

Space Station *Freedom* Common Berthing Mechanism

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## ABSTRACT

The Common Berthing Mechanism (CBM) is a generic device used to join the pressurized elements of the Space Station *Freedom* (SSF) utilizing the Space Shuttle Orbiter Remote Manipulator System (SRMS) or the Space Station Remote Manipulator System (SSRMS). The two berthing halves, the active and the passive, maintain a pressurized atmosphere to allow astronaut passage, as well as to provide a structural linkage between elements. The generic design of the CBM allows any Passive Berthing Mechanism to berth with any Active Berthing Mechanism, permitting a variety of pressurized module pattern to be built.

## INTRODUCTION

The Space Station *Freedom* (Figure 1) is composed of three main sections--the solar arrays which provide power to the station, the truss which supports and connects all Space Station hardware, and the pressurized elements which provide a hospitable environment for the astronauts to live in and work in.

The mass and volume restrictions imposed by the Space Shuttle Orbiter requires the pressurized elements of the Space Station to be segmented into interconnecting elements. The design scheme of the pressurized elements divided them into two types--the common modules and the nodes (Figure 2). The common module, long and cylindrical in shape, is the module type used to house life support, habitation, and laboratory equipment. The common module has a CBM at each of the two axial ports of the module. The node, shorter than the common module, is used to connect the common modules into an efficient pattern. For this, the nodes are equipped with a CBM at each of their six ports--two on the axial ends and four around the radius, 90 degrees apart. The primary design requirements for a mechanism to join these modules on-orbit are as follows:

- Join the pressurized modules;
- Provide pressurized passage for astronauts and utilities;
- Withstand launch, pressure, and on-orbit loads;
- Meet Shuttle payload volume and weight requirements when connected to the pressurized elements;

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- Meet maximum atmospheric leak-rate requirements;
- Survive the low-Earth orbit environment for the 30-year life of the Space Station with the necessary factors of safety.

It was desired and baselined to berth the pressurized modules (bringing the elements together by means of a third party--i.e., robotic arm) rather than to dock them (bringing together without a third party).

Berthing structural/mechanical components perform four necessary functions:

- align berthing halves in proper orientation
- capture and berth the two elements
- maintain a structural connection
- maintain pressurized atmosphere between elements.

Among the preliminary concepts was an androgynous berthing mechanism which, as its name implies, allows any berthing mechanism to mate with any other berthing mechanism. It was determined that an androgynous mechanism would require unnecessary complexity, weight, development time, and expense when compared to a male/female-type configuration. As of mid-November, 1991, the current design consists of elastomeric seals, capture latches, alignment guides, powered bolts, and shear tie assemblies mounted on two structural rings. These assemblies are divided into two CBM halves--the Active Berthing Mechanism (ABM) and the Passive Berthing Mechanism (PBM) (Figures 3 and 4). All active, power-consuming components are located on the ABM to eliminate the requirement for power to be supplied to both modules during berthing operations. The following is a description of each component and the reason for its usage in the CBM.

## **ACTIVE BERTHING MECHANISM**

### **Structural Ring**

The purpose of the structural ring (Figure 3) of the Active Berthing Mechanism is fourfold--to maintain a pressurized passageway between elements, to provide a seal surface when mated to the Passive Berthing Mechanism, to provide structural support and a load path between pressurized elements, and to provide a mounting interface for berthing hardware.

The structural ring of the Active Berthing Mechanism is a machined forging of 2219-T852 aluminum having an outside diameter of approximately 2.0 meters (80 inches) and inside diameter of approximately 1.8 meters (71 inches) with a depth of .19 meter (7.5 inches). The ring is attached to the pressurized element by 64 bolts and sealed by a weld to ensure pressure integrity. The ring supports the Alignment Guides, Powered Bolts, Capture Latches, and Differential Pressure Transducers.

The structural ring was originally designed to carry just the launch, pressure, and on-orbit loads, but was later strengthened to support the deflection loads created by the pressurization of the radial port on the nodes (Figure 2). The ring design accommodates the mounting of berthing hardware, such as the capture latch while not extending into the Orbiter Payload Bay envelope on the Node radial port. The original ring diameter was increased from 1.68 meters (66 inches) to permit the routing of utility connections internal to the CBM.

#### Alignment Guide Assembly

The Alignment Guide Assembly (Figures 5 and 6) ensures proper orientation of the two berthing halves for successful component mating. The alignment guide blade on the ABM slides between two alignment guide blades on the PBM to properly orient the berthing halves (Figure 7). The Alignment Guide Assembly is made of anodized 2219-T87 aluminum with a low-friction surface coating. The guides are designed to withstand impact loads which may occur due to SRMS runaway conditions.

A 1989 study of alignment mechanisms included both external and internal alignment guides, a telescoping berthing arm, conical guides, and a mortar-and-pestle guide (similar to a probe and drogue). The internal alignment guide arrangement was chosen because it was located internal to the berthing ring and it has performed well in preliminary testing. Tests conducted at the Neutral Buoyancy Facility at Marshall Space Flight Center evaluating the accessibility and maintainability of external berthing mechanism components revealed that EVA maintenance was difficult, if not impossible, thus, driving the CBM design to internal components. In addition, internal alignment guides could be launched deployed, reducing Extra-Vehicular Activity (EVA) time needed for berthing.

The alignment guide concept dates back to the Apollo-Soyuz program where a set of very large plate petals were used to align the docking system. Fortunately, the SRMS coupled with an adequate camera/target system is capable of more accurate positioning thus, reducing the necessary size of the alignment guides, saving much weight and volume as denoted in the design.

