhead support methods[1].

2.6 Handling Procedures

Simple handling procedures are outlined below to describe the method of installation and removal of the equipment. These procedures are grouped as follows: preparatory work, seal removal, and seal installation.

Preparatory Work

A flask containing a new valve seal/disc is stored in the pump cell, prior to removal of the old seal/disc. Procedures 1 and 2 (Fig. 4a) outline the new seal/disc installation and temporary storage in the cell.

Old Seal Removal

An empty flask is now installed in the pump cell to remove the old seal and disc. Procedures 3 to 7 (Figs. 4b, 4c) outline these operations: flask installation in the cell, alignment opposite the valve, old seal/disc removal, flask withdrawal and removal from the cell.

New Seal Installation

The flask containing new valve seal/disc is now attached to the valve for the purpose of installing the new seal/disc. Procedures 8 to 11 (Fig. 4d, 4e) outline the new seal installation, flask withdrawal, flask lowering and removal from the cell.

2.7 Summary

The foregoing study shows that the proposed floor mounted flask support hoist concept will minimize the valve/flange misalignments and clamp forces during seal exchange operations.

The scissors hoist concept, designed for a total load of 10 tonnes, will support valve moving parts weighing 4.75 tonnes, while keeping the valve/flask misalignment to within 0.5mm.

Support, alignment and docking of the flask with the valve flange is feasible based on an X-Y-Z alignment system, which supports the flask from trunnion mountings. The flask alignment system is remotely controlled by a multi-axis controller and a/c servomotor based system.

Two dedicated flask support systems are proposed for seal replacement. One flask is used to install new seal/disc equipment while a second flask is used to remove old seal/disc equipment. Inquiries show that hoist equipment of this capacity and lift can be obtained commercially.

2.8 Conclusion

The flask mounted support and alignment system described above will reduce the valve/flange misalignments to approximately 20% of those obtained by overhead support methods. The floor mounted support method is preferred to the overhead support method because a hoist system provides a more rigid base for the transfer operation, thus minimising the potential for the seal/disc replacement operations to malfunction. As flask clamp forces are much lower, the possibility of the valve/flask interface flange opening, with the resultant spread of airborne contamination in the cell, is avoided.

Because the flask, hoist and alignment system is based on the Alsthom-Velan valve design, the impact of small misalignments (approximately 0.5mm) on the valve seal/disc transfer operation should be discussed with Alsthom-Velan.

To minimize the size of support equipment, lighter and dimensionally smaller valves should be used.

In this concept, assembly of the handling equipment in the cell is assisted by the overhead polar crane, but not actually used during the seal/disc transfer operation.

2.9 Recommendations

TVPS pumping schemes, based either on compound cryopumps or TMPs, will require the use of large gate valves, irrespective of the type of pumping system finally proposed. Also, maintenance of these valves is required on a periodic basis to ensure plant availability. The logical next step would be to prepare plans for and demonstrate a typical seal replacement operation (ITER has proposed seal replacement demonstrations for the long term R&D program).

It is therefore recommended that a 3 phase seal replacement demonstration be carried out to confirm seal replacement concepts, for valves in the range of 1.0m to 1.5m. These tests should:

- demonstrate the removal/replacement of valve internals using simple support structure and drives to represent the flask;
- demonstrate removal/replacement of valve internals and contamination control using a mockup of the flask, drives and double door system;
- demonstrate removal/installation of valve internals using a flask hoist and alignment system.

Typical, full size, low cost, representative valves should be used for the proposed demonstrations.

3.0 MULTIPLE TURBOMOLECULAR PUMP CONCEPT/ MAINTENANCE ASSESSMENT

3.1 Background

The main pumping options under consideration for ITER and for which development programs exist in the ITER partners home laboratories are: compound cryopumps (CCPs) and turbomolecular pumps (TMPs).

As test programs are in the early stages and ITER pumping requirements are still under review, both CCP and TMP pumping schemes are being considered as potential reference options for ITER.

Two compound cryopump variations are possible: cryosorption pumps and cryotrapping pumps. Both schemes are to be developed for ITER since available data does not permit a choice.

Information is also available on turbomolecular pump (TMP) development, and test facilities have been constructed by ITER partners for the development of both magnetic and dry film emergency bearings. Test plans for both CCP and TMP pumping systems are foreseen for the long-term R and D program. The ITER pump cell layout drawings reflect the potential to deploy either type of pumping system.

A preliminary remote handling assessment, therefore, as applied to a TMP based pumping system, is both timely and useful. The conclusions can be used at a later date to compare both types of pumping schemes from a remote handling standpoint, and will also provide useful feedback in the development of alternative CCP pumping schemes as the comments are relevant to both systems.

3.2 Discussion

It is recognized that the ITER pump cell layout drawings, Figs. 5, 6 and 7, showing the multiple TMP arrangement, are preliminary and conceptual in arrangement. The size of some components such as exhaust manifolds and their routing from the pumps, the roughing line from the main pumping manifold, are not indicated. However, there is sufficient information to be able to focus on the feasibility and implications of a number of aspects of the system, such as the valve configuration and service connections to pump/valve assemblies. Comments on the cell arrangement are also included.

The scale of the drawings indicates that 0.8m diameter gate valves are used in this system. Industrial suppliers confirm that both 0.8m and 1.0m gate valves are available commercially, and therefore dimensional data can be obtained for these units. This information is used to evaluate access requirements for manipulator equipment. In addition, pipe routing (not shown) will be assumed in this assessment as access to pumps/valves can be affected by these obstructions.

This report provides a brief description of the proposed pumping scheme, a preliminary list of RH requirements and an assessment of the implications of the proposed pump arrangement. It is, however, outside the scope of this report to comment on the pumping performance of the multi-TMP scheme. The following ITER drawings are referred to in this report:

Fig. 5	Plan view of the pump cells
Fig. 6	Plan view of the pump cells (enlarged)
Fig. 7	Elevation of the ITER machine (section)

3.3 Pump System Description

Eight TMP's are shown mounted directly above the torus exhaust manifold and isolated from the manifold by large gate valves. The torus pumping duct and manifold arrangement are essentially identical to the ITER reference duct concept, except that the cryopumps have been replaced by TMPs.

The pump cell arrangement (Fig. 5) shows a cell layout consisting of 4 cell zones; 2 large cells containing 3 pump sets (8 pumps in each set) and 2 small cells containing 8 pump set (8 pumps per set). A total of 64 TMPs is shown for the complete system.

Two maintenance access corridors to the cryostat are indicated, rather than four access corridors as in the NET/ITER current configuration. Access to the cryostat is therefore via the pump cells at only 2 locations.

Mechanical backing pumps are located in a room external to the pump cells. Pump roughing lines are therefore routed between the manifold and mechanical backing pump room, beyond the transfer corridor.

Standard commercial UHV gas operated gate valves, are assumed to be used in this concept. These valves are designed to isolate the pumps from the manifold during servicing. The implications on remote maintenance of making and breaking pump/valve service line connections are discussed in this assessment.

3.4 General Remote Handling Requirements

A preliminary list of remote maintenance design requirements is listed below and used for evaluating the multiple TMP scheme.

- pump components must be mounted/dismounted with the minimum of disturbance to the rest of the system;
- simple linear motions must be used for removal operations;
- any maintenance operation must not exceed 150 hours;
- the location and storage of remote handling equipment should be such that activation of remote handling equipment is avoided during normal operation of the pumping system;
- a service and docking area must be provided for the remote handling equipment when this equipment is not in use. This area should include space for tool exchange, repair and servicing of the remote handling equipment itself;
- maintenance of the pumping components must be carried out remotely with the minimum of disturbance to the rest of the system;
- the life of pumping system components must be maximized to reduce remote handling requirements;
- remote handling equipment must include some form of contamination control;

- remote handling equipment must be compatible with inert gas atmospheres.

Some of the above requirements apply to the design of the pumping system components, while others apply to the arrangement of the pumping system within the cells.

