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ITER - TORUS VACUUM PUMPING REMOTE HANDLING ISSUES PHASE 3

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REFERENCES

1. Alsthom-Velan Drawings — No. 3866.7/1500; No. 9104.SET01/1500/E

2. ITER-TVPS Pump Cell Layout — RP 3711-2 Rev A01; KB 3711-01 Rev A01

3. Wardrop Engineering Inc., ITER-TVPS RH Critical Design Issues, CFFTP Report No. G-9061 — No. 90/8004/05/00; October 1990

4. Valve Sketch: GNB Corporation, Haywood, California — February 1991

SUMMARY

This report describes further critical design issues concerning remote maintenance of the ITER Torus Vacuum Pumping System (TVPS). The key issues under investigation are the valve seal exchange concept under inert gas and an alternative on-line vacuum option; flask handling support methods; flask handling/pump cell access interfacing and valve seal inspection feasibility.

The horizontal exchange of a 1.5m regeneration isolation gate valve moving parts (seals/disc), weighing 4.8 tonnes, in an inert gas atmosphere, appears technically feasible, However, it is recommended that other commercially available valves which are lighter and narrower in width, be examined which would help to reduce the overall size of the flask and simplify the maintenance tasks. A variant of this scheme also appears feasible where the seals are replaced while the torus is under vacuum, using 2 slit valves within the body of the main valve. The advantages of this alternative approach are: reduced cost and minimized remote handling requirements as no flask is required. Potentially there is increased plant availability.

Remote handling of the flask (and valve moving parts) by overhead support methods is studied analytically. The forces and moments acting on the flask and resulting deflections during seal exchange operations show that a more rigid support of the flask is required than can be supplied by use of a crane. An alternative floor mounted support method is proposed. In this concept, the overhead transporter and telescopic arm equipment are used in the handling operation, but not during the actual seal exchange procedure.

Pump cell access is developed from the standpoint of the handling and transfer of a seal exchange flasks as well as other pump room components.

A tool for in-situ inspection of the regeneration-isolation valve seats appears feasible. The concept could be developed for vacuum use as well as for in-situ repair of the seats.

1.0 INTRODUCTION

Wardrop Engineering Inc. has prepared this report for Canadian Fusion Fuels Technology Project (CFFTP). Further critical design issues are studied which have an impact on the torus vacuum pumping system (TVPS). This is a continuation of the ITER Torus Vacuum Pumping System previous (TVPS) design studies (CFFTP No. G-9053) focusing on seal replacement, component inspection and transport. A review of Valve seal replacement in inert gas and in vacuum conditions and valve seat inspection are studied. In addition, issues associated with flask handling and component transportation across a containment boundary are considered as an engineered system and from a remote maintenance standpoint.

2.0 VALVE SEAL REPLACEMENT CONCEPT - INERT GAS OPERATION

2.1 Scope of Investigation

There is a need to replace seals used in large 1.5m diameter regeneration-isolation valves on a frequent basis. Valve seals are degraded by contaminated and activated dust from the first wall. Neutron scattering in the duct and gamma irradiation resulting from activated components will also effect seal life and replacement frequency.

Valve seals and internal working parts requiring periodic maintenance must be capable of being replaced remotely. A flask is proposed for this operation supported by either overhead or floor mounted means. The flask must incorporate some form of contamination control to prevent the spread of contaminants into the pump cell and other parts of the facility, during seal replacement operations. The seal exchange concept identified here is based on the current plasma chamber vacuum pumping system layout (bottom entry pump with a horizontally oriented valve). A horizontal valve arrangement, results in a more complex seal exchange operation than would be encountered with vertically mounted valves.

A valve design, currently under development by Alsthom-Velan[1], has been used as the basis for conceptualizing the seal replacement with flask concept.

This concept includes preliminary sizing of the flask, definition of valve/flask interface requirements and a brief outline of seal exchange procedures. Flask size, weight and stiffness, are required to evaluate flask handling options.

The reference ITER duty cyclo is 2 weeks operation followed by a 5-week shutdown period. The assumption made in this study is that seal replacement operations will be made during the scheduled outage period, as required. In-situ replacement of valve seal components is not considered in this report. All seal replacement operations will be carried out remotely. Seal replacement will take place in an inert gas atmosphere when the torus is vented at atmospheric pressure.

2.2 Design Requirements

Design requirements used in the flask study are as follows:

- The replacement of elastomer seals on the valve disc must be carried out without taking the valve body out of the line.

- Removal of the valve actuator, stem and disc from the body of the valve must be a simple operation based on the linear withdrawal of these components as one assembly and on dismantling the minimum number of joints.

- The design of flask components should provide for handling by crane mounted electric master-slave manipulator equipment.

- Seal exchange operations are to take place in an inert gas atmosphere when the machine is shut down.

- Remote handling concepts must include some form of contamination control.

- Downtime for any maintenance operation must not exceed 150 hours.

2.3 Flask General Description

A flask concept for seal exchange operations is outlined below. The flask facilitates removal/installation of valve internals (bonnet, seal and disc) while providing containment of particulates during seal replacement.

Two flasks are proposed for this operation. One flask is used for seal removal while a second flask is used for installation of new seals when the old seal has been removed. By this means the time to replace valve internals is reduced.

The flask concept is based on the following valve parameters (Fig. 1):

Valve diameter	1.5 m
Valve length (from centreline)	3.2 m (closed)
Distance to the valve flange	2.1 m
Valve moving parts weight	4.8 tonnes

The flask concept proposed for seal replacement (Fig. 2) is composed of the following components: flask outer container and strongback, double door closure system, latching mechanism, retract drive mechanism, roller support beam and jack, latches and guide pins. The function and operation of these components is described in further detail in Section 2.6.

The flask weight is approximately 2.5 tonnes with overall dimensions: 3.35 m(long) x 2.85 m(wide) x 1.25 m(deep).

2.4 Flask Space Requirements

The flask, when mounted on the valve, will extend approximately 5.45 m from the pump centreline into the cell (Fig. 3). During initial installation on the valve, with the valve fully extended (3.77 m), the flask will extend 7.12 m into the cell (without clearance) and 7.20 m (with clearance) leaving a wall clearance of approximately 0.6 m. This is based on the current ITER pump cell arrangement[2]. The outer cell wall is assumed to be located 14.8 m from the cryostat wall.

Therefore, for this particular valve/flask combination, there is adequate wall clearance for seal replacement operations in the pump cells.

2.5 Flask Control

The flask can be designed for either remote or local control:

In the remote control configuration all flask drives are motor operated with the aid of positional readouts. Power is supplied to these drives by an umbilical, the weight of which exerts additional forces on the flask. In addition, there is a need for an auxiliary cable car which is connected via feedthroughs to the plant power supply and control cabling.

In the case of a locally controlled system the flask drives are tool driven with the tools being operated via overhead manipulators and end effectors, thus reducing the need for motor power supply cables. The overhead manipulators have their own control cabling, independent of the flask.

The issue of the type of control system or control philosophy needs to be reviewed against system requirement, once they are established.

2.6 Flask Detail Design

As noted in Section 2.3 the flask assembly consists of roller supports, retract drive, latching mechanism, double door sealing assembly and the flask cover. The arrangement of these components is shown in Fig. 4. The figure shows the flask mounted over the valve bonnet and attached to the valve body. Flask components are described in further detail below.

Roller Support System

Two roller support beams are required to support the weight of the valve moving parts. Each beam, consisting of two 100 mm x 32 mm steel bars, with rollers mounted between the bars. Each beam is supported on the flask interior by a pinned connection at the outboard end and by a jack at the inboard end. The jacks are mounted to the strongback at the bottom of the flask. They are connected to the roller support beams through sealed openings in the bottom of the flask.

The roller support beams were analyzed for three load cases (Fig. 5). The worst case is when the moving parts are completely (Case 3) withdrawn. Bending stresses and deflections in the beams are 122N/mm^2 and 1.5mm respectively.

Retract Drive Mechanism

The retract drive mechanism, consisting of a lead screw driven motor, pulls the valve moving parts, by means of the carriage assembly mounted by rollers on a linear track, to the storage location in the flask. The stroke of the 40mm diameter x 6mm pitch screw is approximately 1.55 m, which is the travel of the carriage assembly required to pull the valve moving parts completely free of the valve body. This stroke is detected by the size of the valve. Speed reduction from the motor to the screw is via a 75/1 gear reducer.

The motor is mounted to the strongback, external to the flask for access purposes, and connected, via a sealed opening in the flask, to the gear reducer. The drive system is designed for two operating modes:

Case 1: Initial bonnet release (high force, low speed).
Case 2: Bonnet withdrawal into the flask (low force, fast retract speed).

The operating power in each case is 0.3 and 0.2 horsepower respectively. In Case 1, the retract force is high (4000 N) as it will be necessary to pull the bonnet flange free of the guide pins (sliding friction and stiction assumed). In Case 2, once the flange is free of the guide pins, the retract force is low (900 N) so that the retract speed can be higher (25 mm/sec).

Latch Mechanism

The latch mechanism (Fig. 6) consists of two hinged fingers spring loaded to the open position, and mounted on the carriage assembly. A locking sleeve, driven by a screw, mounted on the carriage assembly, is used to lock the fingers in the closed position over the bonnet handle attachment during the latching operation. The screw is driven by a motorized gear reducer mounted on the outer end of carriage assembly. The latch is capable of exerting a force of 4000 N to overcome stiction during initial separation of the valve bonnet from the valve casing.

Double Door System

The front, or open end of the flask, consists of a double door system for contamination control by isolating the vacuum system from the cell. Its function is to isolate and seal the valve and flask after the valve internals have been transferred to the flask, thus minimising contamination spread.

Initially, both doors are locked together to become one door and are mounted integral with the valve flange by clamps. Operation sequence of the double door system is shown for three stages of operation (Fig. 7).

The flexible boot is an integral part of the double door system. It is attached to the outer door (flask) and the exterior of the bonnet flange. The boot has sufficient flexibility to permit removal of the bonnet and seal/disc (1).

During seal/disc removal operations the flask chamber is clamped to the double door flange (2), the valve internals withdrawn into the flask and the double doors closed. The doors are then unlocked and the flask removed (3).

The nominal flask door opening is .86 m x 2.6 m (Fig. 8). The door opening is sized to allow removal of the valve moving parts. The door is raised and lowered by a chain, the input drive being operated by the overhead manipulator. The approximate weight of the door assembly is 620 kg, each door weighing approximately 100 kg.

Flask Chamber

The flask chamber is made out of 6mm sheet steel and suitably ribbed for stiffness, and is equipped on the bottom edge with a skid or strongback running the full length of the flask. The purpose of this is to resist bending loads during handling and transportation. During handling all weights are transferred via the skid to underneath or overhead lifting beam attachment points for transportation.

Bending stresses in the skid beams are at a maximum during removal of the valve internals and are approximately 29 N/mm^2. Initial sizing of the skid appears adequate in bending when supported on 1.85 m centres.

2.7 Seal Exchange Operation

Seal exchange operations are described below and illustrated in Figs. 9 and 10. The remote handling exchange scheme is based on the assumption that a malfunctioning seal, disc and stem can be withdrawn from its operating position (valve closed) to its stored position (valve open) prior to removal from the valve body, by means of a valve 'backup' drive (redundant system).

A simplified removal procedure (Fig. 9) is outlined as follows:

- Retract the valve moving parts into the valve open position using the valve actuator or backup drive.
- Align the flask (by overhead manipulator video system) and attach to the valve outer flange.
- Undo the valve bonnet flange bolts (by overhead manipulator).
- Retract the valve bonnet and internals into the flask.
- Close the double door system, check for leaks and decouple the doors.
- Remove the flask (one door remains with the valve).

For seal installation these procedures are reversed (Fig. 10). The flask concept is designed for either crane or floor mounted support methods. At this point a preference has not emerged and further studies to compare the features of each are indicated.

2.8 Valve/Flask Interface Requirements

To ensure the feasibility of the flask concept, the following valve/flask interface requirements, shown incorporated in the valve design (Fig. 1), are listed as follows:

a) Current internal guides design needs to be split to permit removal of the valve internals;

b) Part of the internal guides must be integral with the valve bonnet to permit removal of the valve internals;

c) Flange bolting must be installed from the inboard side of the valve and be captive in the body of the flange;

d) Internal linear support bearings must be mounted on the flask internal wall to support the guides;

e) A bonnet handle must be mounted on the external surface of the bonnet to facilitate removal of the valve internals;

f) Guides must be provided on the external surface of the bonnet to facilitate removal of the bonnet and internals;

g) Valve flanges must be extended around their periphery to facilitate mounting of the flask on the valve.

2.9 Summary/Conclusions

A flask concept for the horizontal exchange of seals in a large 1.5 m regeneration-isolation valve as outlined in this report is feasible. The flask is designed for seal exchange in an inert gas atmosphere and incorporates a double door system for contamination control purposes. Studies show that there is adequate clearance (0.6 m) in the current ITER pump cell arrangement to assemble the flask over the valve, during handling operations. The flask, weighing approximately 2.5 tonnes (unshielded), is based on valve moving parts of 4.8 tonnes. The approximate overall dimensions of the flask are: 3.25 m (L) x 1.25 m (H) x 3.0 m (W). The feasibility of the scheme is based on a number of remote handling features being incorporated in the valve design (as listed in Paragraph 2.8 of this report).

