DESIGN FEATURES OF SELECTED MECHANISMS DEVELOPED FOR USE IN SPACELAB

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ABSTRACT

The paper introduces the Spacelab and selected mechanisms developed for this program. It addresses a typical interface of a flight hardware to mechanical ground support equipment. Then one of the most attractive MGSE mechanism, the "roller rail", is described being used to install/remove the Spacelab floor loaded with racks carrying experiments. The details of the design and criteria are explained.

The next two mechanisms are related to the astronaut crew operations. The foot restraint is a special Spacelab development allowing the use of Orbiter common suction cap shoes. The design requirements as well as the design features are presented. The last element is the Lithiumhydroxide canister. In view of the multiple usage on orbit simplicity was the prime driver.

INTRODUCTION

Spacelab (Fig. 1), Europe's contribution to the Shuttle Program, stimulated the design of a number of mechanisms departing from standard industrial engineering design.

Depending on the usage, on ground or in space, different design drivers became predominant, although low cost, low mass, easy and safe operation are common requirements to all of them.

One of the most sophisticated mechanism assemblies of Spacelab is the Scientific Airlock and is therefore discussed in a separate paper.

This paper explains the design features of other elements selected against the following considerations:

- Related to the modularity of the Spacelab concept
- Astronaut operations

The MGSE to Spacelab Interface, as well as the "roll-in roll-out" concept for the quick replacement of payloads mounted in rack/floor assemblies of the habitable area of Spacelab, belong into the first category. Typical for the second one is the foot restraint mechanism in combination with handrails and the lithiumhydroxyde canister replacement on orbit.

SYMBOLS / ACRONYMS

SL	Spacelab
MGSE	Mechanical Ground Support Equipment
LIOH	Lithiumhydroxyde
mm	Millimeter(s)
Kg	Kilogram(s)
m	Meter(s)
g	Earth Gravity
N	Newton(s)
s	Second(s)

THE SPACELAB TO MGSE INTERFACE

One of the prime interfaces is the support of the entire Spacelab. In order to avoid degrading/damage of the Spacelab to Orbiter interface, a different interface was selected for MGSE. The MGSE to Pallet interface is essentially conventional with a statically determinant fixation. The Module interface on the other hand is statically indeterminant.

Figure 2 shows the integrated pallet on the assembly stand and Fig. 3 the details "1" and "4". Support "1" is a bearing which allows presetting in all directions. The support strut "2" allows movement in lateral direction and strut "3" gives the freedom in axial direction. Detail "4" shows the support frame bolted to the pallet. This MGSE had to accommodate quite important tolerances and deflections resulting from the pallet.

The tolerances between two trunnions (item 5) in axial direction, (vertical to the plane shown in Figure 2), for a three pallet train (three pallets bolted together) are

$\pm$ 13mm pallet manufacturing

+ 9mm) for thermal distortion
- 5mm) (-10° to $+55^{\circ}$C)

$\pm$ 4mm MGSE manufacturing

resulting in + 26 / - 22mm tolerance range.

THE "ROLL-IN" - "ROLL-OUT" CONCEPT OF THE RACK/ FLOOR ASSEMBLIES

The concept was conceived to allow fast removal and installation of SL payloads installed in racks or on the floor as illustrated in Fig. 4. Initially (1973) standard aircraft design was looked at but turned out not to be useable mainly because of

- the multiple/heavy fixation points required to accommodate a great number of possible rack locations
- high mass of the roller assembly (about 60Kg/m on each side)
- considerable reinforcement of rack structures violating the minimum mass criterion

incompatibility of plastic materials or lubricants with the stringent requirements concerning outgassing and flammability of parts and materials.

Therefore new design solutions were developed without losing the feature of fast ground operation.

Figure 5 shows the rack/floor assembly mounted on the MGSE stand.

An MGSE rail (see Fig. 5, 7) is inserted in between the primary structure and the floor. Then the floor and rack attachment bolts are removed and the rolls moved up. The clearance between the racks and primary structure is such that the rack/floor assembly can be rolled out on the MGSE stand.

The concept of the removable non flyable roll device allowed a decoupling of "1g" operations with its negligible load conditions from the flight load condition seen by Spacelab during ascent/descent. The design driver in the latter case is the crash landing within a 20^{o} half cone angle in flight direction with 9,0 g's.

Thus low mass and lower costs could be achieved than making the typical aircraft design work for Spacelab. In addition, this solution avoided the anticipated problems of tolerances and additional loads due to deflections.

The design of the roller rail assembly (Fig. 7) represents sophisticated engineering concept driven by extraordinary design requirements. These resulted from the philosophy - less complexity on the flight articel but on the MGSE where mass is not a driver.

The nominal design load was 7,5 tons for the long experiment rack/floor assembly of 4,4m. The safety factor of 2 was applied for limit load.

Specific difficulties resulted out of the Module floor displacements schematically shown in figure 6.

In addition a lateral tolerance of $\pm$ 3mm of the mainfloor had to be compensated. Figure 7 illustrates the main features of the roller rail assembly:

- vertical movement of upto 12mm by Rollers "1" together with the upper housing "2", lifting the rack/floor assembly sitting on this plate. This is achieved by spreading the levers "3". Since these elements are arranged in a mirror fashion, no movement in axial direction occurs (requirement from flight hardware). The activation of the levers "3" is achieved by a remotely operated spindle "4", operated by a worm gear.

- For installation/removal of the unladen roller rail assemblies, the bottom rollers (7) are used, they will be retracted when moving the rack and floor assembly.