3.5 Assessment

As the TMP pump concept is very conceptual, only a preliminary remote handling assessment can be made at this time. The focus of the comments is therefore directed at the following: valve configuration, service line corrections to pump/valve assemblies, and the cell pump arrangement.

3.5.1 Valve Configuration

Gate valves are used in UHV systems in order to isolate pump components, and achieve low conductance losses while minimizing spatial requirements.

The current multiple TMP concept shows 8 pump/valve assemblies per cell mounted directly over the torus exhaust manifold. The centre distance spacing of the valves is approx. 1.3m. This spacing poses considerable restraints from an access standpoint for remote handling equipment. The impact of the valve spacing on remote servicing of pump/valve assemblies, and therefore on the pumping system, is examined in further detail below.

Spacing

Valves used for the purpose of this study are based on standard 0.8m diameter and 1.0m diameter VAT valves.

Fig. 8 shows the centre distance spacing (1.7m) for an 0.8m diameter valve. This spacing is based on a 0.2m clearance between adjacent valves, which will provide adequate access for remote handling equipment. Based on a valve spacing of 1.7m, only 6 valve/pump assemblies can be assembled in a 10m long manifold.

Similarly, if 1.0m diameter valves are used, then a centre distance spacing of approximately 2.0m is required (Fig. 9) to provide sufficient space for access by manipulator. Based on a duct length of 10 meters, and a centre distance between valves of 2.0m, only 5 valve/pump assemblies can be assembled in 10m long manifold.

Valve Conductance

Valve diameter has a very significant effect on pumping performance of the system. The valve data listed below shows the variation of molecular flow conductance with valve diameter for 3 sizes of VAT valves:

Valve Diameter (m)	Molecular Flow Conductance (1/sec)
0.8	320,000
1.0	550,000
1.25	990,000

These parameters show that, where possible, larger valves should be used in order to take advantage of the greater conductance. The spatial requirements for remote handling equipment dictate that fewer and larger pump/valve assemblies must be used. The effect on pumping performance should therefore be re-evaluated based on fewer and larger valves.

Seal/Disc Replacement

Gate valve internal working parts, such as seal/discs, toggle drives and bellows, can malfunction due to the environment in which they function, necessitating their replacement on a periodic basis. From previous studies[1], it has been shown that seal/discs and supporting bonnet can be replaced by remote means, in a horizontally oriented valve, using seal exchange flasks. This operation is feasible without having to remove the valve body from the line, with the minimum of disturbance to the rest of the system.

To permit assembly of the flask on the valve, the valve flanges must be suitably modified, and all flange bolts must be captive and accessible externally by overhead manipulator. Therefore, valve centre distance spacing is critical in order to meet access requirements for remotely operated flask equipment.

3.5.2 Pump/Valve Service Connections

As TVPS components, such as pumps and valves, need to be serviced on a regular basis, ease of access to these components is of major importance. The number and routing of power and service lines from the pump/valve assemblies, which tend to restrict access, should be considered early on in the conceptual design. A preliminary list of service lines to each valve and pump is outlined below. This list is preliminary and needs to be reviewed with specific pump/valve manufacturers, as the designs develop. The impact on restricted access to pump/valve connections by RH equipment are evaluated in this section. Service line connections are:

Valves - Electrical
- Shop air or gas
- Thermocouples
- Purge line connections
- Leak detection line

TMPs - Electrical connections (magnetic bearings)
- Electrical connections (motor drives)
- Vibration sensors
- Thermocouples
- Instrumentation connections (speed sensor)
- Cooling lines (if required)

From a remote handling standpoint, it is important to minimize the number of connections to be assembled/disassembled when removing a pump or valve from the line. The more connections there are, the greater will be the outage time for the maintenance operation. Increased outage times could potentially impact plant availability. In addition, too many service lines could obstruct access to TVPS components, making the maintenance operation both difficult and time consuming.

For example, in the present multi-TMP scheme, assuming approximately 12 connections per pump/valve assembly, 0.8m valves and 6 pump/valve stations per cell, the total service line connections will be approximately 72. Similarly, for a 1.0m diameter valve system, using 5 pump/valve assemblies, 60 service line connections will be required in total per cell. Therefore, there is concern that, in the current pumping scheme, the routing of this many lines could potentially obstruct access for remote handling equipment. Fewer pump/valve assemblies would help to minimize the problem and simplify handling operations.

From the foregoing, the number of pump/valve connections must be minimized in order to: reduce the number of make/break connections, avoid obstructing access to the equipment requiring replacement, and to minimize the impact on outage times for maintenance operations.

3.5.3 Pump Cell Configuration

Although the pump cell and backing room configuration is conceptual in terms of layout, a number of useful comments can be made which will provide reference information at a later date during the engineering design phase. The following comments focus on cryostat access, mechanical pump room remote handling requirements, and pump cell overhead transporter storage.

Cryostat Access

In the ITER layout drawings, 4 cryostat access ports are shown but only 2 access corridors are indicated. This implies that access to the cryostat is via the pump cells (in two cases). Cryostat access should be independent of the cells to avoid the spread of contamination into the chamber. Concerns are expressed that contamination of the cryostat could impact the cryostat pumping system. The cryostat pumping system is not necessarily designed for remote maintenance.

Another concern is that if there are only two cryostat ports, then the reach requirements of manipulator equipment to access magnet cryogenic connections will be excessive. Four access ports are required as a minimum.

Mechanical Backing Pump Room

In the multiple-TMP pump scheme, the mechanical backing pump room is shown located external to the pump cells. As roughing lines are required connecting the manifold and pumps with this room, contaminated and activated dust from the torus could be transported to the roughing system. Remote maintenance of the mechanical backing pump room may therefore be required.

Overhead Transporter Requirements

Overhead transporter remote handling equipment must service all pump components. Facilities for storage, docking and servicing of this equipment, when not in use, must be provided. In the present pump scheme there appears to be only two zones where this equipment could be stored, that is, over the two cryostat access corridors. There are concerns, therefore, that two transporters may be inadequate to service 96 pump/valve components, and that the travel requirements for the transporter power and control catenaries are excessive. Previous studies show that 4 transporters are needed and that, in this arrangement, the reach requirements of the catenaries is minimised. In the multiple TMP scheme overhead transporters must reach from pump cell T14 to T17; similarly, for cells T13 to T18. This arrangement would require excessive reach requirements for catenaries.

3.6 Summary

The results of the preliminary assessment of the multi-TMP pumping concept are summarized below:

Valve Spacing

- current gate valve centre distance spacing of 1.5m is inadequate for remote maintenance equipment and must be increased;
- based on a centre distance of 1.7m, only 6-0.8m diameter valves can be accommodated in the available cell space, not 8 as shown;
- based on a centre distance of 2.0m, only 5-1.0m diameter valves can be accommodated in the available space.

Valve Seal Maintenance

- there is insufficient space between valves to assemble seal exchange flask equipment in the current pumping scheme;
- valve external bonnet flanges must be extended around their periphery to accept seal exchange flask equipment;
- a total of 192 valve seals will require servicing, based on using 6-0.8m diameter valves per cell and 4 seals per valve.

TMP Servicing

Based on using 6 TMPs/cell:

- 6 TMP exhaust pipes and one collector manifold are required per cell;
- 1 shut-off valve and actuator are required for each TMP exhaust line;
- isolation valves are required in all exhaust lines to isolate the TMPs during removal;
- 96 magnetic bearings and 96 emergency bearings must be maintained.

Pump/Valve Service Connections

Assuming 12 power and service lines connections are used for each pump/valve assembly, then:

- Based on using 6-0.8m diameter valves, a total of 72 power and service lines and their connectors per cell must be routed and maintained remotely. Combining all pump cells, a total of 576 power and service lines must be routed from the cells.
- Based on a 1.0m diameter valve, 60 service lines and their connectors must be routed per pump cell, to give a total of 480 power and service lines to be routed from the cells.

Pump Cell Configuration

In the current pumping scheme:

- 2 access ports to the cryostat are shown;
- pump cell grouping implies that if there are any leaks particulate could spread over 3 cells;
- remote maintenance of the mechanical backing pump room will be required because of the potential for contamination spread in this room;
- there is inadequate storage space for remote handling equipment;
- travel requirements for remote handling equipment catenaries is excessive.