Basic concerns are that the flask is too wide and too heavy. However, flask proportions are essentially based on the valve design. It is believed that if alternative valve configurations are studied, such as those commercially available worldwide, then the flask parameters (size and weight) could be reduced substantially.

2.10 Recommendations

The impact of remote handling requirements on the design of a large gate valve is considerable. Similarly, the flask design is dependent on the valve configuration. Seal exchange flask concepts should therefore be carried out in parallel with the valve development. Flask design studies show that the design of an regeneration-isolation valve should include, as a minimum remote handling as a basic functional requirement, and remote handling features need to be incorporated in the valve design.

A scaled or full size prototype flask design should be prepared for the long term seal exchange demonstrations, in parallel with the valve design. Preferably, the flask design used for these tests should be based on the smallest and lightest valve commercially available.

3.0 VALVE SEAL EXCHANGE CONCEPT - VACUUM OPTION

3.1 General Overview

Valve seal exchange in vacuum without having to bring the torus up to atmospheric pressure has significant advantages, such as: reduced outage times, increased plant availability and less demand on remote handling to change seals during plant outages. In this concept a flask is not required for seal exchange operations. In earlier studies[3] the feasibility of using rectangular gate valves within the body of the main valve to provide for an on-line and simpler seal exchange method, was examined.

It appeared that to obtain rectangular gate valves (slit valves) of adequate size and a workable flange bolting arrangement was not feasible. However, recent discussions with GNB Corporation of Haywood, California[4], high vacuum specialists, supply large slit valves suitable for a 1.5 m gate valve application. Their comments were solicited on this application and they expressed concern that linear guide tracks within the valve would have to be supplied in two separate lengths to permit withdrawal and removal of the seal/disc between valve compartments. GNB reported that as long as machined ways are used there appears to be no problem in this approach.

The slit valves operate like the double door system described in Section 2.6 and therefore the need for a flask is avoided. Handling space requirements within the cell are reduced because a flask is not required.

The advantage of the use of slit valves is that seals may be exchanged on-line (in vacuum) without having to bring the torus up to atmosphere, followed subsequently by a long pump-down and conditioning period.

3.2 Concept

An arrangement of the concept is shown in Fig. 11. The major components of the valve are:

- inner and outer valve chambers
- 2 slit valves
- valve actuator drive system

The valve actuator can move the seal/disc from the closed position to the retracted (open position). Both slit valves are UHV duty valves. They are open during the main valve cycling (1 per 2 hours). They are closed when the seal is withdrawn into the bonnet and when the bonnet is removed for seal maintenance.

During seal removal (Fig. 12) the seal/disc is retracted to the open position. Following this operation both slit valves are closed, after which, the outer casing or valve bonnet is removed and transported from the cell by overhead or floor mounted remote handling equipment.

A new seal/disc assembly is installed in essentially the same manner, using the procedure in the reverse order.

3.3 Conclusions/Recommendations

The valve assembly concept outlined permits removal of valve disc seals under vacuum conditions. Based on preliminary estimates received, valve costs are not excessive and valve weights are below current European designs. In addition, as a separate seal exchange flask is not required, additional savings are realized both in time to replace seals and in capital equipment required.

Further decontamination studies, as outlined in CFFTP Report No. P-9184, are required to determine the feasibility of purging and decontamination of the space between the slit valves, prior to separation. Vacuum cleaning methods, similar to those proposed for the removal of particulate from the bottom of the cryopump manifold, may be required for the clean-up of this space.

Since slit valves are commercially available in the sizes that are being considered for the regeneration-isolation valve, this valve assembly concept should be explored in more detail in parallel with the development of the regeneration-isolation valve concept. By doing so resources being spent developing a basic valve design in Europe could be directed to taking programs using existing technology.

4.0 FLASK HANDLING SUPPORT METHODS

4.1 Scope of Investigation

There is a need to examine the feasibility of horizontal transfer of valve internal parts during seal exchange operations when supported by overhead means. This section examines the loads and deflections which occur during a seal exchange operation.

During the seal exchange operation the flask is assumed to be clamped to the valve external flange while simultaneously supported by the overhead crane bridge as shown in Fig. 3. The weight of the valve internals (when removed) is therefore shared by the polar crane bridge and the flask clamp attachment. The flask weight is supported by the crane.

One area of concern in the flask handling support system is that the load distribution between the bridge crane and the flask must not result in separation of the valve/flask interface as opening of the flanges could potentially lead to the escape of particulate contaminates in the cell. A second concern is that large valve/flask misalignments could cause jamming of the valve internals during transfer.

4.2 Flask Clamp Forces

Load sharing between the flask and the bridge crane is dictated by the relative stiffness of the bridge crane, the supporting cable and the flask strongback. From these relationships the moment acting on the valve separation flange and the force acting on the clamps are determined. A finite element model of the above structural arrangement is shown in Fig 13.

Imputed data (Fig. 14) shows structural properties, geometry and applied load (valve moving parts weight). From this information the cable load, flask/valve interface bending moment and flask deflections are obtained. The output of the analysis is shown in Fig. 15. These results show that the flask will deflect 3.5 mm relative to the valve body when the valve moving parts are transferred to the flask. The force in the cable is approximately 35000 N and the moment acting on the flask is 13800 N-m, which results in a force of 27600 N acting on the clamps.

As the clamp force is excessive, increasing the stiffness of the crane bridge was examined from the standpoint of reducing this force. This is illustrated by plotting the clamp force for various bridge second moment of area values. These results show that a considerable increase in bridge stiffness is required to produce only minor reductions in clamping forces (Fig. 16).

4.3 Summary

The foregoing work is summarized as follows:

a) The horizontal transfer of 4.8 tonnes of valve moving parts during the seal exchange operation results in forces in the flask clamps of 27600 N.

b) Structural deflections of the flask relative to the valve are approximately 3.5 mm.

c) A 100% increase in the bridge crane stiffness results in only a 20% reduction in the clamp forces.

4.4 Conclusions

During the horizontal transfer of the valve internals, large forces and moments act on the flask clamps, followed by a significant deflection of the flask relative to the valve. The resulting misalignment of the flask has the potential to cause binding of the valve moving parts during the transfer operation. A large increase in the bridge stiffness does not produce a significant reduction in the clamp forces. It would appear therefore that much lighter valve moving parts are required, if overhead support methods are to be used for valve seal exchange operations (in a horizontal attitude).

In conclusion, a more rigid base is required to support valve moving parts of the magnitude (4.8 tonnes). Therefore, a floor mounted system is proposed to support, align and mount the flask on the valve. In this concept (Fig. 17) the polar crane is used to position the support equipment and flask on the floor opposite the valve requiring seal replacement. The polar crane is not used during the actual transfer operation.

4.5 Recommendations

Since a rigid support system is required for valve seal exchange operations, it is recommended that the following work be carried out:

- Develop a floor mounted support system for the flask.
- Develop an alignment system integral with the flask support system.
- Develop a procedure for flask handling using the floor mounted concept.

5.0 FLASK HANDLING/PUMP CELL ACCESS

5.1 General

Both during construction and the operational phases of the facility of the pump system, tools and auxiliary support equipment will have to be transported and installed in the cell. In addition, valve seal exchange operations will require power/service lines (catenaries) deployed from cable carts. Tooling and other equipment, used to support cut/weld operations, inspection and testing, must have access to the cell. The effects of remote handling and maintenance requirements on pump cell access must be considered early in the pump cell design. Airlocks are proposed for pump cell access and these are examined from a remote handling standpoint.

The transition from the physics to the technology phase implies a change to fully remote maintenance. Large components, such as pumps, valves and seal exchange flasks, must be transferable to the external corridor, from the pump cells, to a hot shop discharge port for further processing.

During the D-T operations, in the technology phase, the pump components may become contaminated with Tokamak debris. Flasks employing a double door sealing system are used to minimize the spread of contamination during seal exchange operations.

Shielding of the airlock using a shielding door, is required to protect personnel and airlock components from neutron streaming. Shielding doors could weigh as much as 60 tonnes, and their doors, drives and seals, must be integrated into the airlock design to provide for their own maintenance as well as permitting access for remote handling equipment.

The airlock design requirements must include needs dictated by the operational program and be adaptable to the changing operational phases of the machine life.

In summary, airlock concepts must:

- Meet the changing needs of the machine.
- Facilitate transportation of equipment, personnel and tooling in/out of the cell during initial construction.
- Facilitate the transition from the physics to the pre-technology and technology phases.
- Provide a controlled point of entry across the containment boundary.
- Separate/contain hazardous environments during the D-T phase.
- Provide special features (feedthroughs) which assist RH operations.
- Provide dual functions as airlock and gross decontamination chamber.
- Facilitate the adaption of additional contamination control chambers as required.
- Provide supplemental shielding to protect personnel.
- Reduce neutron streaming to minimize component activation.
- Provide for periodic maintenance of the shielding door equipment.
- Provide unobstructed access for the passage of remote handling equipment through the lock.

5.2 Concept

A number of alternative airlock configurations were considered to meet the requirements noted above and are categorized as follows:

a) Concrete
b) Steel

c) Mobile

d) Flexible shroud

e) Combined steel/contamination control chamber.

Of these arrangements, concept (e), a combination of (b) and (c), appears to be the most adaptable for meeting the needs of a remote handling system. This preferred scheme is shown in Fig. 18.

The concept consists of a cylindrical steel airlock mounted so that the airlock is flush with both the cell and the transfer corridor floor levels. A constant floor level is preferred for the unobstructed transfer of equipment. A recess is suggested in the transfer corridor floor, adjacent to each airlock entrance, to provide for a future addition of a mobile contamination control chamber.

In Fig. 18 the transfer sequence of the flask by mobile floor mounted support equipment is depicted. Fig. 18-1 shows the assembly of the flask on the valve, 18-2 shows handling through the airlock, and in 18-3 final transfer to the external transfer corridor is shown. For alignment of the flask with the valve an adjustable height floor mounted support device is required.

Fig. 19 shows a cross section of the airlock. It will be observed that the size of the airlock is dictated by the height and width of the cryopump.

An airlock shielding door external to the pump room is preferred as its location provides more access for periodic maintenance of the door drive system. The current NET drawings locate the door in the cell, on the inboard side of the airlock. The final location of the door will, however, depend on a number of remote handling factors. It is outside the scope of this report to comment on its location as this needs discussion with ITER

Building designers. Either location for the door will not affect the flask transfer operation 3.

The airlock scheme proposed includes provisions for a mobile decontamination chamber, if this should be required during the technology phase. The installation of this chamber is made possible by incorporating an adjustable platform located in the floor recess.

5.3 Conclusions/Recommendations

The proposed airlock concept outlined above complies with most of the requirements outlined in this report and facilitates the ease of transfer of remote handling equipment in and out of the cell. The scheme presented here is an alternative option to the current ITER pump cell airlock reference configuration, and should be reviewed by ITER Configuration people.

The current shielding door location, in the NET baseline scheme, needs to be discussed with ITER Configuration people as its present location could impact maintenance requirements of the doors themselves.

6.0 VALVE SEAT INSPECTION

6.1 Discussion

There is a need to inspect seal seating surfaces for damage in the large 1.5 m regeneration-isolation valves. These surfaces must be capable of being inspected, repaired or refurbished in-situ without having to remove the valve from the line. The feasibility of in-situ inspection of the seating surfaces by remote means is discussed below.

It is assumed that inspection will take place in an inert gas atmosphere when the machine is shut down.

The seal/disc must be withdrawn into the 'open' position in order to provide sufficient space within the valve and to expose the seats for inspection purposes. Space limitations within current large gate valve designs do not permit in-situ inspection of the seals themselves.

6.2 General Requirements

Some general requirements used in developing a concept are outlined below:

- The entire seating surfaces (upper/lower) of the valve must be inspected.
- The inspection equipment must be capable of being attached to and removed from the valve remotely.
- Inspection is to take place in an inert gas atmosphere.

6.3 Concept Description

The valve inspection concept as illustrated in Figs. 20 (elevation) and 21 (plan) consists of the following components: storage container, isolation valves, articulated arm, inspection head, video system and drives.

The method of operation of this equipment is as follows: The articulated arm, consisting of telescopic and parallel sections, supported from a storage container mounted to the side of the valve, is used to deploy an inspection head on the internal seating surfaces of the valve. The inspection head is rotated by the arm in a horizontal plane over entire upper and lower seating surfaces, to inspect for surface irregularities, scratches, etc. The container, mounted on the side of the main valve during inspection missions, is used to support and store the articulated arm (and inspection head) before and after use.

Once the inspection process is complete, the arm is retracted back into the container, the isolation valve closed and the tool assembly removed from the valve by remote means.

The drive systems function as follows: the installation/retract drive (M1) is used for installing and removing the inspection arm inside the valve. The telescopic arm drive (M2) is used to extend the reach of the telescopic portion of the arm. The yaw drive (M3) is used to rotate the inspection tool in the horizontal plane over the seating surfaces. The rotation drive (M4) is used to rotate the parallelogram section of the arm about the horizontal centreline so both upper and lower seating surfaces can be examined. The head pitch drive (M5) is used to raise/lower the parallelogram arm to position the inspection head against the seating surfaces.