- lateral track misalignment compensation by means of springloaded rollers 5.

- compensation of lateral mainfloor tolerances (between roller rail assembly and Module primary structure) by means of adjustable eccentrically driven rollers (see detail "6").

- the axial movement of rack and floor assembly is achieved by a driving mechanism using a tooth gear "8" along the roller rail assembly in combination with a driving trolley manually operated.

The capabilities of the design have already been demonstrated through successful usage during Spacelab Engineering Model System Integration.

ASTRONAUT FOOT RESTRAINTS

The design features developed for Skylab were considered in the initial design phase but could not be used because the mainfloor could not be made from triangular grid structure (structural and noise reasons). This lead to the "suction cap shoes" used on the flat surfaces of honeycomb panels.

Due to the severe mass constraints and the multiple location requirements, a versatile design concept was found using the handrails as attachment, see Figure 8.

The specific design requirements are

- rotable in 15^{o} increments
- fully adjustable along double rack handrails and aft end cone handrails
- loads:
  - 589N each direction
  - torsion moment normal to attachment plane: 200Nm
  - kick loads: 9 Kgm/s at a max. velocity of 1,5m/s

The kick load requirement is being verified by a drop test of 6Kg with a 5mm radius point from a height of 100mm.

The design has passed the qualification program successfully. Flight unit production drawings are almost ready.

LIOH STORAGE CONTAINERS

LIOH is used for decontaminating the air exhausted by the crew. The cartridges are identical to those used in the Shuttle Orbiter but the containers are different.

One of the main considerations of the storage containers design was the location of the cartridges. The replacement of the cartridges in use by the environmental control and life support system (in the sub-floor area) had to be optimised for easy crew operation on orbit. Figure 9 shows study details of the crew systems analysis and Figure 10 further details of the cartridge container design, where simplicity was the main driver.

The design has passed its qualification successfully. Flight unit production drawings are in final preparation.

REFERENCES

1. Spacelab Critical Design Review data package 1978

2. Spacelab System Support Specification SR-ER-0008

3. SENER drawing 612.011 0301.000.03

4. Unger, Burnell:

   TN-ER-37-005-76 Verification of Work-bench and Central Console Architecture, incorporating foot restraint utilization.

5. T. Ward, U. Munkelt:

   TN-ER-37-004-76 LIOH Task Analysis.