3.7 Conclusions

From the foregoing work it is concluded that the current pump/valve assembly spacing is excessively restrictive for remote handling equipment. Preliminary investigations show that there is insufficient space to assemble flask equipment for seal exchange operations, or to access valve flange bolts by overhead manipulator.

To provide increased access for maintenance fewer valves must be used. Fewer valves will increase conductance losses and adversely affect the pumping performance. To some extent this can be offset by using larger valves. However, an increase in the valve size implies the use of larger TMPs. TMPs in excess of 0.5m diameter (5000 l/sec) are not commercially available.

The routing of power and service lines to the pump/valve assemblies is of major concern. In the case of the 0.8m diameter valves there will be 72 lines per cell. A total of 576 power and service lines and their connectors must be maintained remotely for the complete pumping system. It is concluded that the number of connections to be maintained remotely is excessive, and that fewer (and larger) pumps should be used, thus minimising the number of connectors.

Similarly, in the case of 1.0m diameter valves, although there is a reduction of 96 lines for the larger valve, a total of 480 power and service connections will be required to be maintained remotely for the complete system. From a remote maintenance standpoint this number of pump/valve assemblies is still excessive and means must be found to reduce the number of connections.

In the current concept there is insufficient space in the cells for the storage and servicing of remote handling equipment. In addition, travel requirements for overhead transporter catenaries is excessive.

3.8 Recommendations

The following recommendations are made to improve remote maintenance aspects of the proposed multiple turbomolecular pump scheme:

- re-evaluate the pumping scheme to minimise the number of pump/valve assemblies;
- ensure adequate spacing between adjacent valves for remote handling equipment;
- minimize the number of power and control cables per valve assembly;
- provide more space in the cells for storage and servicing of remote handling equipment;
- reduce travel requirements for power and service catenaries;
- provide valving on TMPs to contain the spread of contamination during replacement operations.

The pump/valve arrangement as shown provides insufficient space for handling equipment. The multi-TMP scheme must be reviewed to assess the feasibility of using fewer valve/pump assemblies.