The container, which is part of the valve body boundary, provides contamination control during deployment, handling and transportation. When the valve is closed it isolates the container, once the tool is retracted. The shut-off valve is used to seal the main valve casing when the container is removed. This valve must be design for UHV duty.

Surface Inspection Tool

Several tools could be used but the proposal is for a stylus device which will provide accurate measurement of surface irregularities from 0 to 1000 microns. Centreline average (CLA) and root mean square (RMS) readings can be taken also. A very light force is exerted by the stylus on the surface under examination. All but very fine scratches (similar to those produces in a lapping process) are detected and examined with this type of instrumentation.

Viewing Cameras

Two viewing cameras are proposed for the tool. One camera is mounted on the articulated arm while a second camera is mounted on the inspection head. The viewing camera, mounted on the base of the inspection arm, monitors the inspection head as it sweeps around the valve seat. This system also monitors the deployment of the arm and instrument head from its 'stored' to its 'inspection' position. The second camera, mounted adjacent to the surface inspection tool, is used for close-up inspection of surface irregularities. Space limitations and the working environment dictate that very compact rad resistant cameras and integral lighting should be used. It is assumed that camera cooling is not required.

6.4 Conclusions

Based on preliminary considerations:

- In-situ inspection of the seating surfaces, by remote means using a special purpose tool, appears feasible.
- The entire upper and lower seating surfaces of the valve can be inspected by such a tool.
- The tool can be designed to operate in inert gas, but an upgraded for vacuum service appears feasible also.
- The tool is designed for inspection purposes only but could be designed for repair work on the seating surfaces if required.
- An isolation port (and UVH isolation valve) is required on the side of the main valve body for mounting of the inspection tool.

6.5 Recommendations

The following recommendations are made for the development of the concept:

- A concept for a valve seat inspection tool should be developed in parallel with the development of a regeneration-isolation valve design, as inspection equipment will impact the design of the valve.

- The concept should be studied for operation in inert gas as well as for vacuum application.

- The concept should be studied for application to repair of the seating surfaces, as well as for inspection purposes.

- Integrate the tool concept with current valve designs.

- Investigate the feasibility of in-situ inspection of valve seals.