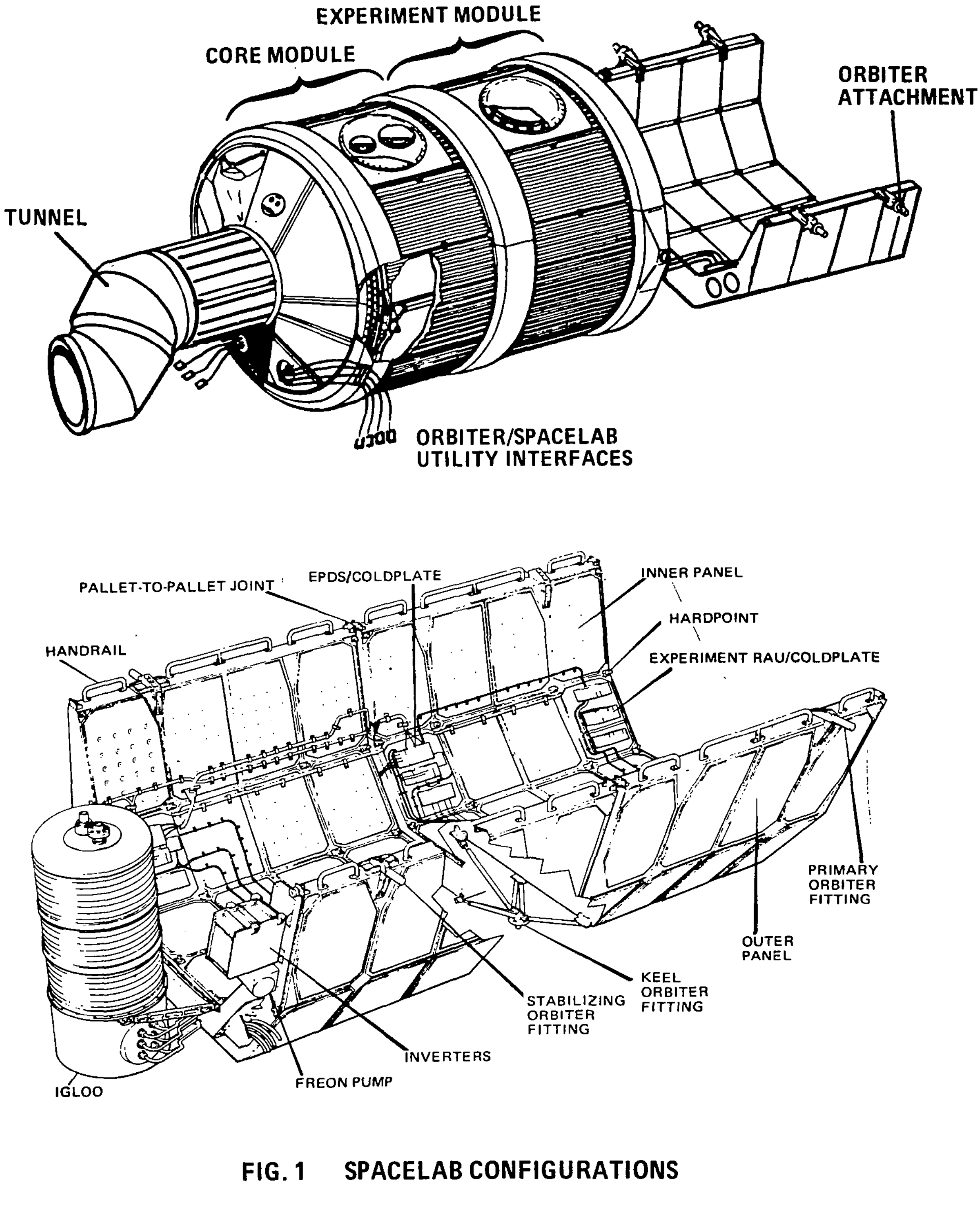


FIG. 1 SPACELAB CONFIGURATIONS