FIGURES

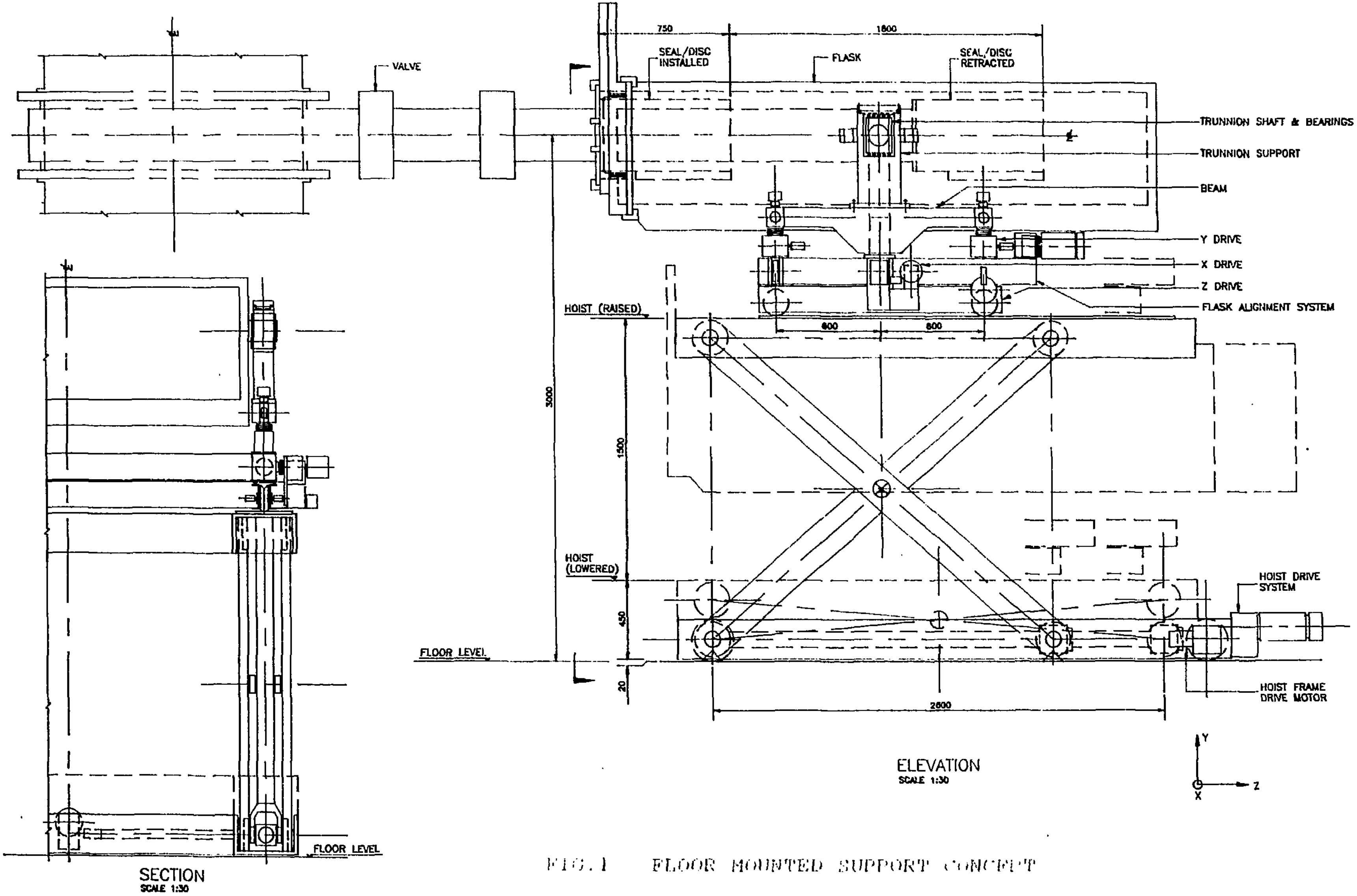


FIG. 1 FLOOR MOUNTED SUPPORT CONCEPT

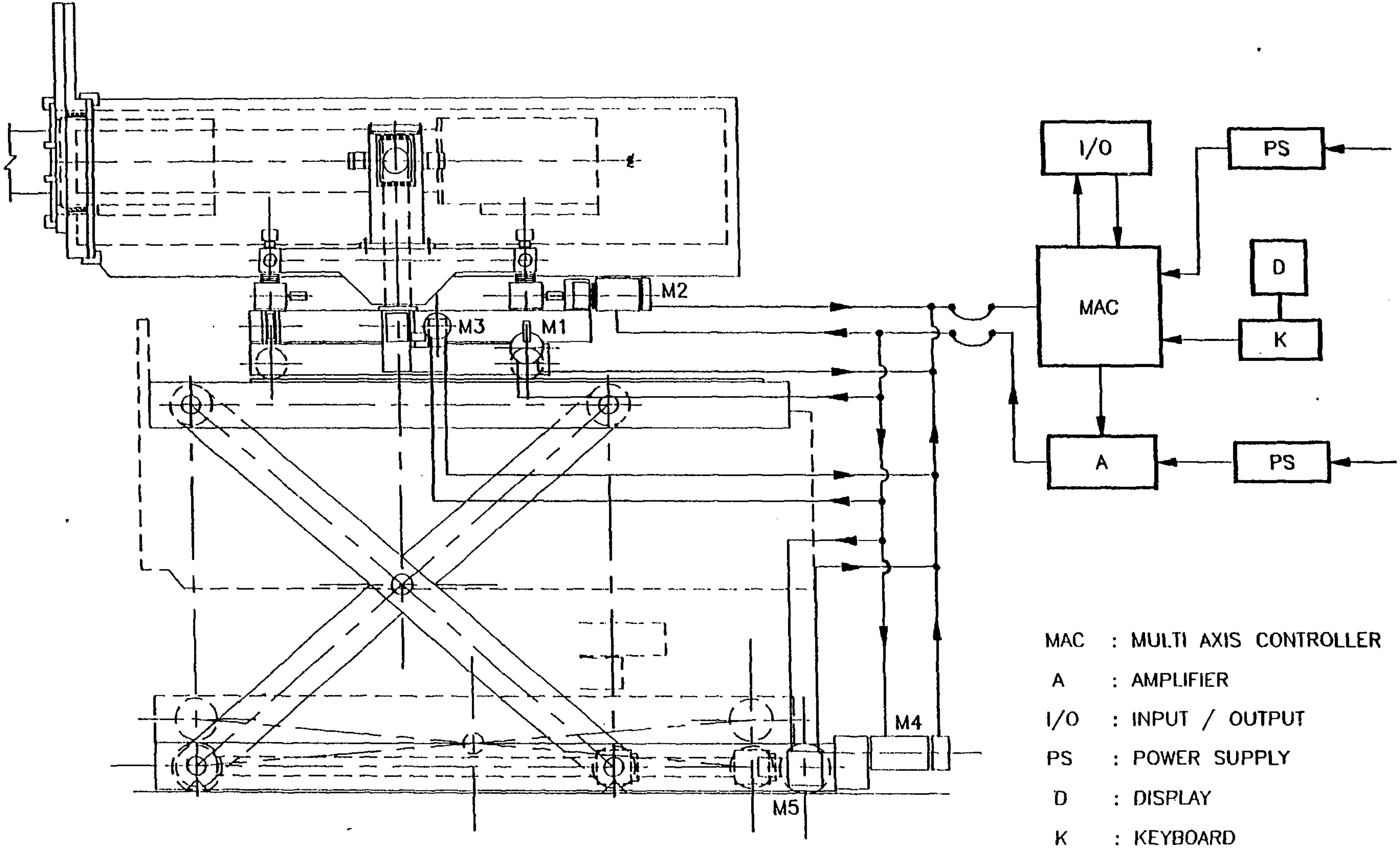


FIG.2 ALIGNMENT AND CONTROL CONCEPT

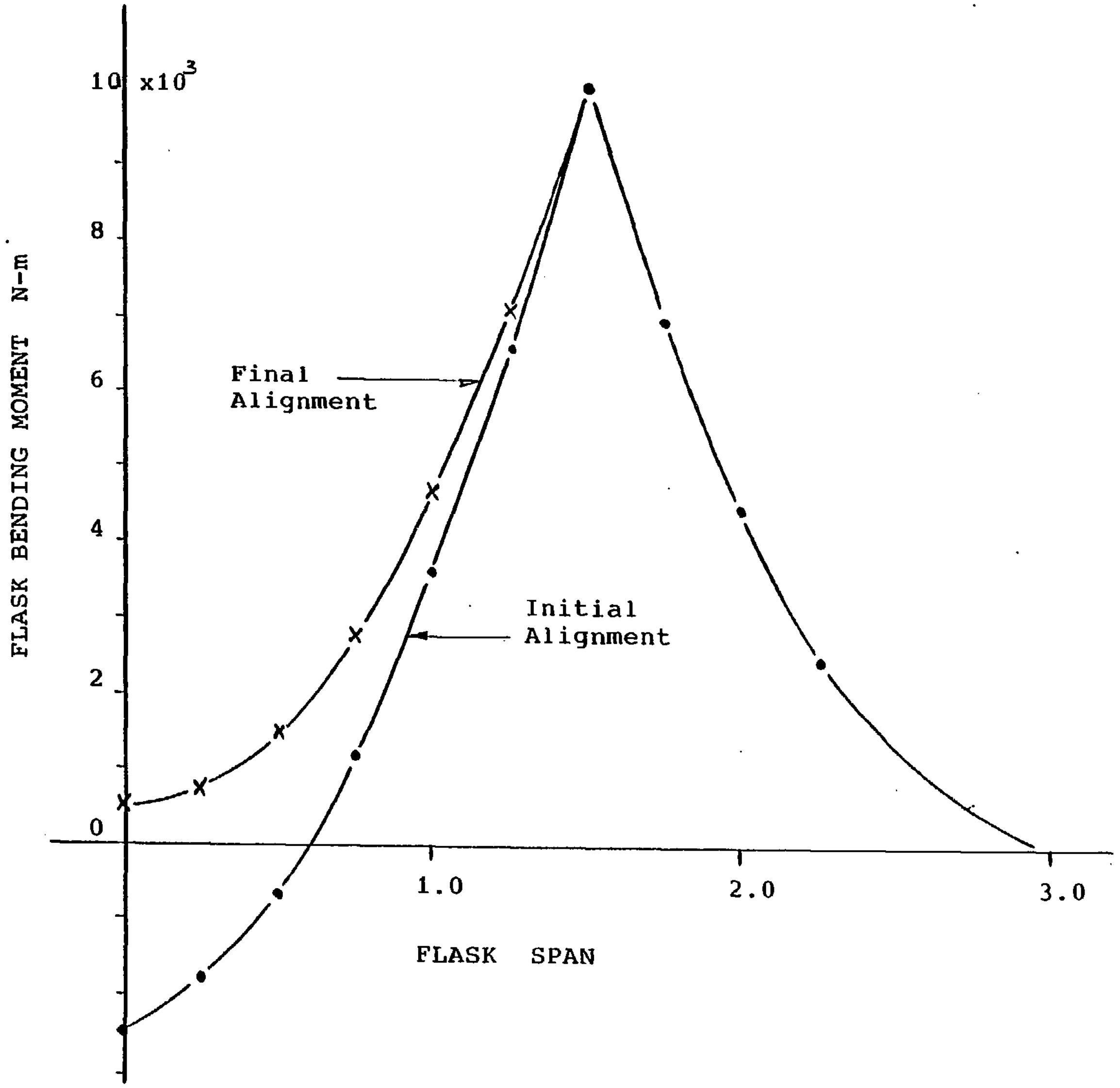


FIG.3 FLASK BENDING DIAGRAM

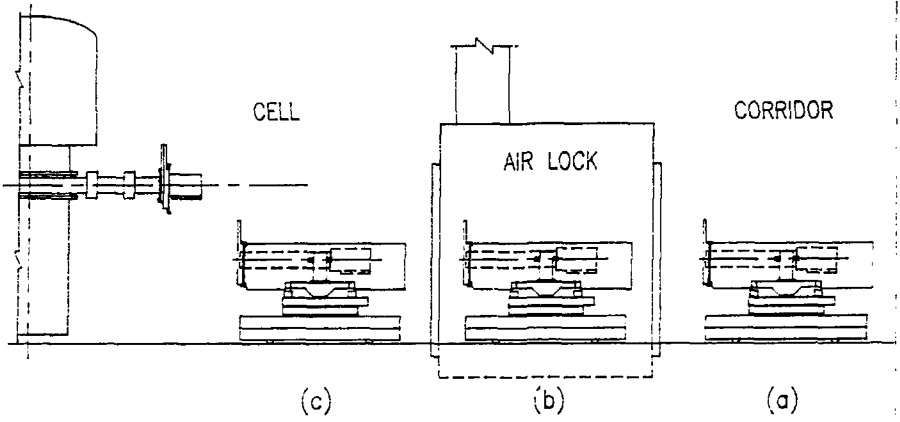
PREPARATORY WORK

1 INSTALL FLASK (WITH NEW SEAL/DISC) IN PUMP CELL

a) INSTALL FLASK/HOIST ASSEMBLY IN TRANSFER CORRIDOR

b) TRANSFER TO AIR LOCK

c) TRANSFER TO PUMP CELL



2 TEMPORARY STORAGE OF FLASK IN CELL

a) ATTACH LIFTING BEAM USING OVERHEAD TRANSPORTER

b) STORE IN LAYDOWN AREA

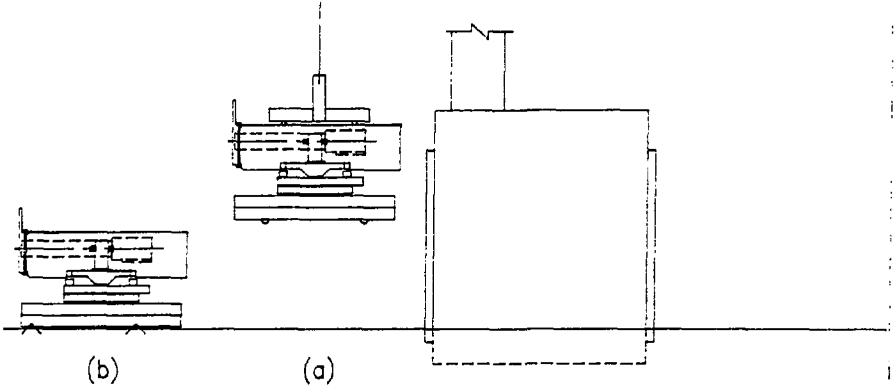