FIGURES

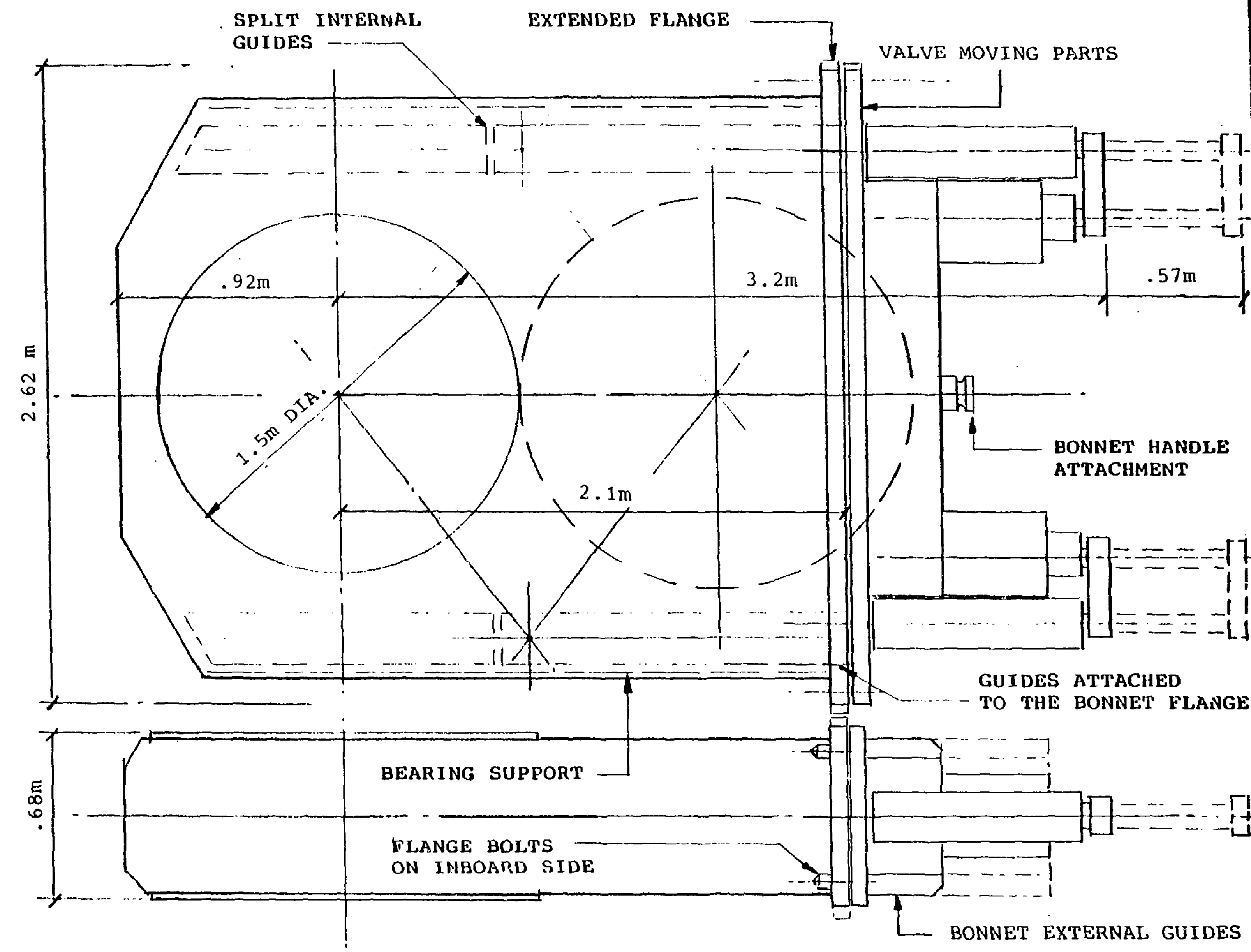

FIG.1 REGENERATION-ISOLATION VALVE

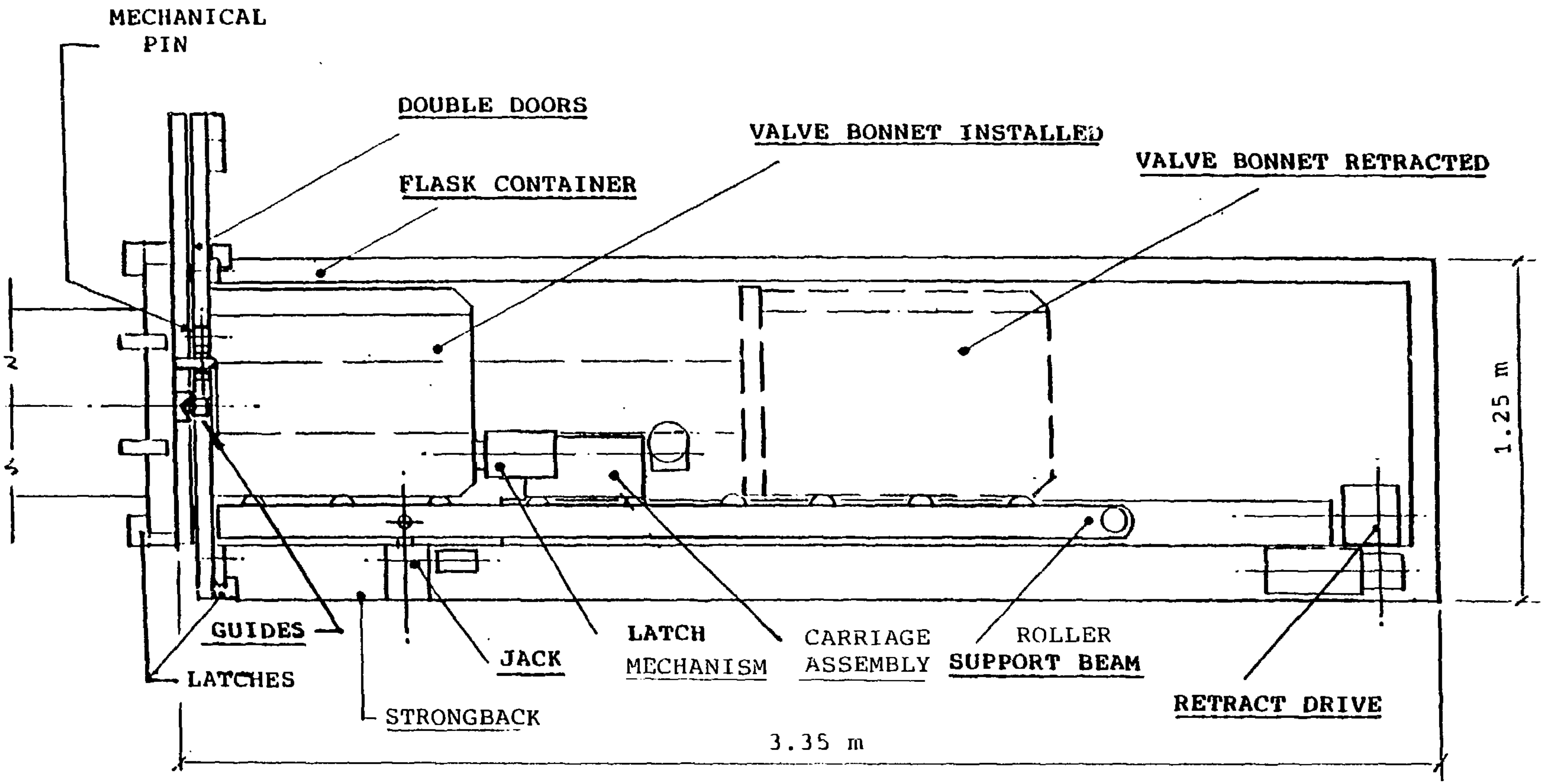

FIG.2 SEAL REPLACEMENT FLASK CONCEPT

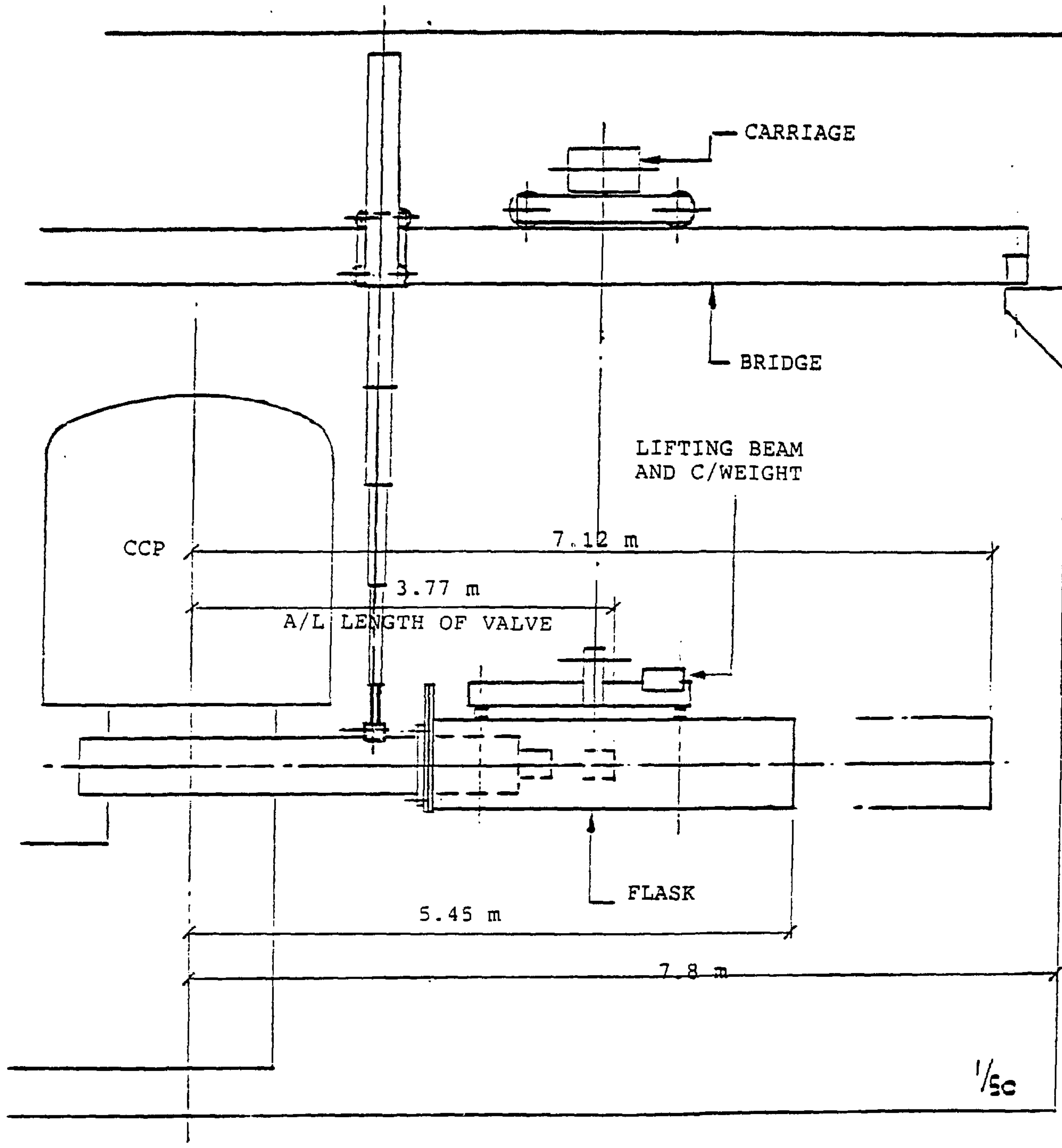

FIG.3 PUMP CELL CLEARANCES

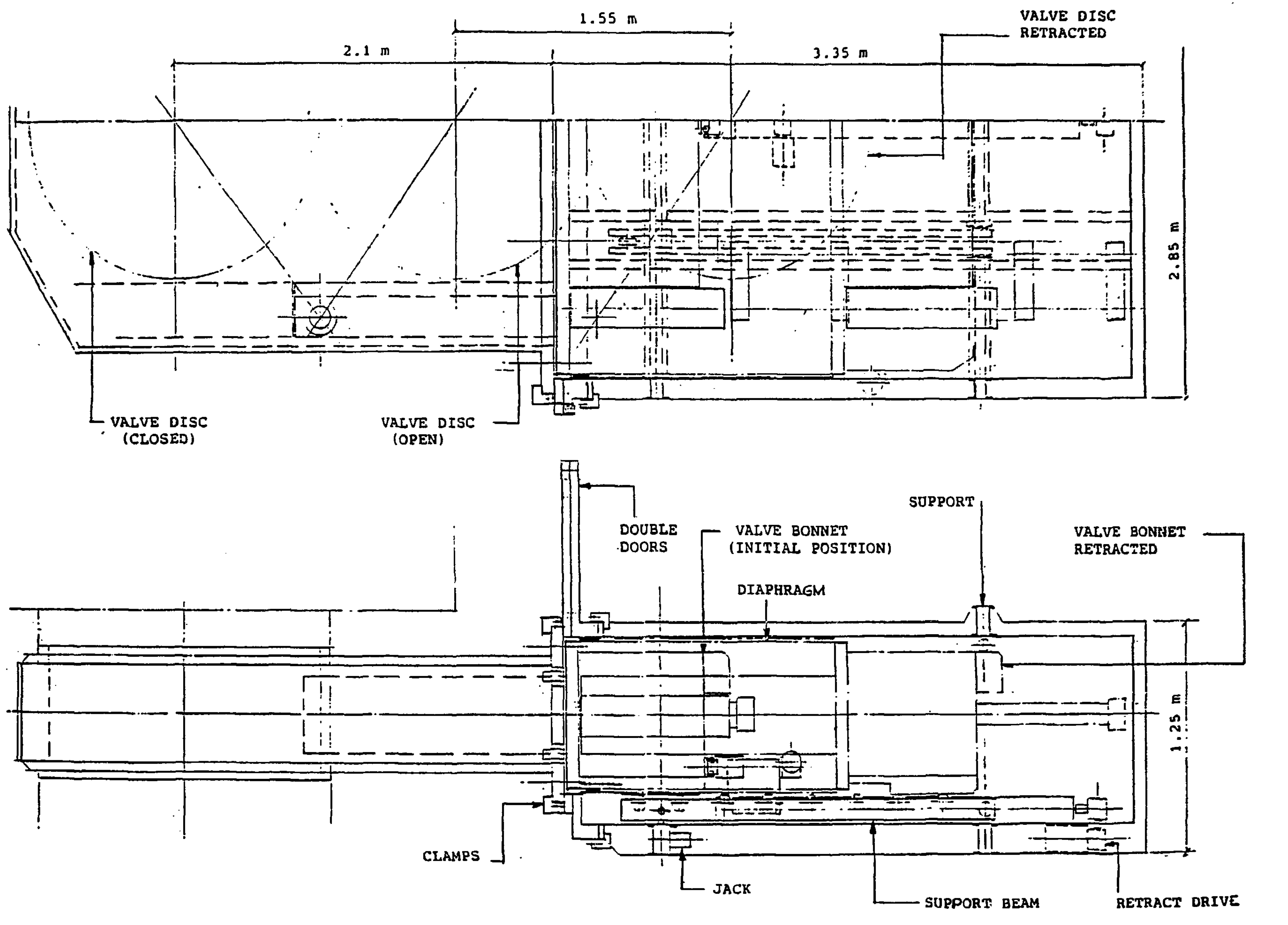

FIG. 4 FLASK ARRANGEMENT

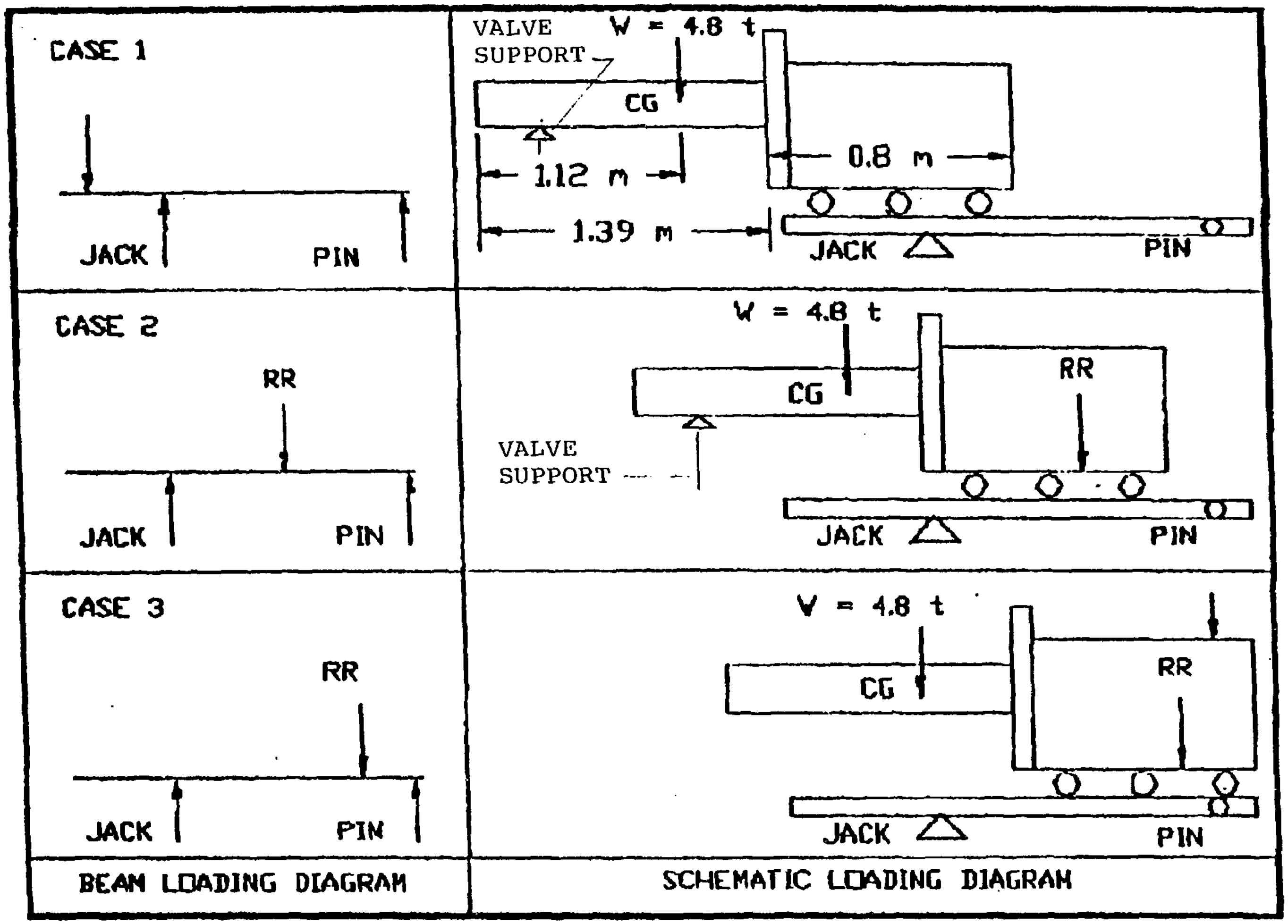

FIG.5 LOAD CASES

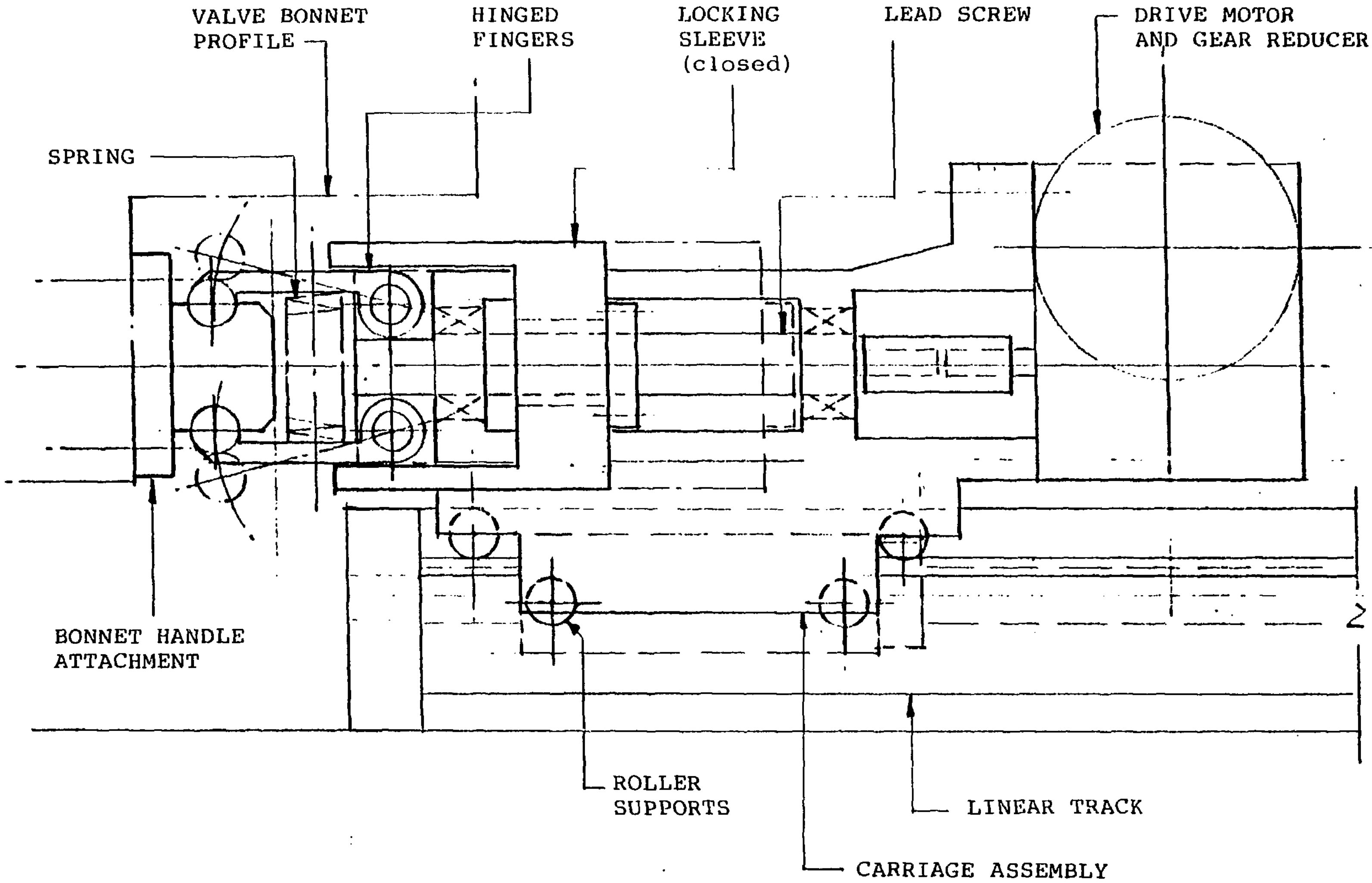

Fig. 6 LATCH MECHANISM

1. INITIAL ARRANGEMENT OF DOORS, VALVE AND BONNET FLANGES.

2. FLASK CHAMBER ATTACHED BONNET REMOVED AND DOORS LOWERED.

3. FLASK REMOVED, DOORS SEPARATED, AND VALVE DOOR CLAMPED.

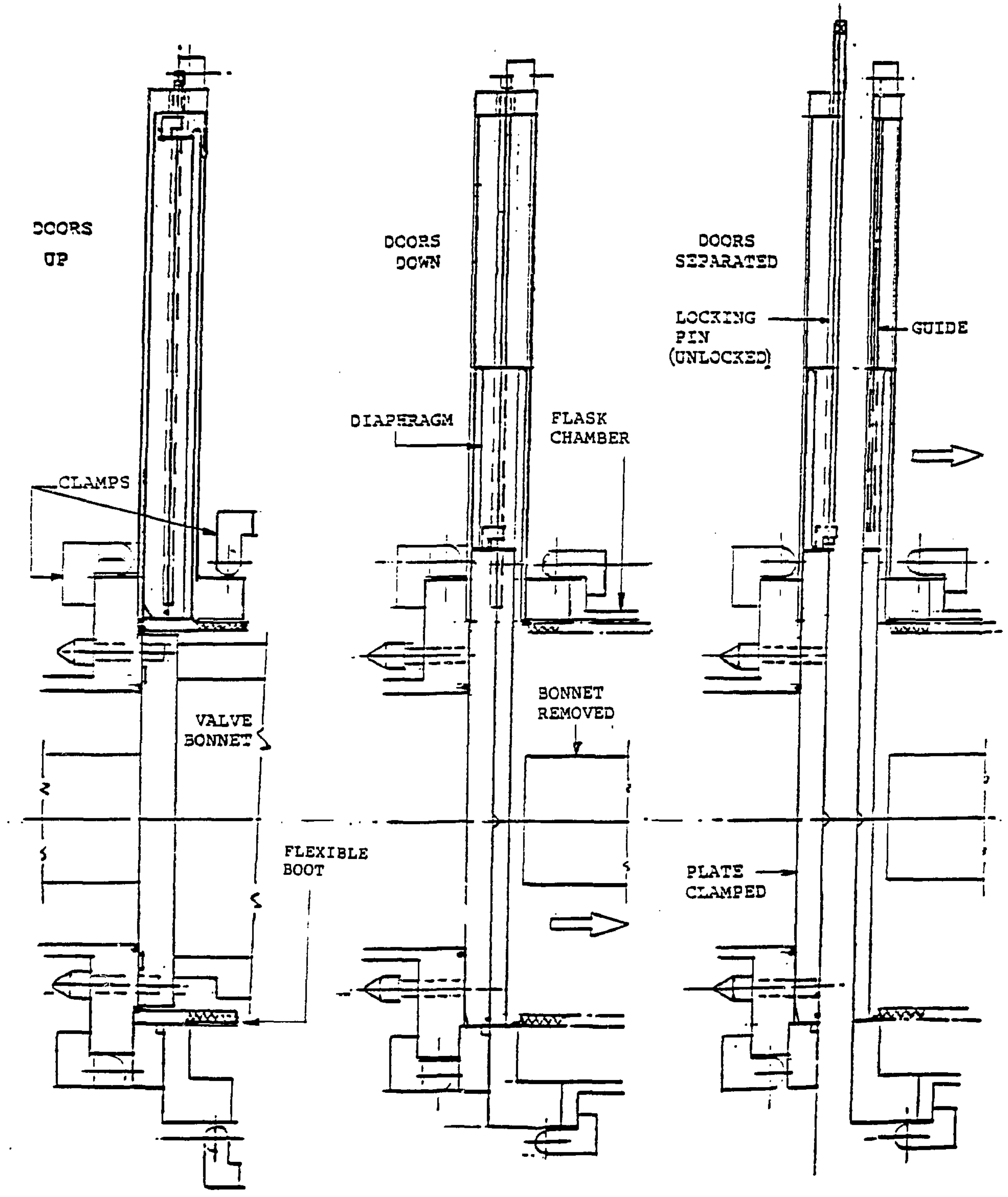