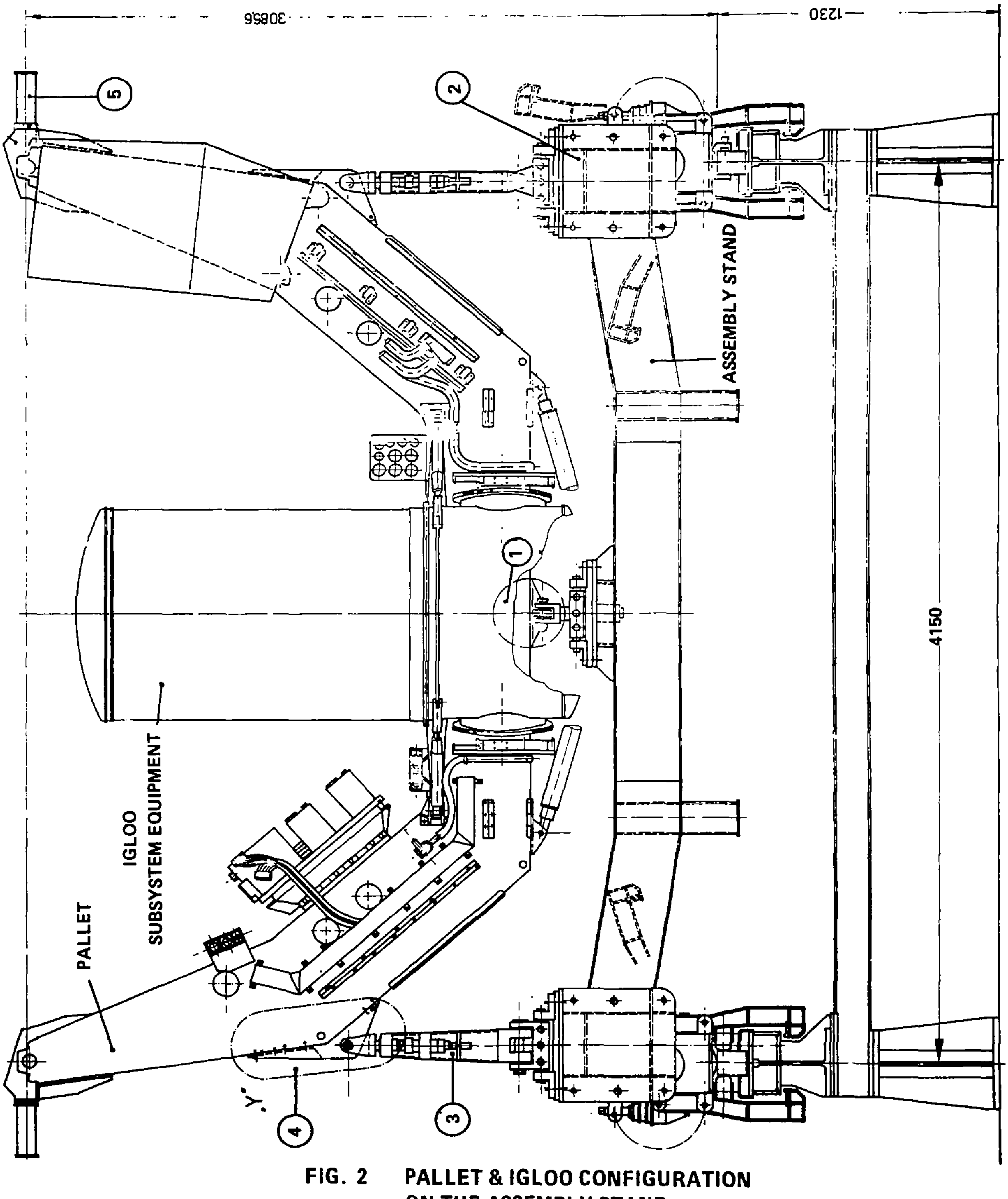
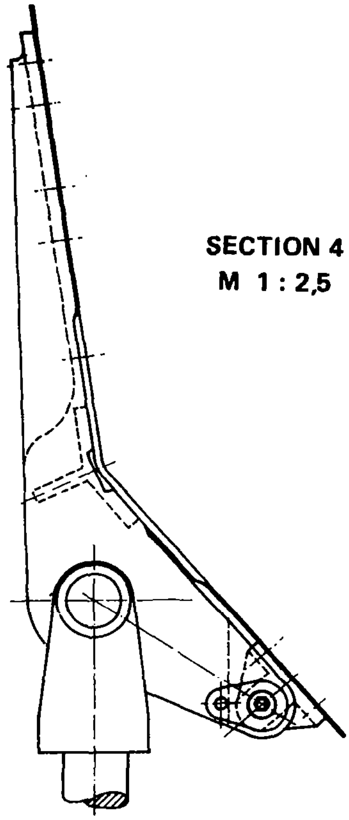