FIG.4a FLASK HANDLING PROCEDURES

OLD SEAL REMOVAL

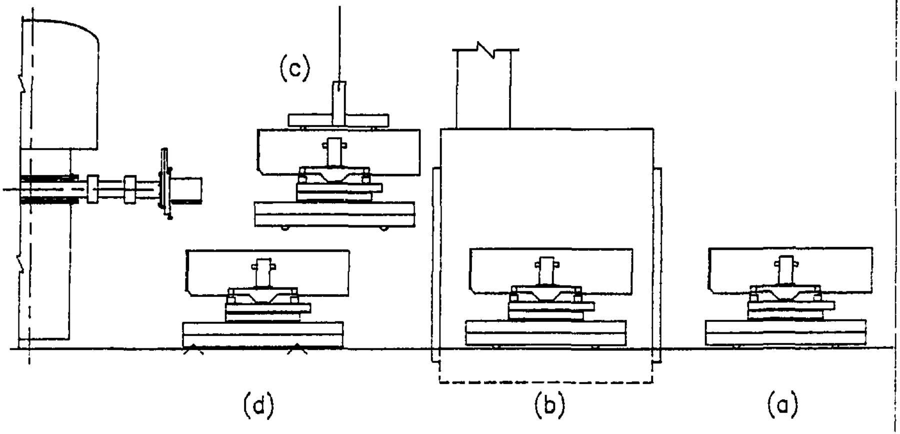
3 EMPTY FLASK INSTALLATION IN CELL

a) ASSEMBLE EMPTY FLASK/ HOIST IN TRANSFER CORRIDOR

b) TRANSFER TO AIR LOCK

c) TRANSFER TO CELL/ ATTACH LIFTING BEAM

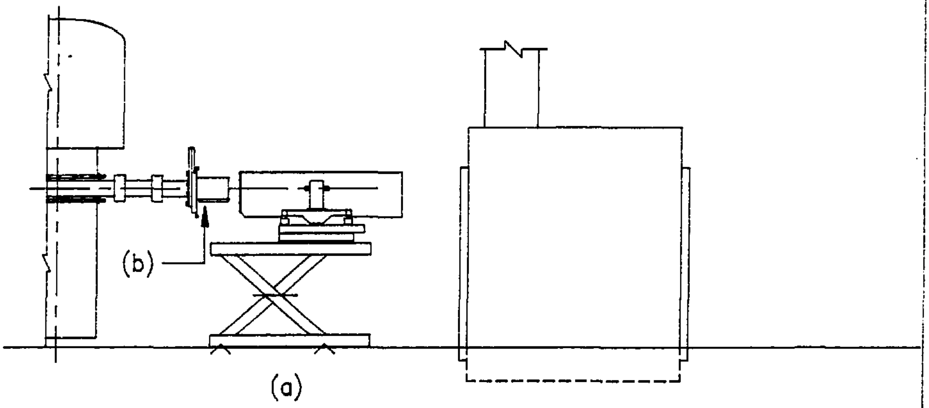
d) MOUNT OPPOSITE VALVE



4 EMPTY FLASK ALIGNMENT OPPOSITE VALVE

a) RAISE HOIST & FLASK

b) ALIGN FLASK ON VALVE /CLAMP



5 OLD SEAL/DISC REMOVAL

a) UNBOLT FLANGE

b) WITHDRAW VALVE INTERNALS (SEAL/DISC) INTO FLASK

c) CLOSE DOUBLE DOORS /UNLOCK

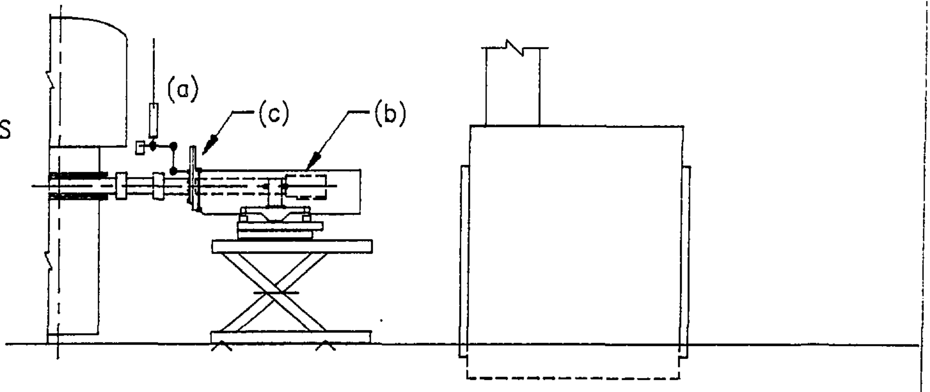
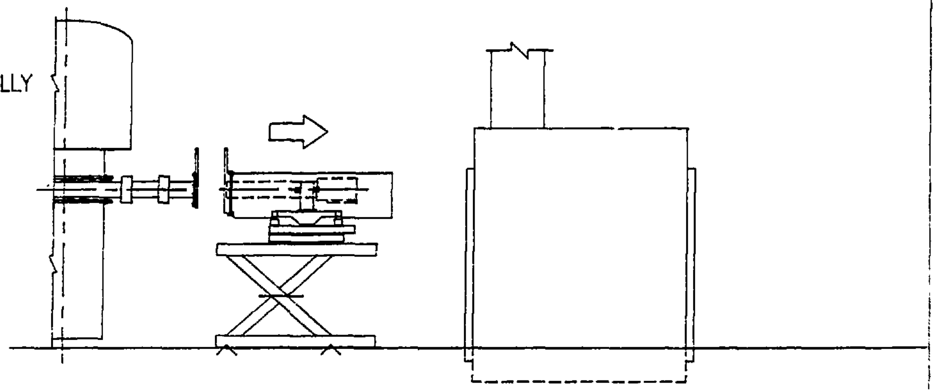