Fig. 7 OPERATIONAL SEQUENCE

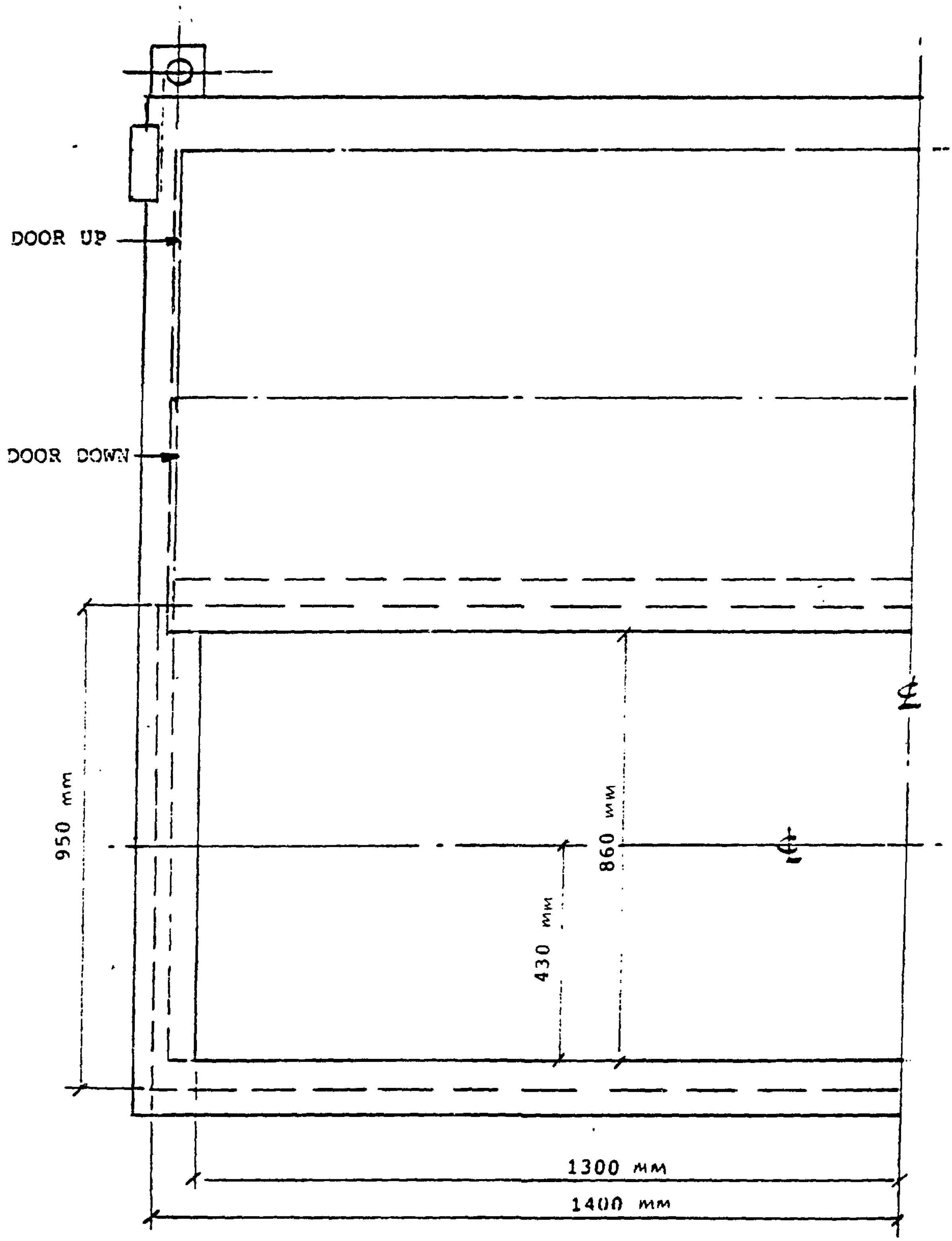

Fig. 8 DOOR ELEVATION

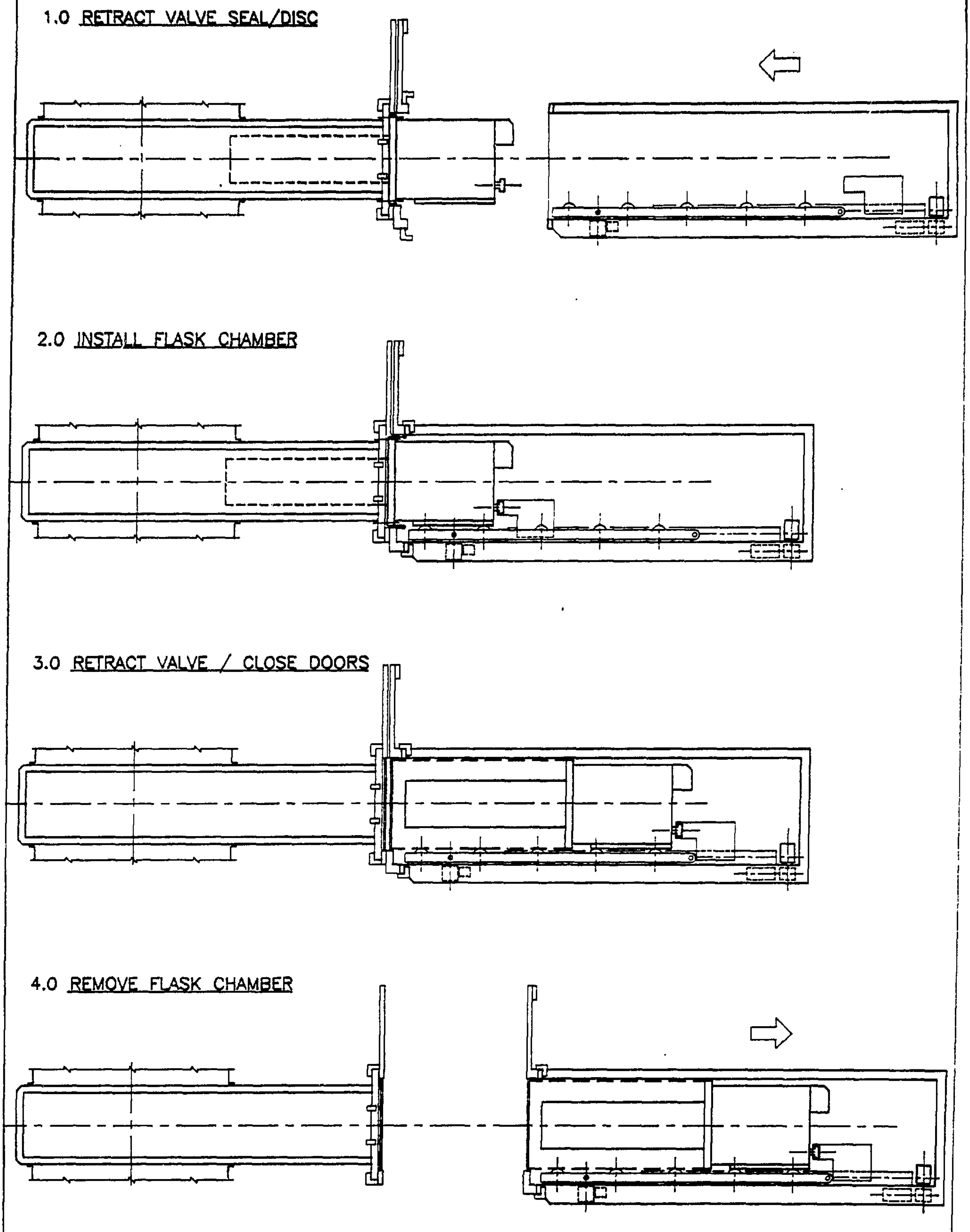

FIG.9 SEAL REMOVAL OPERATION

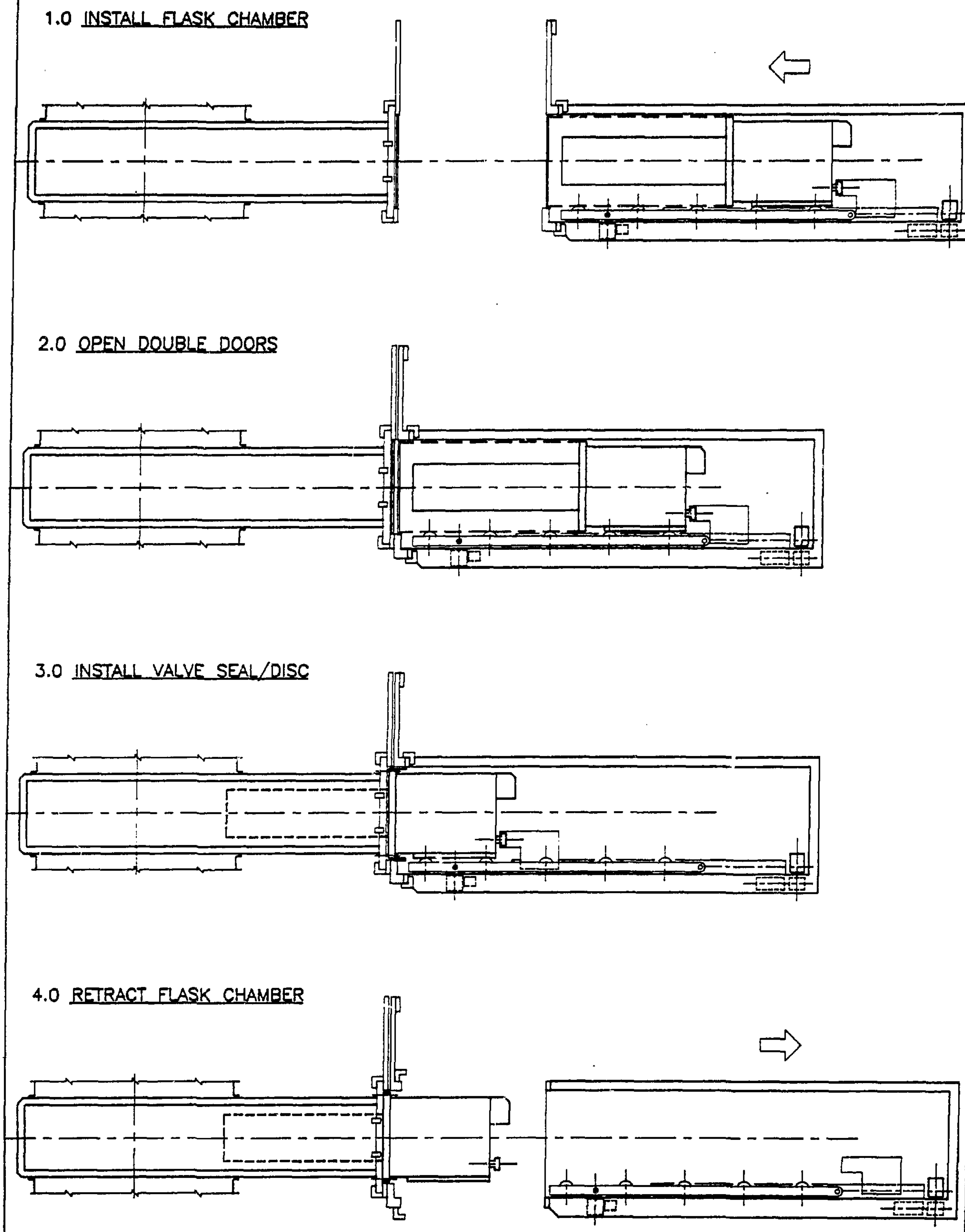

FIG.10 SEAL INSTALLATION OPERATION

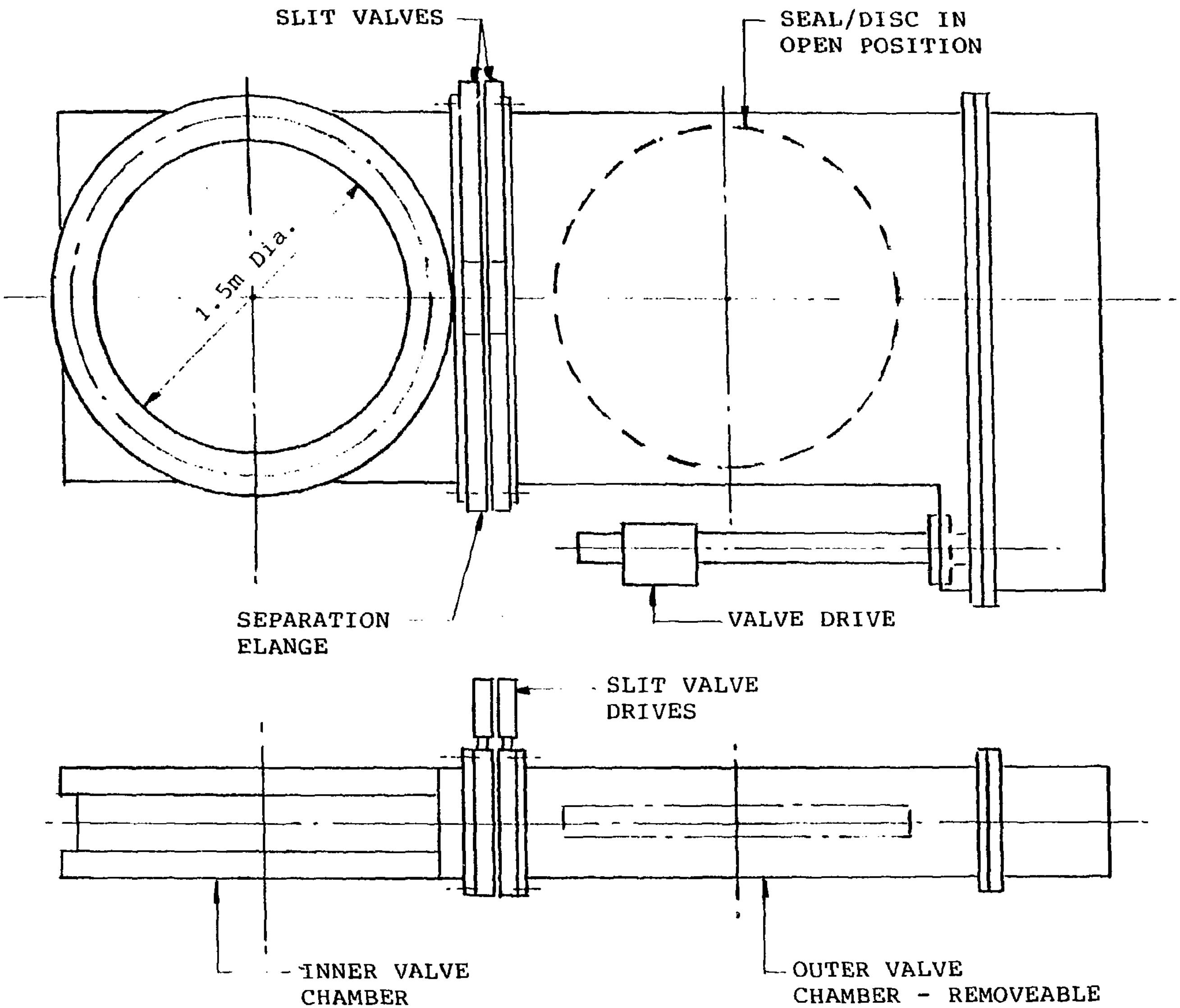

FIG.11 GATE VALVE CONCEPT

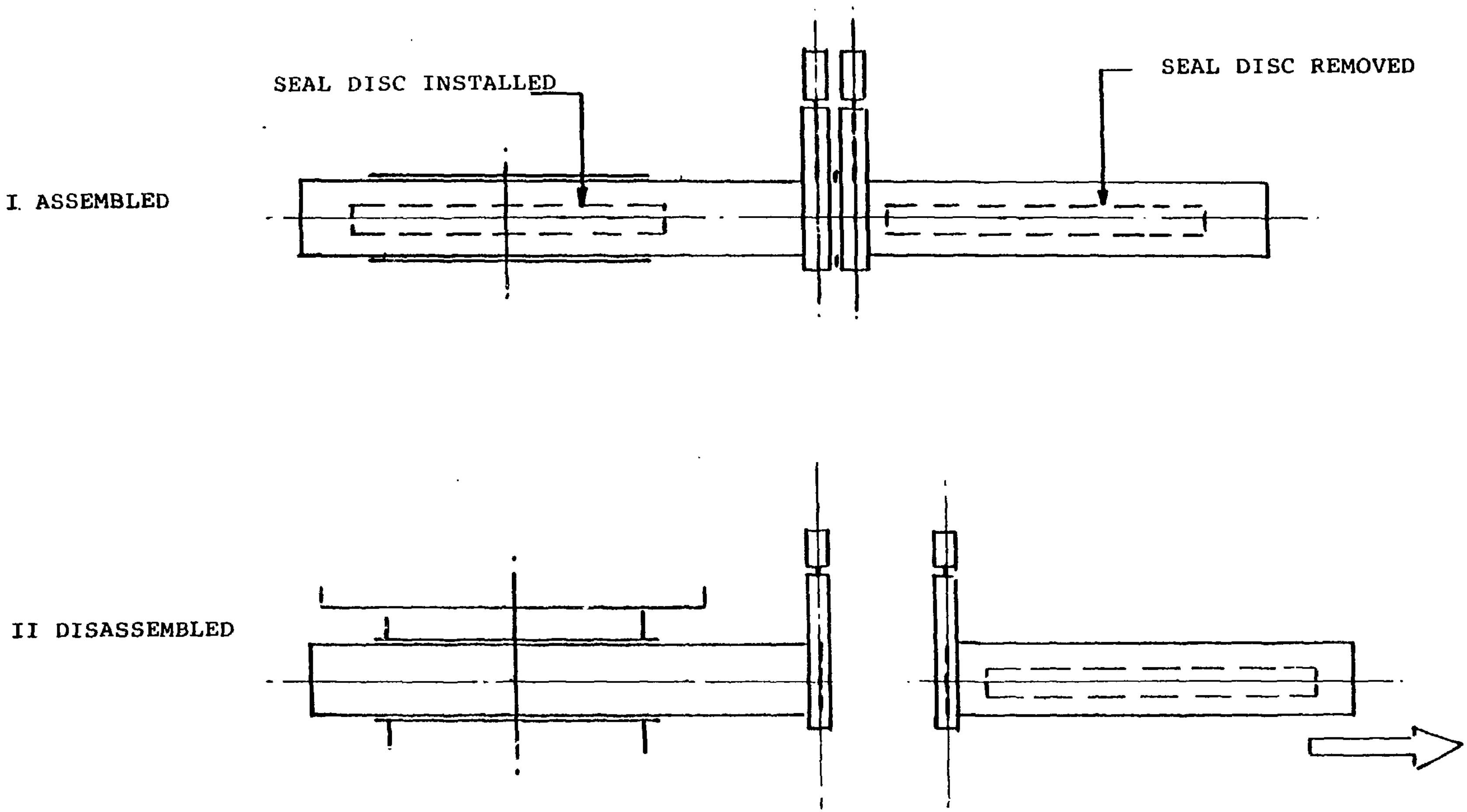

FIG.12 SEAL REMOVAL

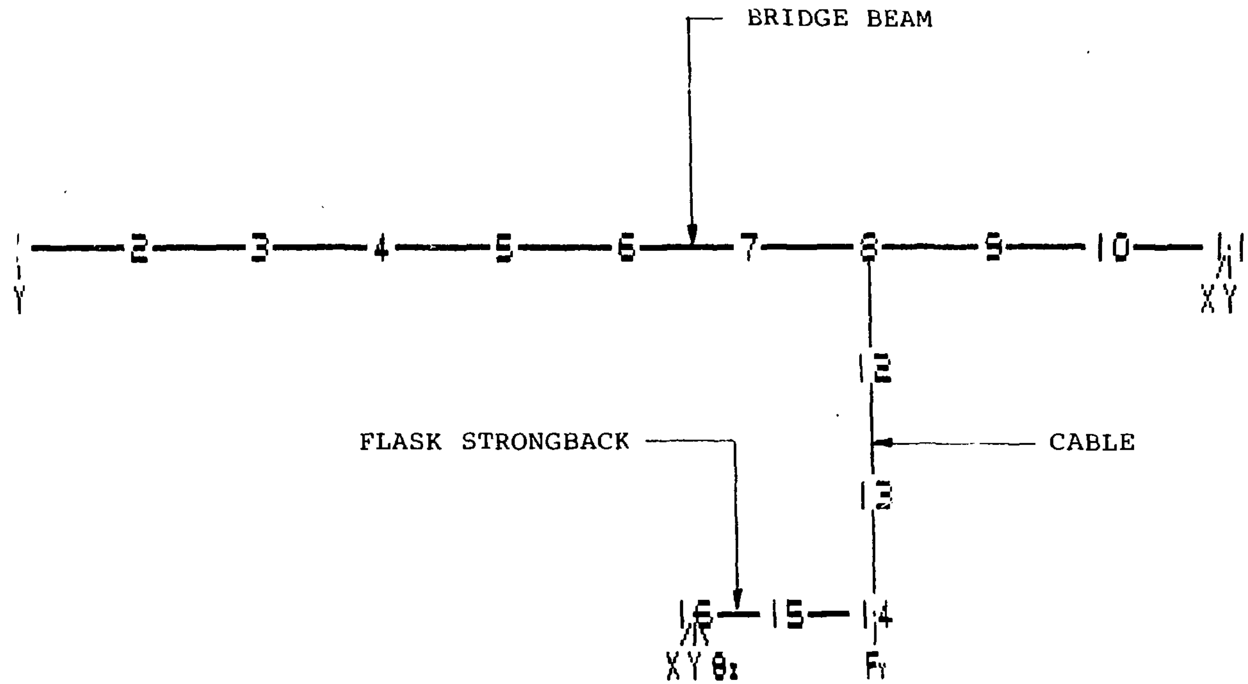

FIG.13 STRUCTURAL MODEL

TITLE: BEAM1

MODEL DESCRIPTION:

ELEMENT TABLE:

ELEM	TYPE	ELEMENT CONSTANTS			
1	3	.2100E+05	.2900E+05	.2000E+10	-.2500E+00
2	3	.2100E+05	.2840E+03	.5000E+05	-.2000E-01
3	3	.2100E+05	.2900E+04	.1330E+08	-.2700E-01

NODE COORDINATES:

NR	X	Y
1	.000	.000
2	1000.000	.000
3	2000.000	.000
4	3000.000	.000
5	4000.000	.000
6	5000.000	.000
7	6000.000	.000
8	7000.000	.000
9	8000.000	.000
10	9000.000	.000
11	10000.000	.000
12	7000.000	-1000.000
13	7000.000	-2000.000
14	7000.000	-3000.000
15	6250.000	-3000.000
16	5500.000	-3000.000

MODEL ELEMENTS:

NR	ELEM	CONNECTS NODES	
1	1	1	2
2	1	2	3
3	1	3	4
4	1	4	5
5	1	5	6
6	1	6	7
7	1	7	8
8	1	8	9
9	1	9	10
10	1	10	11
11	2	8	12
12	2	12	13
13	2	13	14
14	3	14	15
15	3	15	16

FIXED NODES:

NODE	COMP	DISPLACEMENT
1	2	.000
11	1	.000
11	2	.000
16	1	.000
16	2	.000
16	3	.000

APPLIED LOADS:

NODE	COMP	FORCE
14	2	-.4363E+04

FIG.14 INPUT DATA

TITLE: BEAM1

SOLUTION:

LARGEST FRONT = 9

DISPLACEMENTS:

NODE/COMP	1	2	3
1	-.1368E-03	.0000E+00	-.6206E-03
2	-.1368E-03	-.6118E+00	-.5944E-03
3	-.1368E-03	-.1173E+01	-.5199E-03
4	-.1368E-03	-.1637E+01	-.4029E-03
5	-.1368E-03	-.1967E+01	-.2495E-03
6	-.1368E-03	-.2126E+01	-.6559E-04
7	-.1368E-03	-.2089E+01	.1429E-03
8	-.1368E-03	-.1834E+01	.3700E-03
9	-.9122E-04	-.1359E+01	.5691E-03
10	-.4561E-04	-.7212E+00	.6929E-03
11	.0000E+00	.0000E+00	.7355E-03
12	-.2222E+01	-.2412E+01	-.1993E-02
13	-.1517E+01	-.2989E+01	.3051E-02
14	-.7937E-03	-.3566E+01	-.3546E-02
15	-.3968E-03	-.1117E+01	-.2679E-02
16	.0000E+00	.0000E+00	.0000E+00

FIXED NODES:

NODE	COMP	REACTION
1	2	.2282E+04
11	1	.2778E+02
11	2	.3661E+04
16	1	.3222E+02
16	2	.8797E+03
16	3	.1330E+07

MODEL ELEMENTS:

TYPE 3

NR	FORCE	STRESS	MOMENT(0)	MOMENT(L)	SHEAR(0)	SHEAR(L)
1	.0000E+00	.0000E+00	.1795E+02	-.2157E+07	-.2282E+04	.2032E+04
2	.0000E+00	.0000E+00	.2157E+07	-.4063E+07	-.2032E+04	.1782E+04
3	.0000E+00	.0000E+00	.4063E+07	-.5720E+07	-.1782E+04	.1532E+04
4	.0000E+00	.0000E+00	.5720E+07	-.7126E+07	-.1532E+04	.1282E+04
5	.0000E+00	.0000E+00	.7126E+07	-.8283E+07	-.1282E+04	.1032E+04
6	.0000E+00	.0000E+00	.8283E+07	-.9189E+07	-.1032E+04	.7816E+03
7	.0000E+00	.0000E+00	.9189E+07	-.9846E+07	-.7815E+03	.5315E+03
8	.2778E+02	.9578E-03	.9859E+07	-.6823E+07	.2911E+04	-.3161E+04
9	.2778E+02	.9578E-03	.6823E+07	-.3536E+07	.3161E+04	-.3411E+04
10	.2778E+02	.9578E-03	.3536E+07	-.5543E+01	.3411E+04	-.3661E+04
11	.3443E+04	.1212E+02	-.1304E+05	-.4741E+04	-.2778E+02	.7777E+01
12	.3443E+04	.1212E+02	.4741E+04	-.2518E+04	-.7777E+01	-.1222E+02
13	.3443E+04	.1212E+02	.2518E+04	.1971E+05	.1222E+02	-.3222E+02
14	-.3222E+02	-.1111E-01	-.1971E+05	-.6629E+06	-.9202E+03	.9000E+03
15	-.3222E+02	-.1111E-01	.6629E+06	-.1330E+07	-.9000E+03	.8797E+03