FIG. 2 PALLET & IGLOO CONFIGURATION ON THE ASSEMBLY STAND



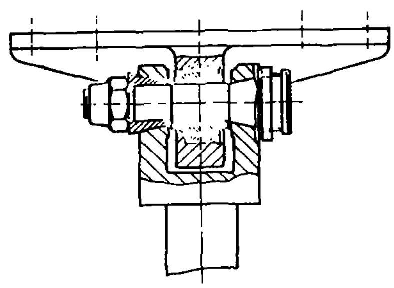


FIG. 3 DETAILS 1 AND 4 OF PALLET SUPPORT MGSE

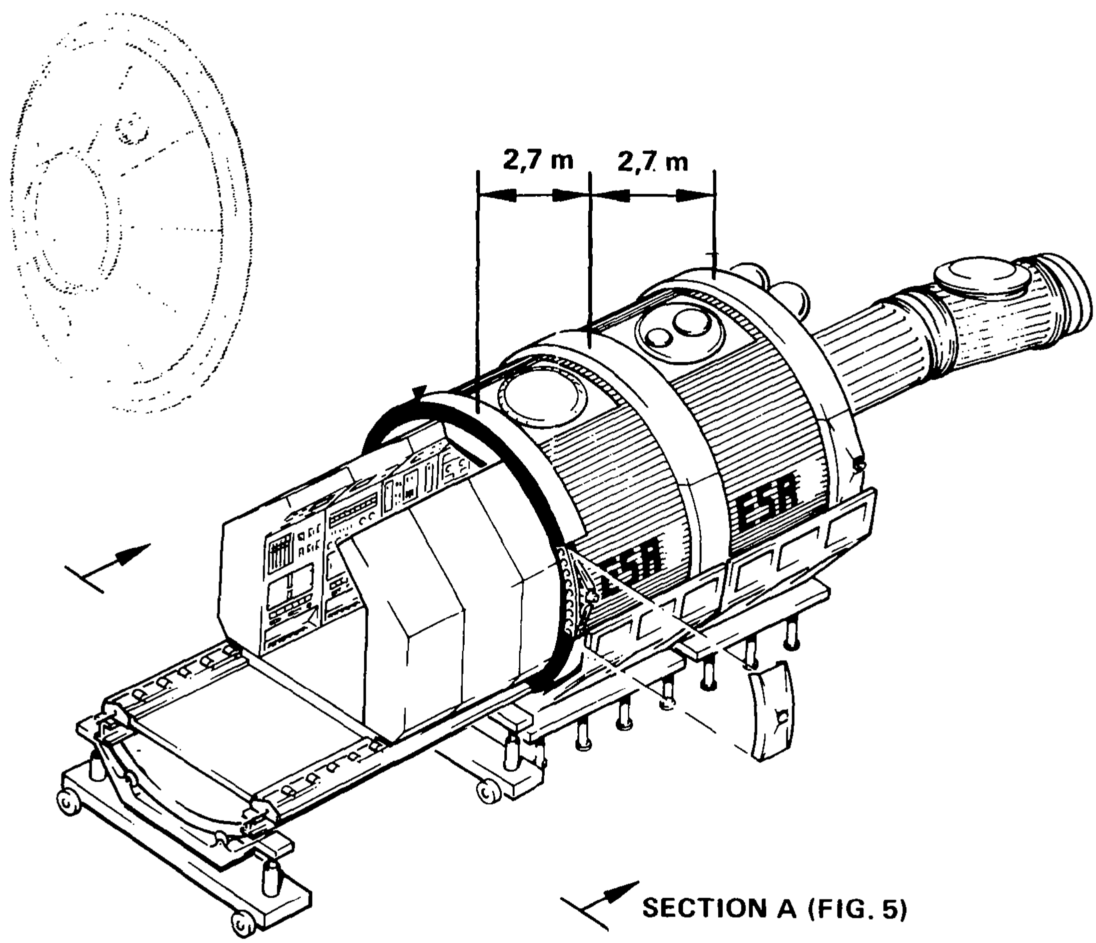


FIG. 4 "ROLL–IN – ROLL–OUT" CONCEPT FOR SPACELAB RACK/FLOOR ASSEMBLIES

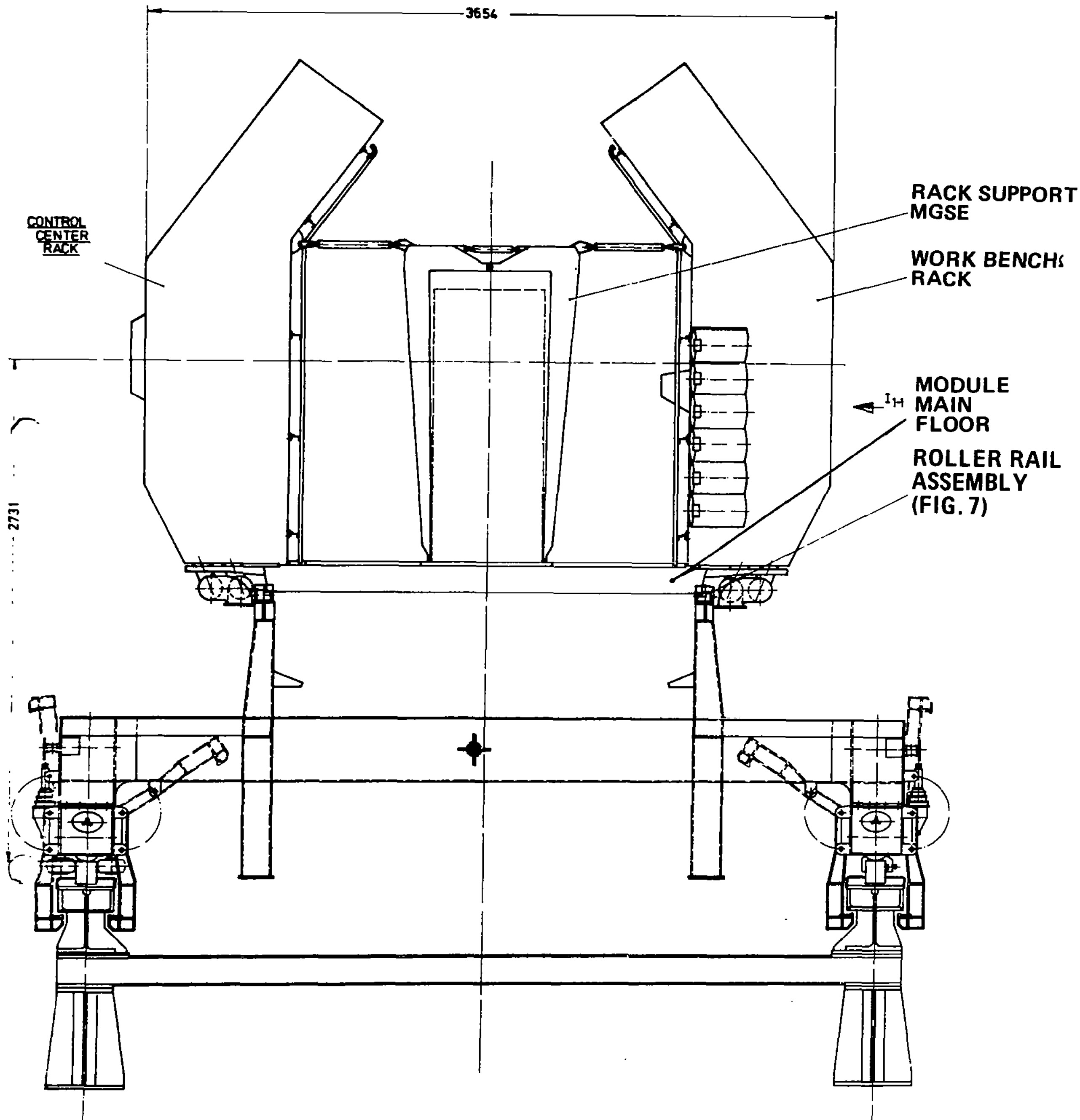


FIG. 5
RACK AND FLOOR ASSEMBLY AND STAND
(SECTION A OF FIG. 4)