FIG.4b FLASK HANDLING PROCEDURES

6 FLASK WITHDRAWAL FROM VALVE

* RETRACT FLASK HORIZONTALLY



7 FLASK REMOVAL FROM CELL

a) LOWER HOIST

b) ATTACH LIFTING BEAM,
MOVE ASSEMBLY OPPOSITE
AIR LOCK

c) TRANSFER THROUGH A/L

d) TRANSFER TO CORRIDOR

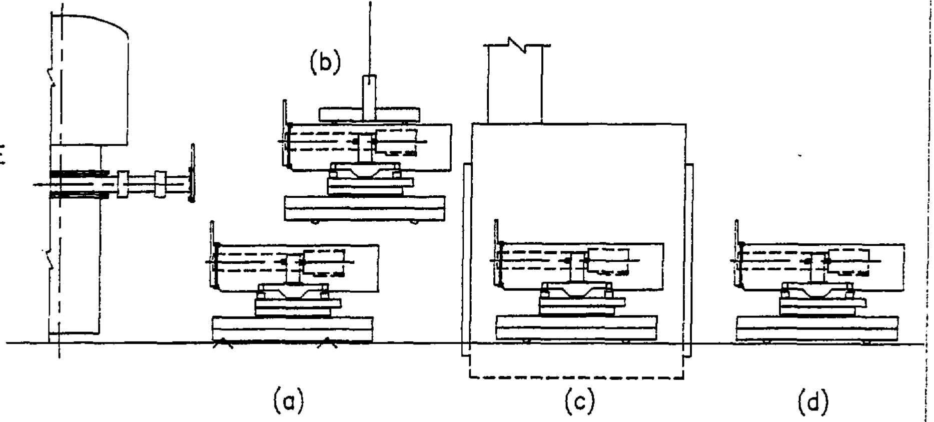


FIG.4c FLASK HANDLING PROCEDURES

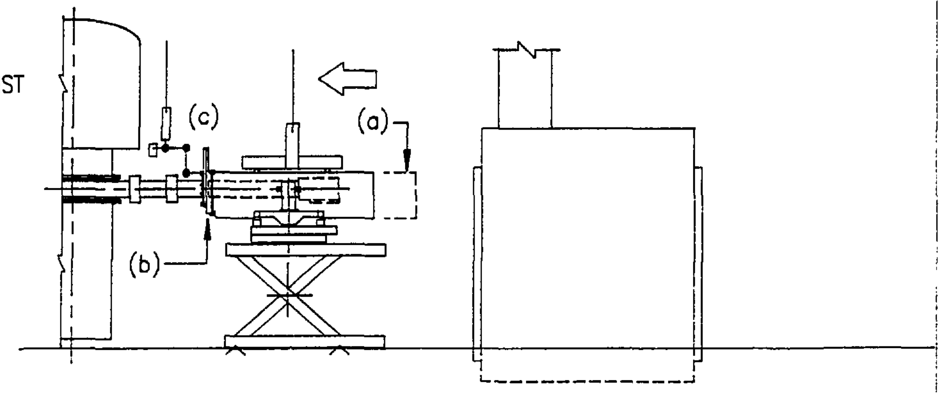
NEW SEAL INSTALLATION

8 NEW SEAL/DISC INSTALLATION

a) MOVE STORED FLASK/HOIST ASSEMBLY OPPOSITE VALVE, RAISE HOIST

b) ALIGN FLASK WITH VALVE /CLAMP

c) OPEN DOUBLE DOORS
- INSTALL SEAL/DISC IN VALVE
- BOLT FLANGE
- CHECK



9 FLASK WITHDRAWAL

- UNCLAMP FLASK LATCHES
- WITHDRAW FLASK HORIZONTALLY ON HOIST

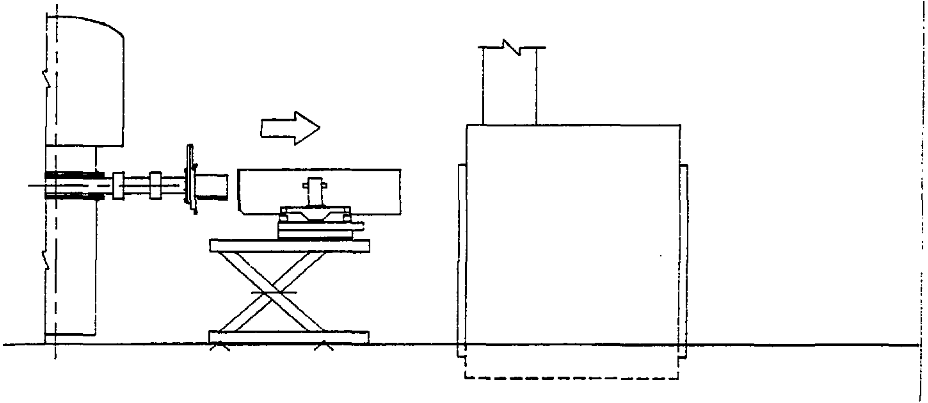
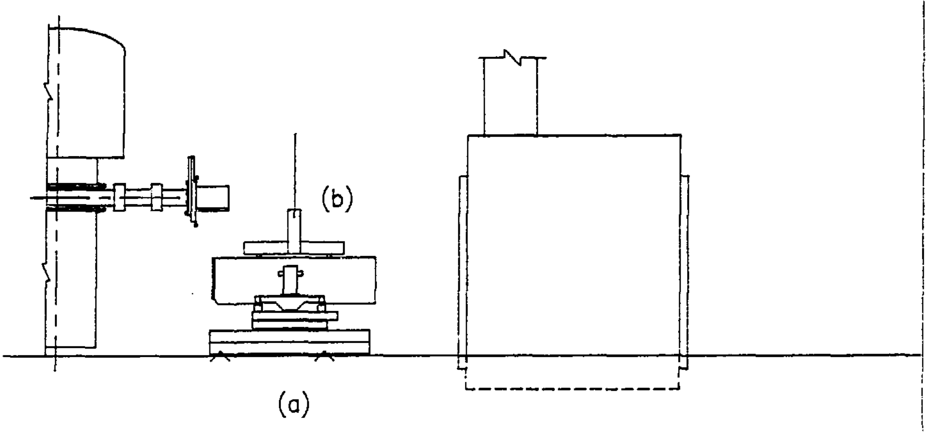