FIG.15 ANALYSIS RESULTS

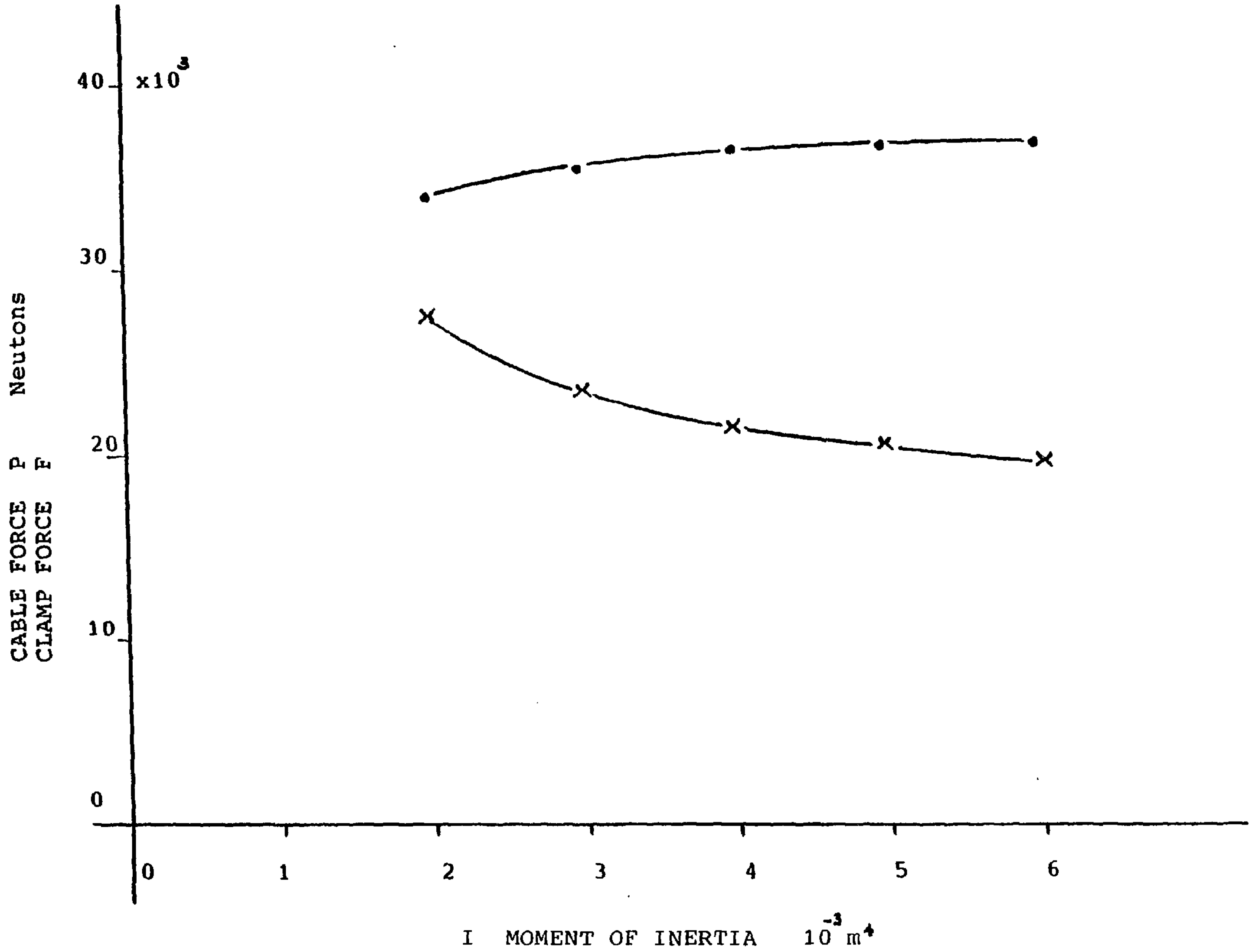

FIG.16 FLASK CLAMP FORCES

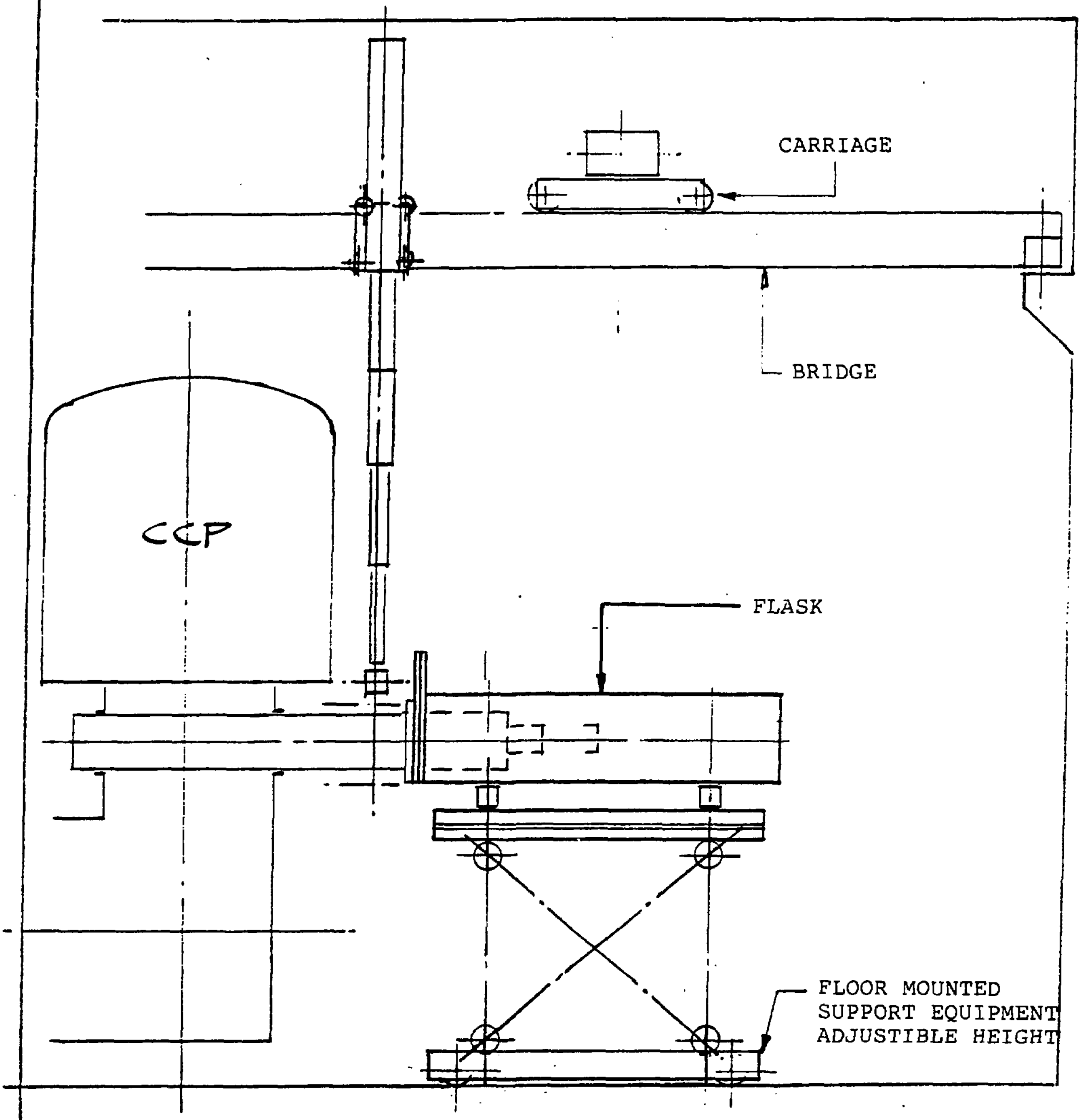

Fig.17 FLOOR MOUNTED CONCEPT

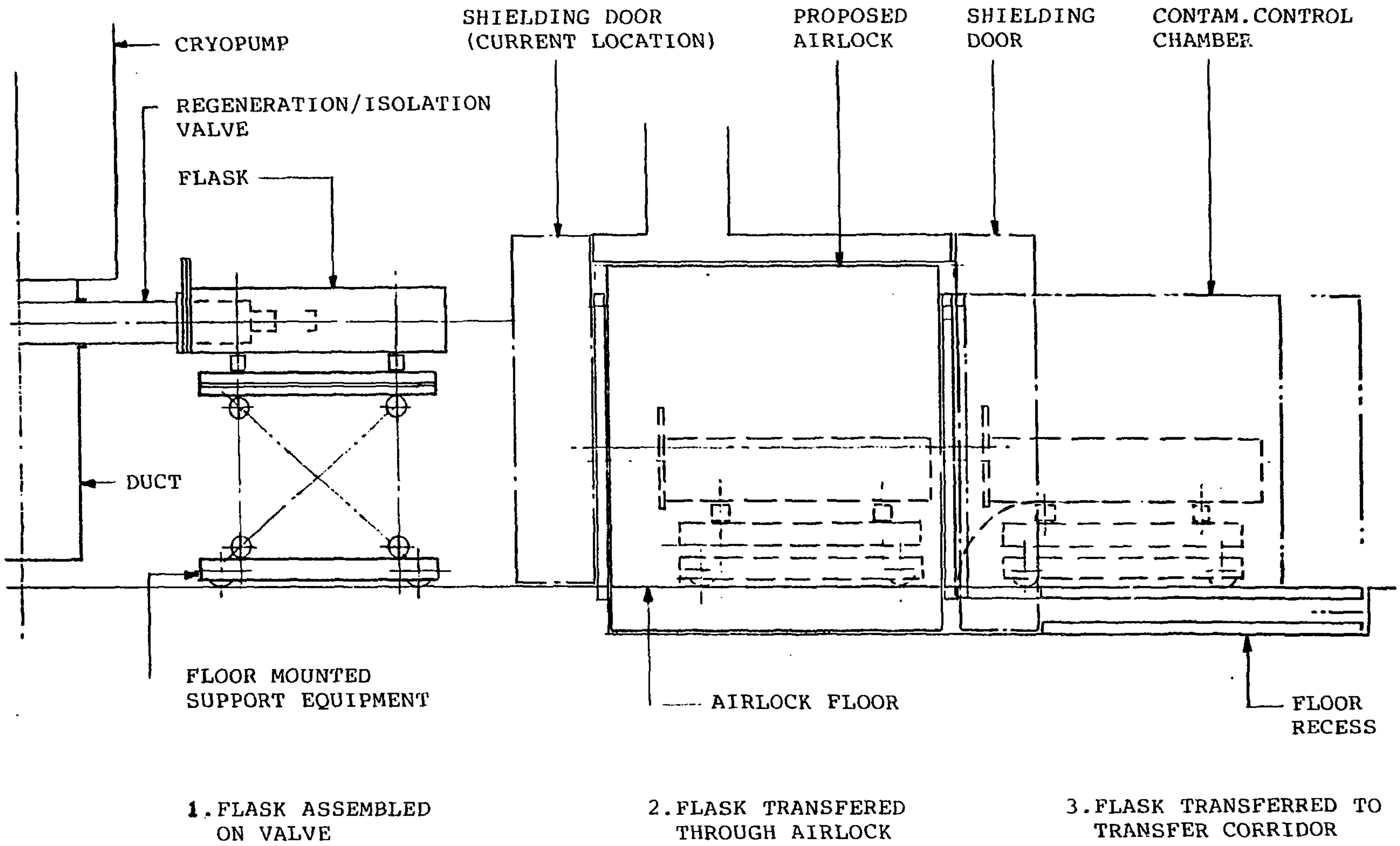

FIG.18 AIRLOCK CONCEPT

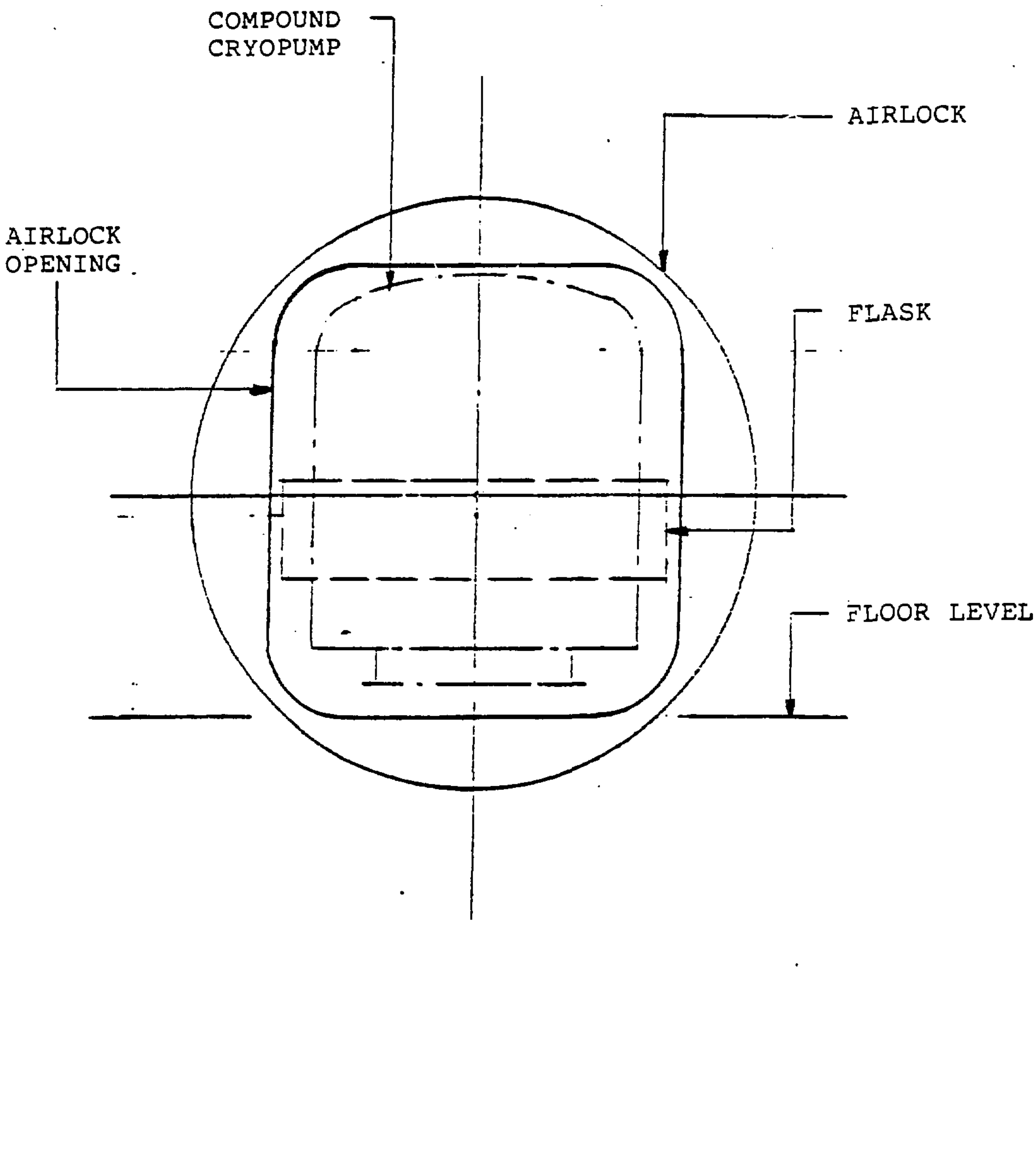

FIG.19 AIRLOCK SECTION

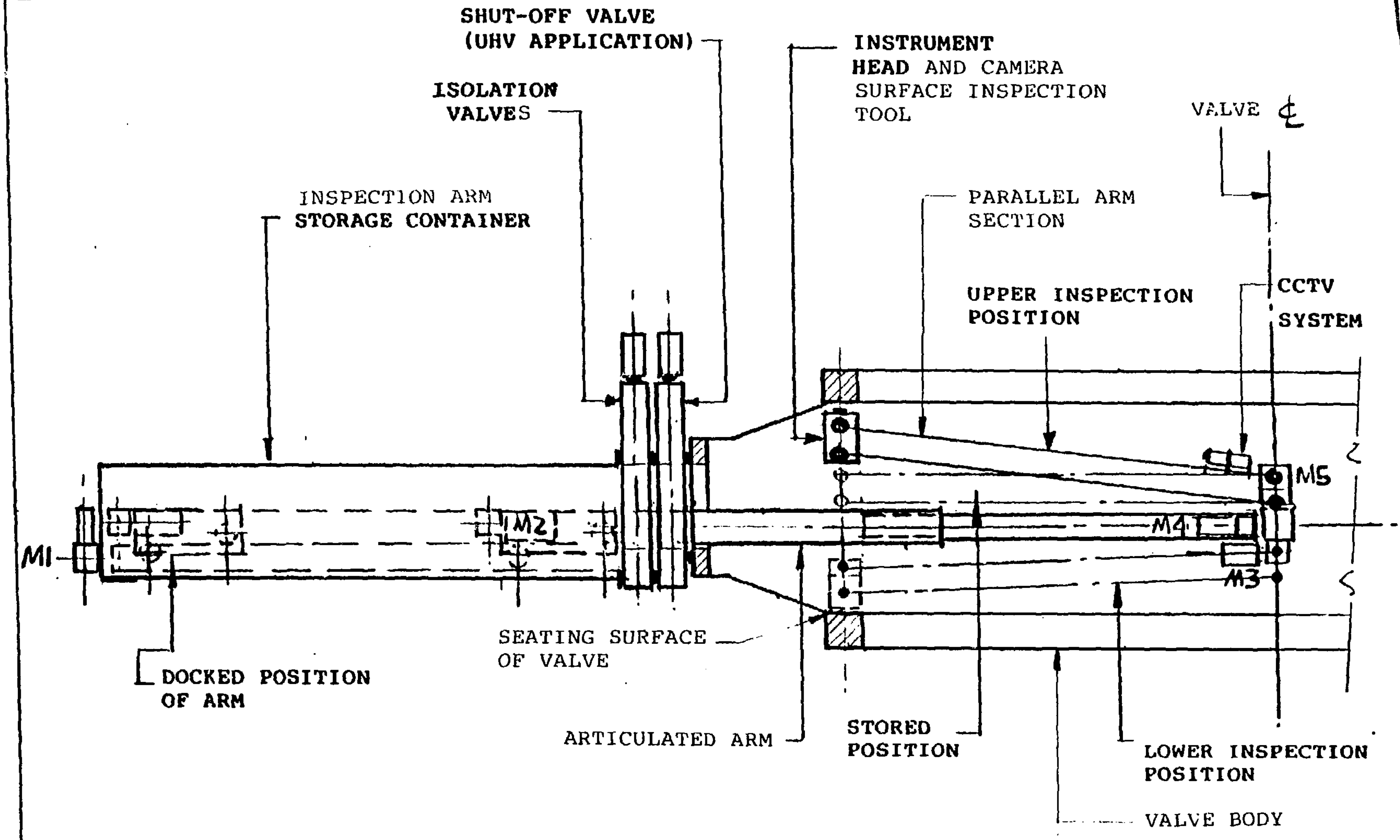

FIG.20 INSPECTION ARM CONCEPT (VIEW A-A)

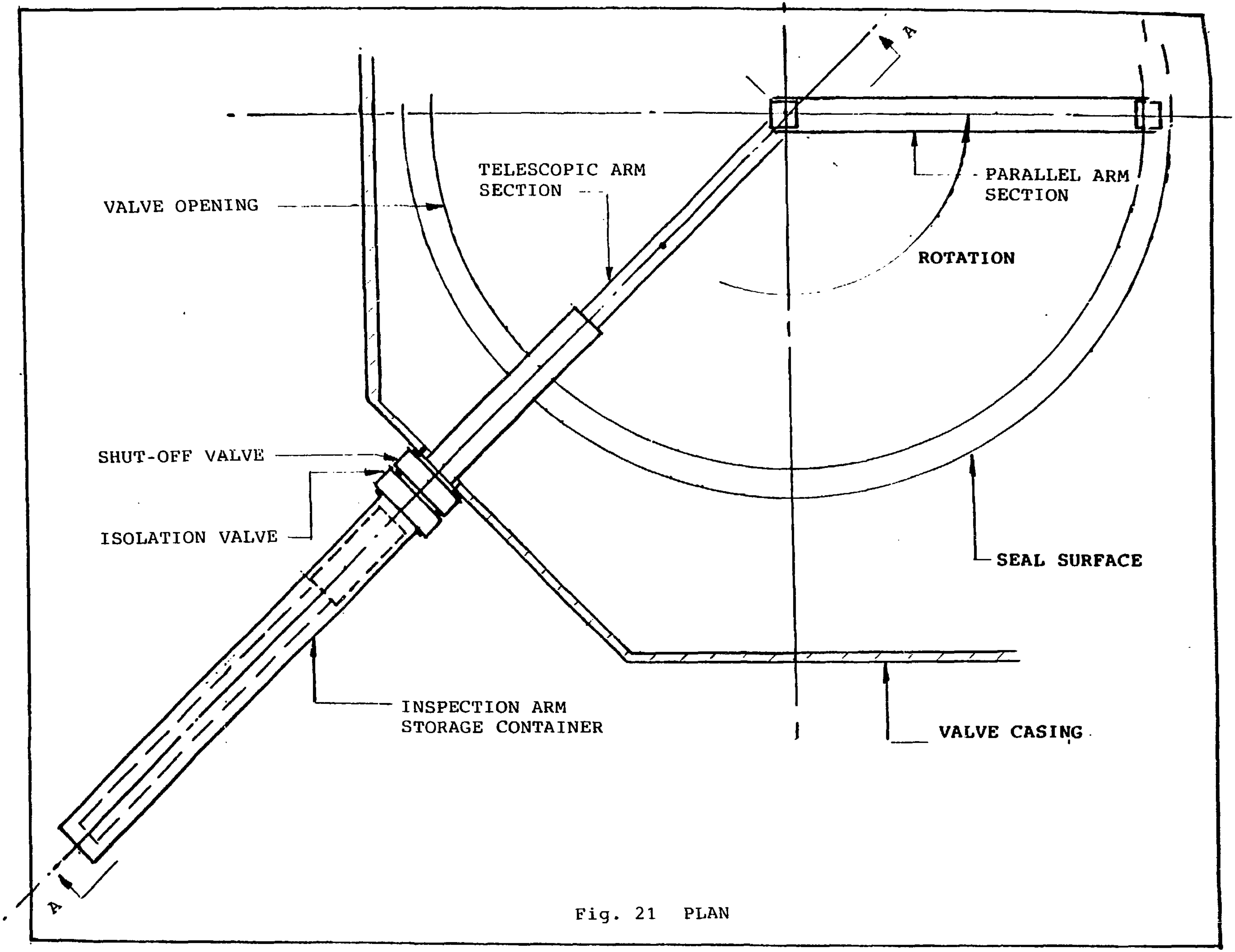
A
TELESCOPIC ARM
SECTION
PARALLEL ARM
SECTION
VALVE OPENING
ROTATION
SHUT-OFF VALVE
ISOLATION VALVE
SEAL SURFACE
INSPECTION ARM
STORAGE CONTAINER
VALVE CASING
A

Fig. 21 PLAN