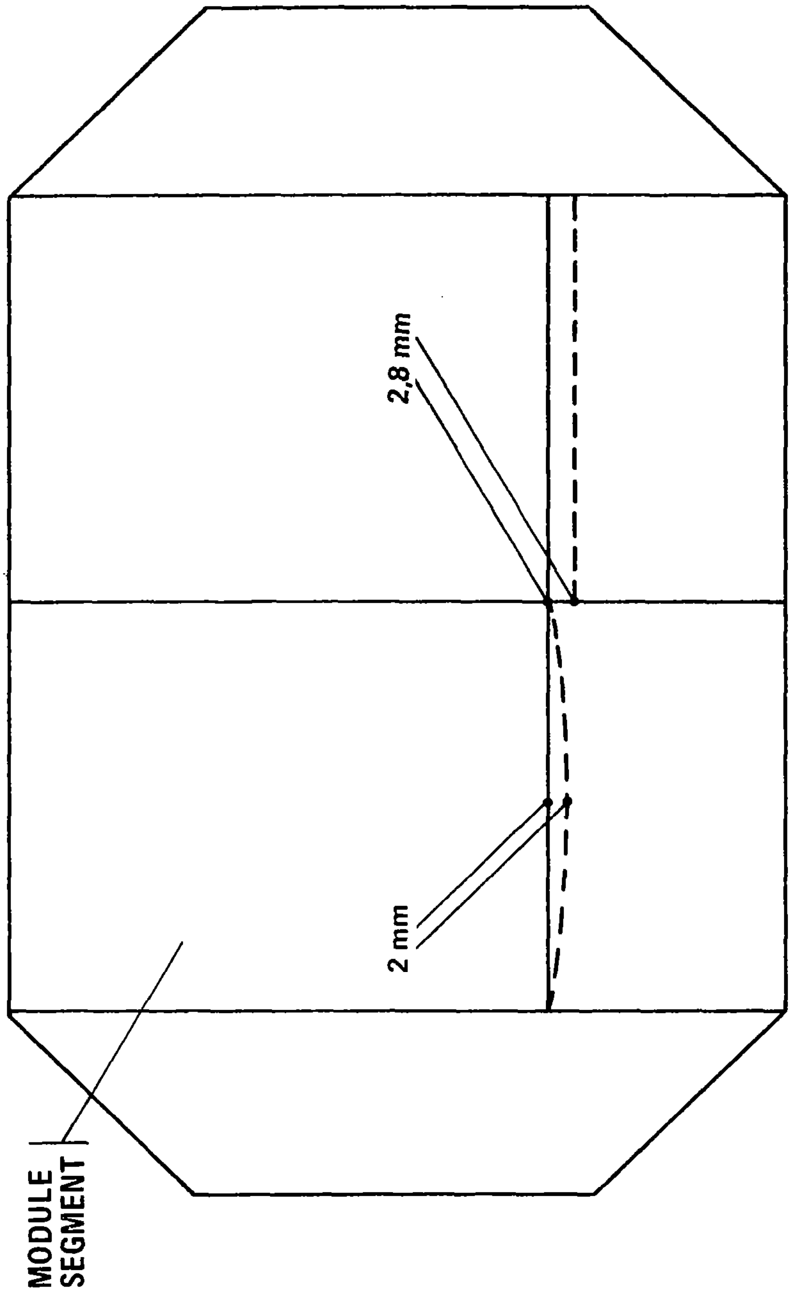


FIG. 6 MAINFLOOR DISPLACEMENTS TO BE COMPERATED BY ROLLER RAIL MGSE

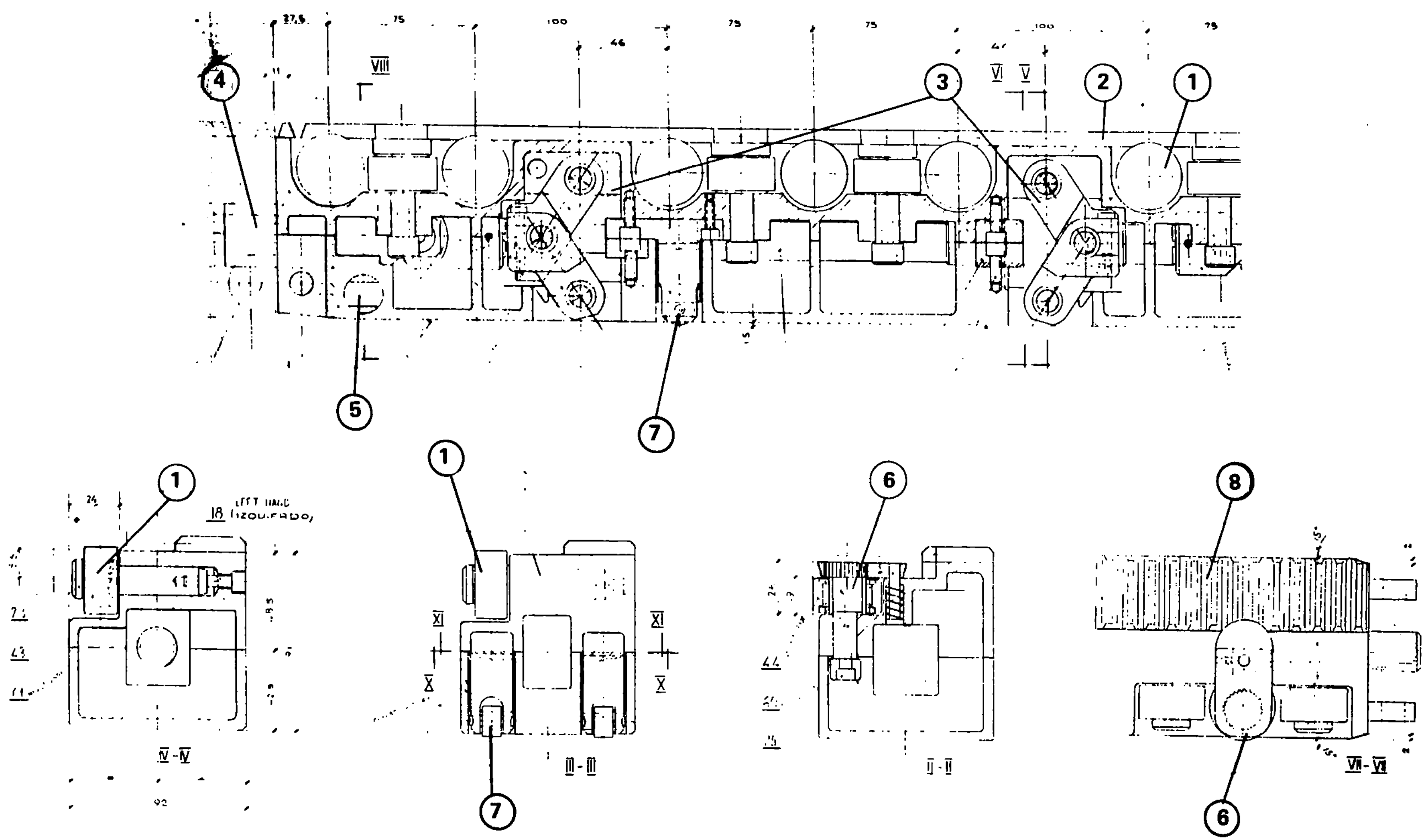