FIG.4d FLASK HANDLING PROCEDURES

10 LOWER FLASK

a) LOWER HOIST/FLASK

b) DEPLOY LIFTING BEAM ON FLASK



11 FLASK REMOVAL FROM CELL

a) MOVE ASSEMBLY OPPOSITE AIR LOCK

b) TRANSFER THROUGH A/L

c) TRANSFER TO CORRIDOR

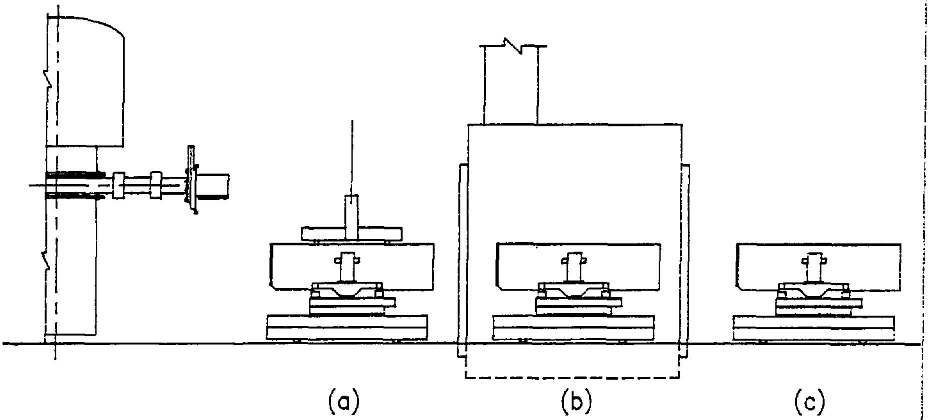


FIG.4e FLASK HANDLING PROCEDURES

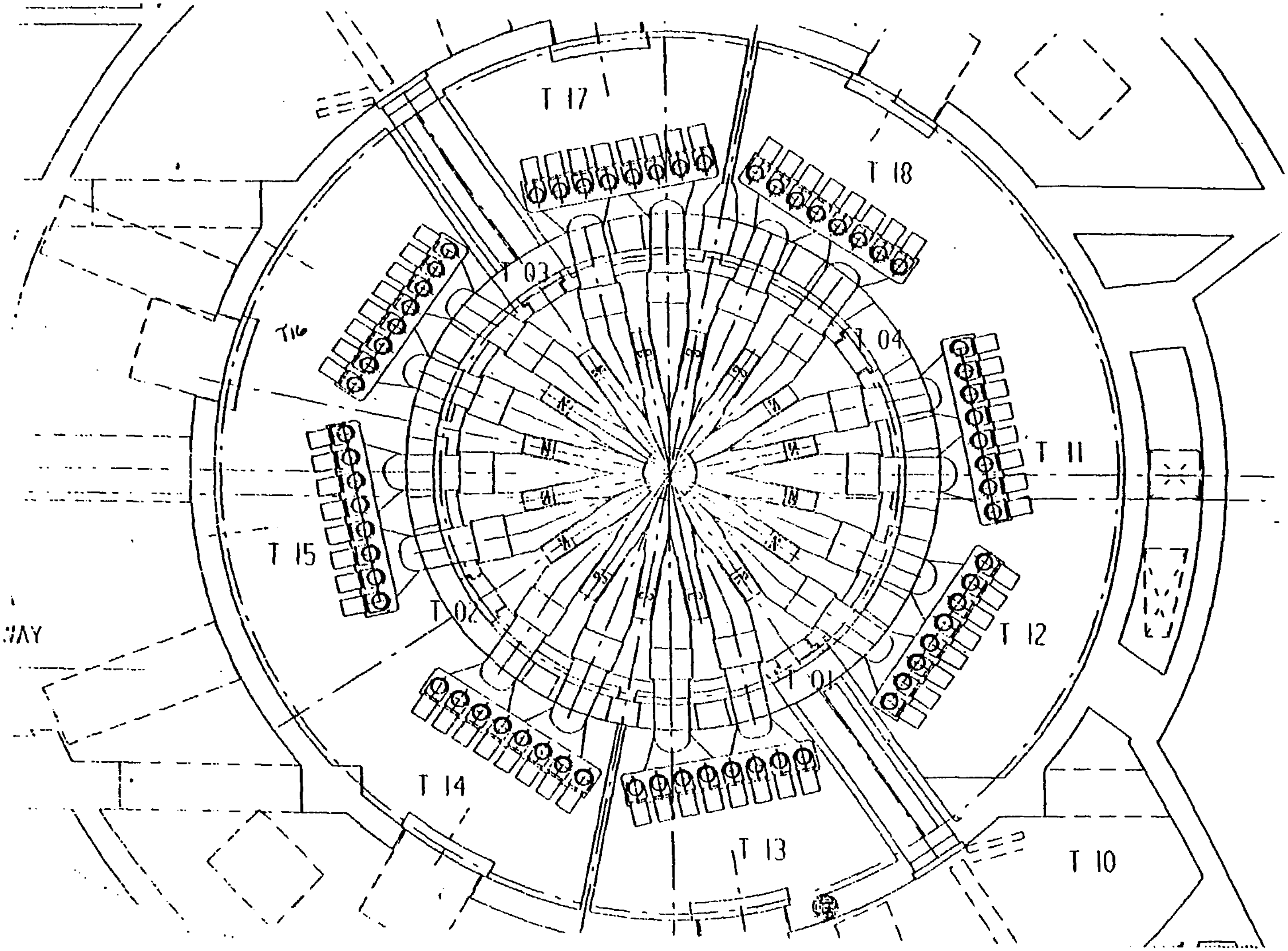


FIG.5 PUMP CELLS (PLAN)

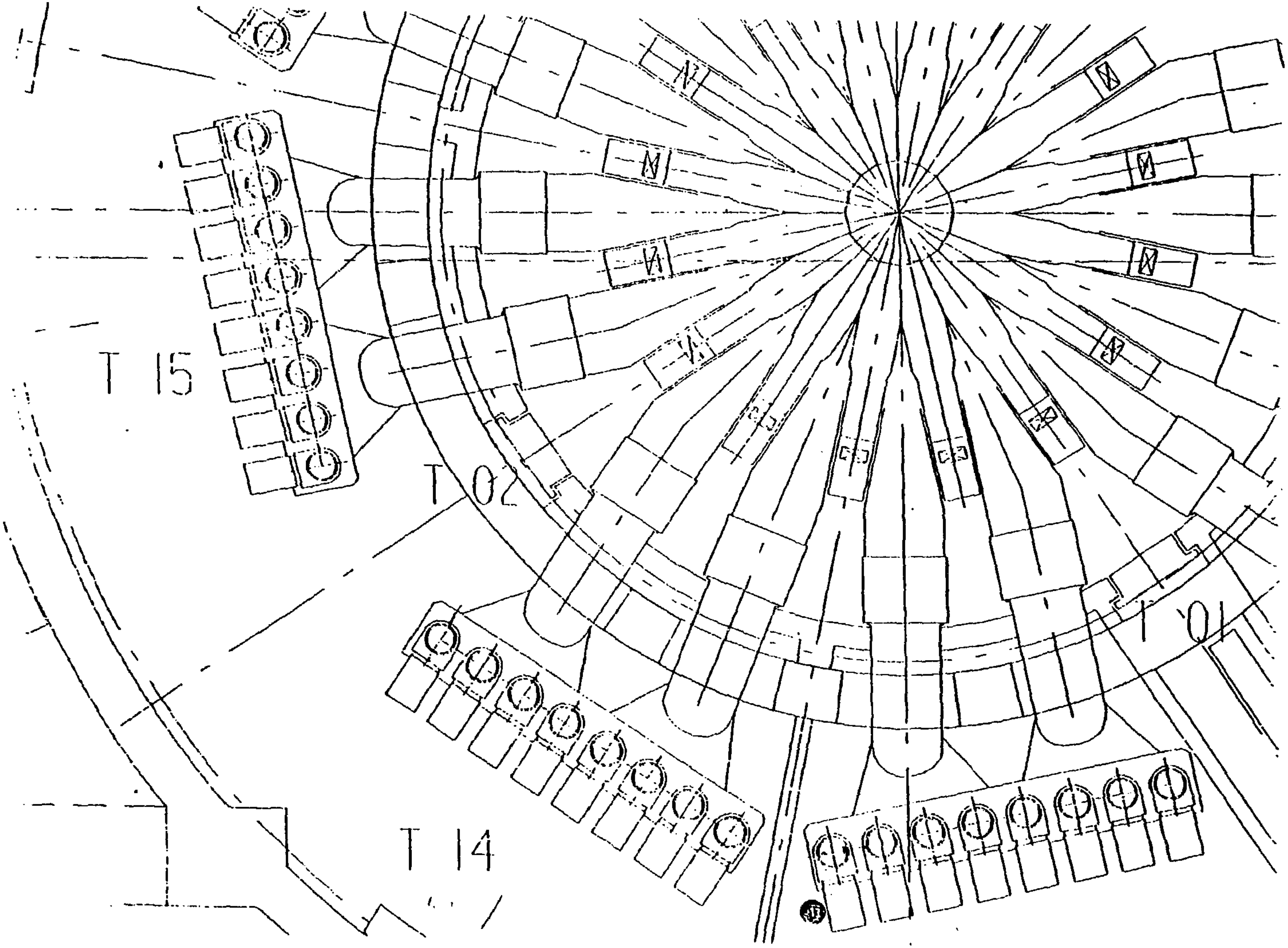


FIG.6 PUMP CELLS PLAN (ENLARGED)

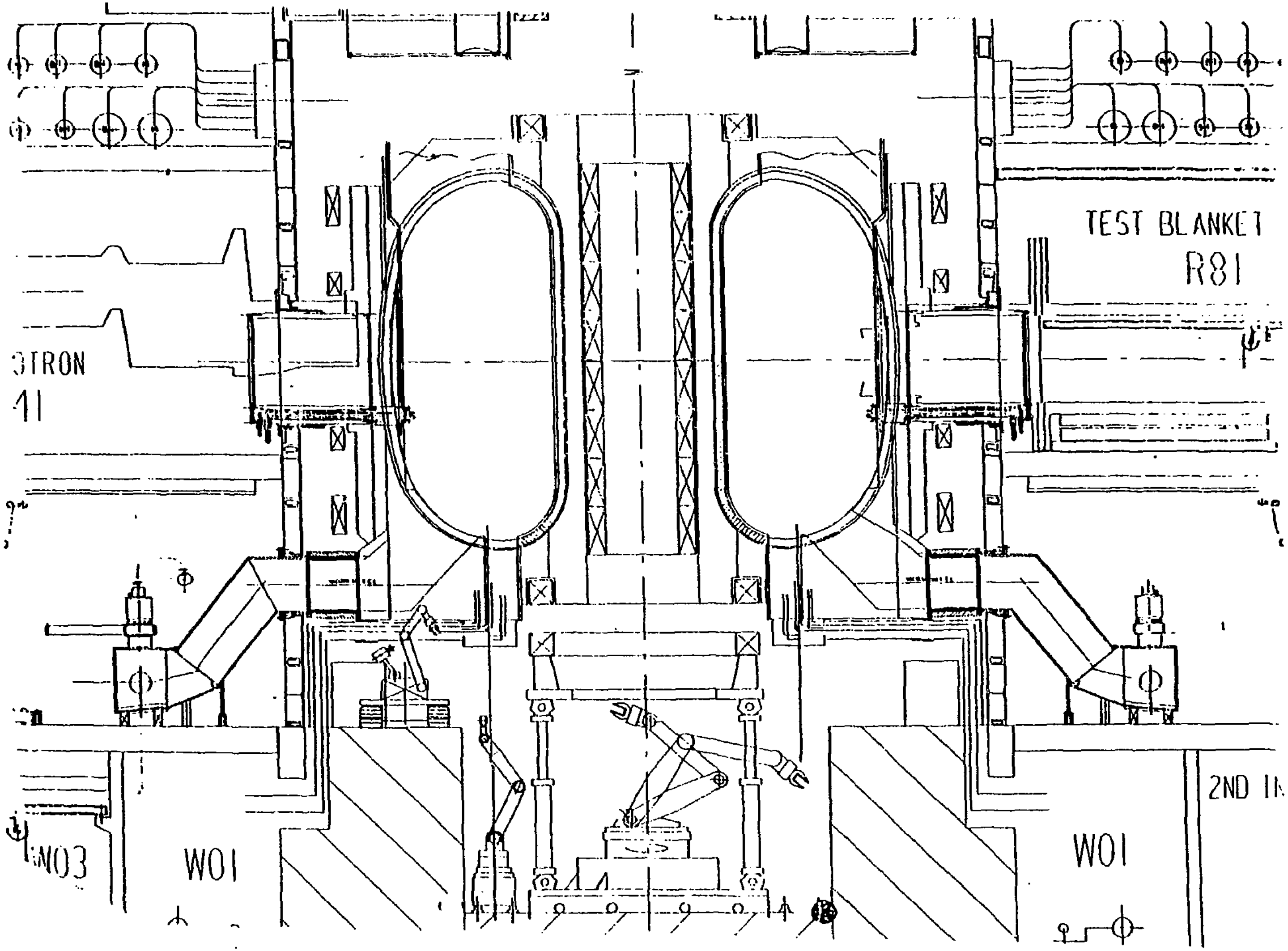
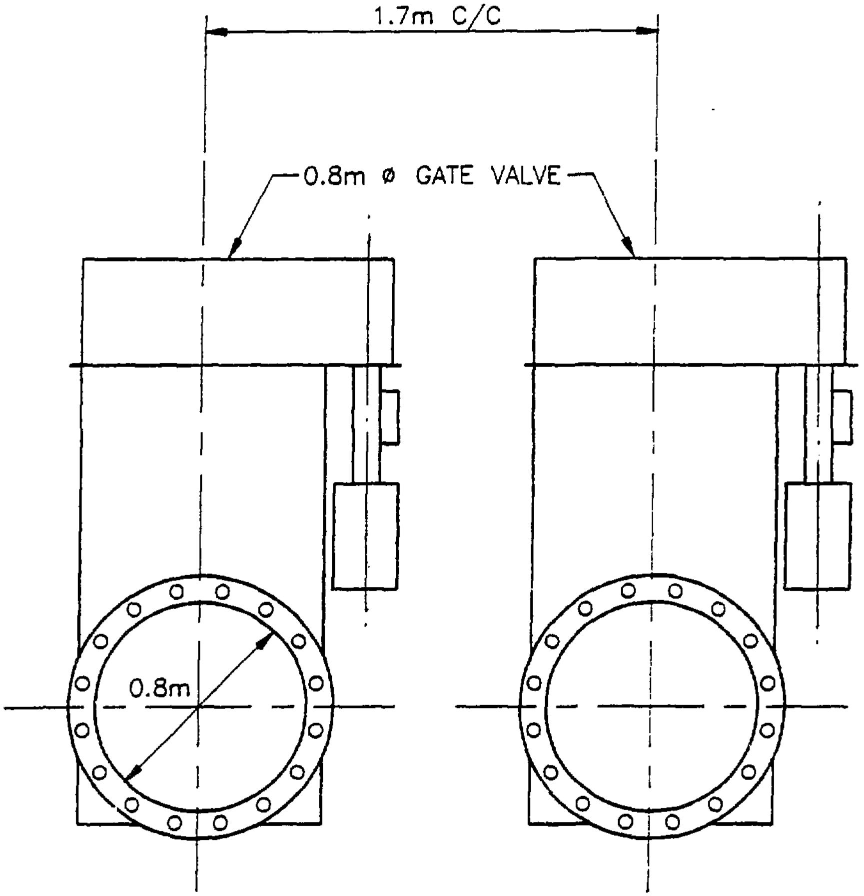
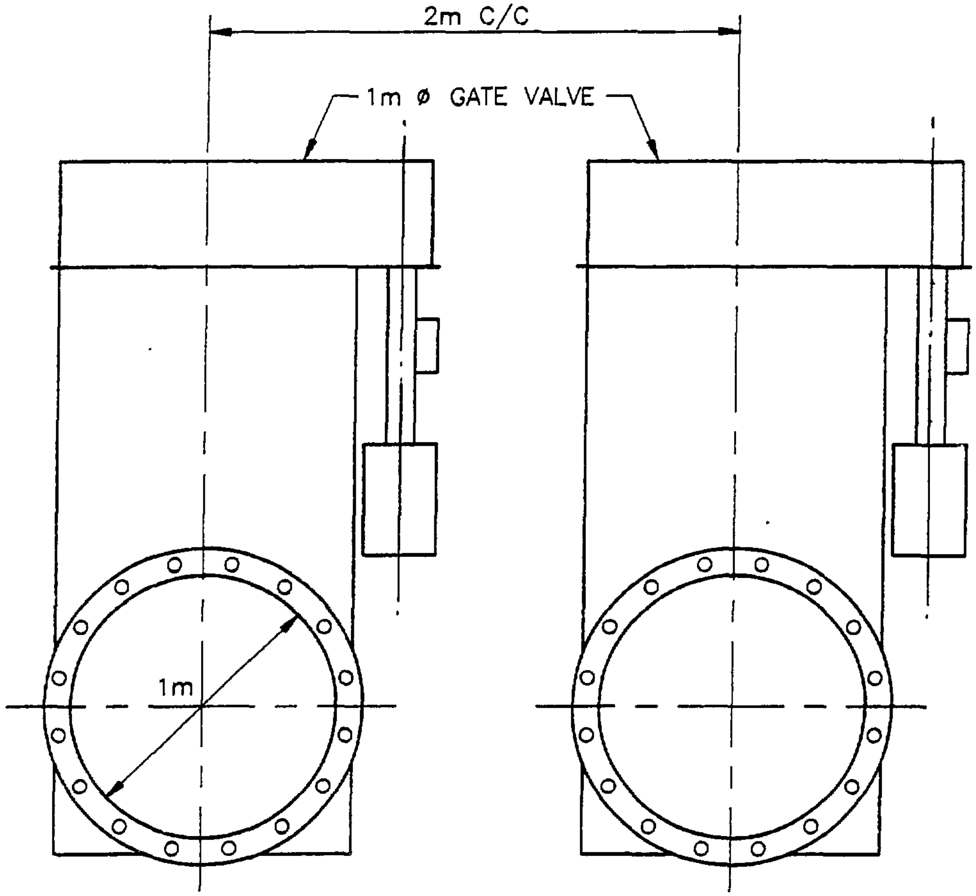


FIG.7 MACHINE ELEVATION (SECTION)



SCALE 1:25

FIG. [illegible] 0.8 m VALVE SPACING



SCALE 1:25

FIG.3 1.0 m VALVE SPACING