FIG. 7 ROLLER RAIL ASSEMBLY AND VARIOUS SECTION VIEWS

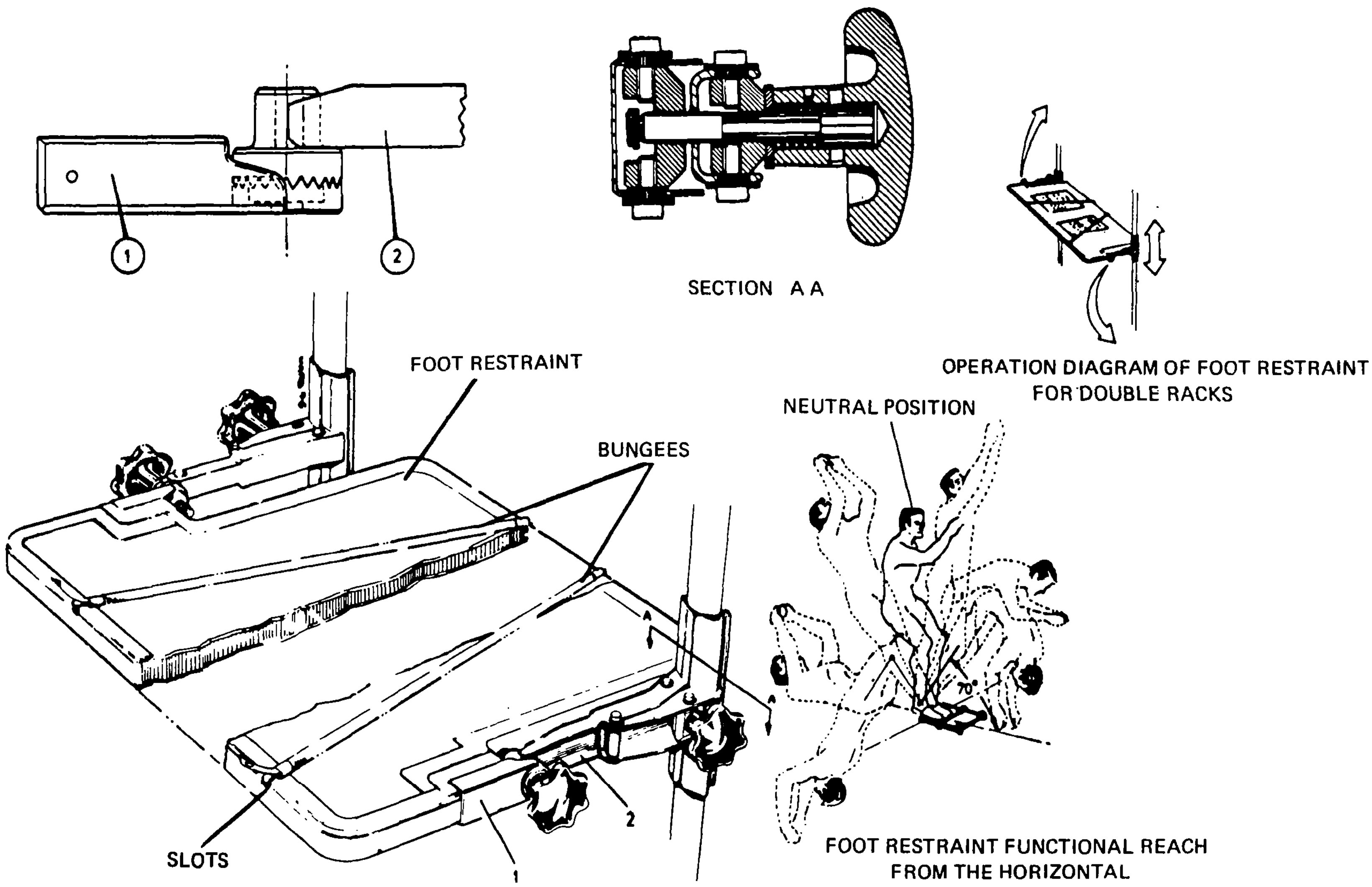


FIG. 8 DOUBLE RACK FOOT RESTRAINT WITH TEMPORARY RESTRAINT

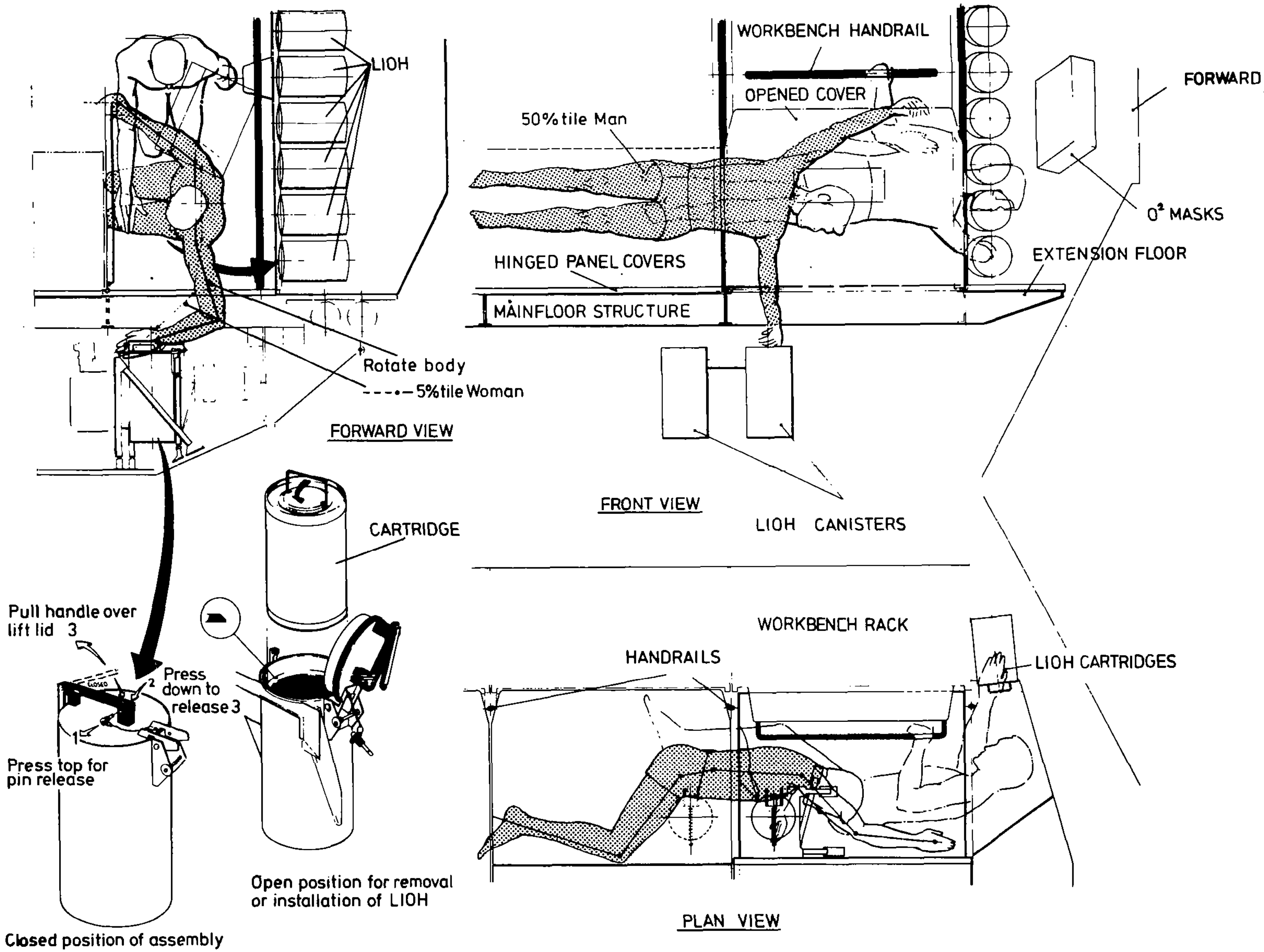


FIG. 9 LIOH OPERATION AND REMOVAL

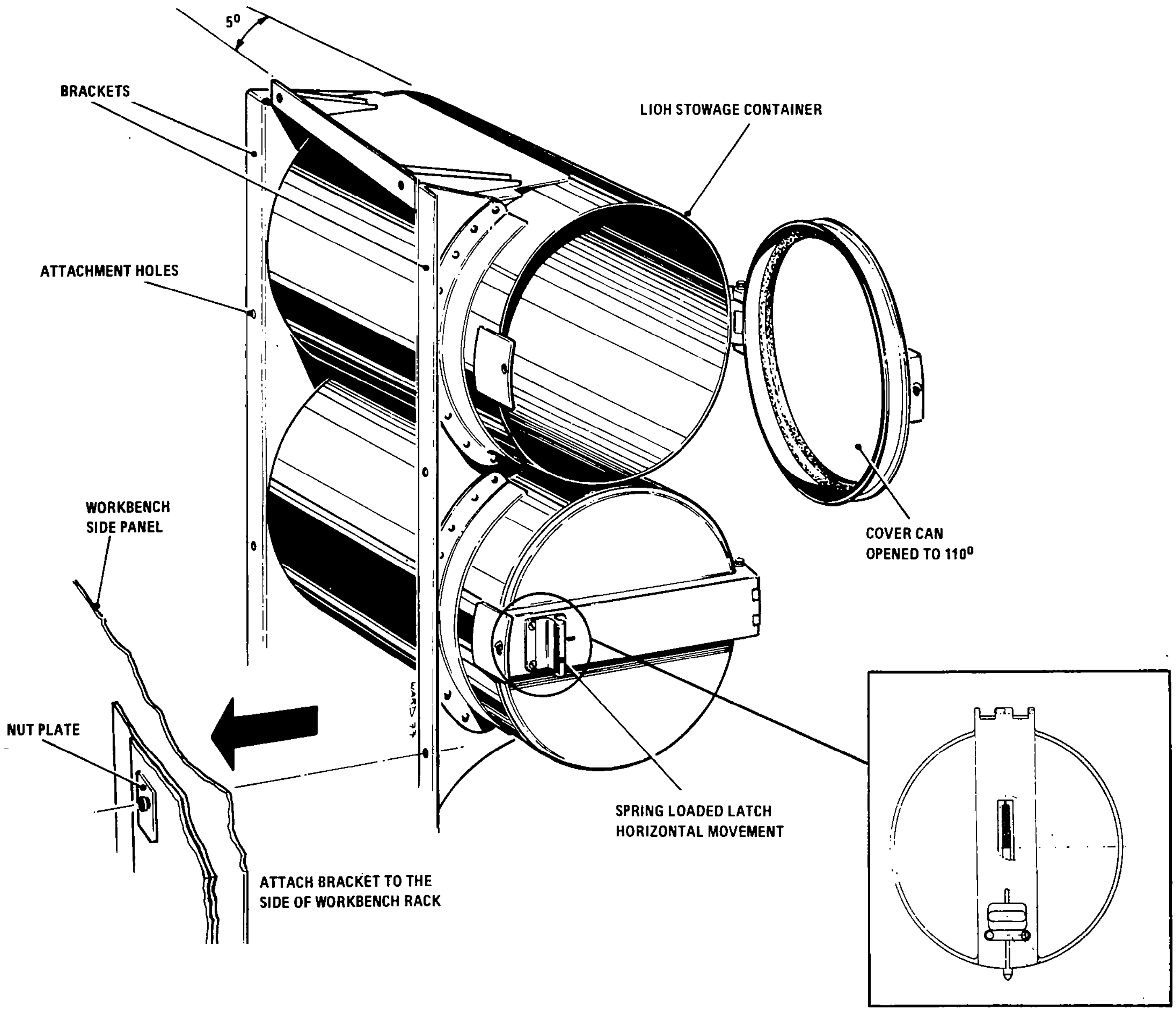


FIG. 10 STOWAGE OF THE LIOH CARTRIDGES