### Capture Latch Assembly

The Capture Latch Assembly (Figures 8 and 9) is composed of four identical mechanisms which extend, capture, bring the berthing flanges together, and maintain position for the Powered Bolts to engage. The capture envelope of the capture latch compensates for misalignments between berthing flanges due to SRMS and visual errors without jeopardizing the capture sequence. Only three latches are necessary for capture, therefore allowing one failure without hindering berthing operations. The capture latch, which is fastened to the active berthing ring, is composed of a four-bar linkage driven by a motor, with an internal clutch, which is controlled internal to the pressurized element. The latch has been designed to provide sufficient force to backdrive the SRMS (overcoming the inertial of the SRMS drive motors) in limp mode. The linkages are made of 7050 or 7075 aluminum while the other components are mostly 15-5 stainless steel.

Several proposals were made for a device to bring the two berthing flanges together. The three most favorable are a capture clamp (a pincer-like device which grapples a trunnion), a gear-driven capture latch and a linkage-driven capture latch. Although the capture clamp did not need alignment guides and was similar to devices presently used in the aerospace industry, the linkage-driven capture latch was chosen based on its superior reliability and larger capture envelope. It also provides a more controlled capture (the capture latch maintains contact with the passive flange while the capture clamp allowed the trunnion on the passive flange to bounce around) and is lighter, including the alignment guides.

## Powered Bolt Assembly

The Powered Bolt Assembly (Figure 10) creates the structural tie and provides the necessary compressive force to the elastomeric seal to ensure pressure integrity. The bolts preload the joint to at least 42,275 newtons (9500 pounds) per bolt after bringing the berthing flanges into metal-to-metal contact. The bolt's guide threads move the bolt into the nut allowing them to engage without any applied load. Then, the guide threads disengage allowing the bolt to compress the flanges together (Figure 11). The 5/8-inch-diameter bolt with .625-18 UNJF rolled thread is made of Inconel 718 (AMS 5664) and coated with a dry film lubricant to help prevent galling during the nearly 400 engage/disengage cycles required. The bolt ends are tapered to help align and engage them with the Powered Bolt Nut (discussed in the PBM section). The housing is made of high-strength Nitronic 60 (UNS S21800) while the drive train is made of Custom 455 (S45500 H950). The Powered Bolt Actuator can provide up to 101.7 newton-meters (900 inch-pounds) torque to drive the bolt to the required preload. The required torque was originally only 19.78 newton-meters (175 inch-pounds), but it was found through analysis that the radial port on the Space Station Nodes, when pressurized, will deflect the berthing flange. The additional torque was necessary to overcome the flange deflections to bring the flanges into metal-to-metal contact before preloading the bolted connection.

A V-clamp was also evaluated for providing the structural connection between the berthing flanges. The V-clamp consisted of a formed metal band which tightened via drive bolts oriented tangentially around the outside of the flanges. The main reason the V-clamp was not chosen was its lack of redundancy; if one of the drive bolts failed, the clamp failed. The Powered Bolt Assembly was designed so that one of the bolts could fail without jeopardizing structural integrity. In addition, the Powered Bolt was chosen because it did not require EVA to maintain (all components are located internal to the CBM), whereas the V-clamp had most of its components external to the berthing flange. Furthermore, the V-clamp had difficulty in creating a predictable uniform clamping force.

## Differential Pressure Transducers

Due to the criticality of maintaining pressure within the berthing vestibule area, differential pressure transducers along with a monitoring system are necessary to periodically check the seal performance (Figure 12). In each ABM, two differential pressure

transducers are connected to a firmware controller that alerts the crew should the seals fail prematurely.

Pressure transducers were chosen over other methods mainly because they do not require extensive crew time to check the seals. The suitability of Pressure Decay, Flow Meter, and Trace Gas Analysis techniques were assessed in addition to Differential Pressure Transducers. The Pressure Decay and Flow Meter methods base their operation on a pressurized vessel of known volume. It is impractical to check each seal independently by monitoring the pressure in or the flow rate out of the vessel when connected to a leak check port. Since each seal must be checked on a regular basis, it is obvious that Pressure Decay and Flow Meter Methods would require a great deal of crew time as well as equipment. The Trace Gas Analysis technique involves introducing an inert gas into the pressurized volume and detecting leaks outside of the seal using a probe to check for the inert gas.. The necessary EVA to probe outside each seal location is not practical from both cost and EVA time standpoints.

#### Shear Tie Assembly

The purpose of the Shear Tie Assembly is to remove the high torsional shear load on the Powered Bolts created by the Orbiter docking to one of the cantilevered modules on the Space Station. The shear tie is made of 6061 aluminum and is, obviously, manufactured to tighter tolerances than the bolt. The tighter tolerances will inadvertently make the shear ties act as alignment guides of sorts.

Other shear-carrying devices were evaluated including an eccentric-shaped deployed pin, a pair of pins with mating slots, and a device similar to the current design, but using interlocking teeth instead of the single protrusion. The shear tie was chosen over these because it was simple, did not depend on flanges being in flat contact, was more easily aligned, and was less likely to damage the berthing flanges.

## PASSIVE BERTHING MECHANISM

### Structural Ring

The structural ring (Figure 4) of the Passive Berthing Mechanism, which is machined from a 2219 aluminum forging, has the same outside diameter of approximately 2.0 meters (80 inches) and inside diameter of 1.8 meters (71 inches) as the ABM structural ring, but is nearly twice as deep at .343 meter (13.5 inches). In order to meet clearance requirements, the additional depth of the structural ring is necessary to make up for the depth of the Active Berthing Mechanism, which is constrained by the Orbiter Payload Bay envelope, when mounted to a Node radial port. The structural ring is attached to the pressurized element by 64 bolts and sealed with a weld to maintain pressure within the berthing vestibule. The ring supports the Capture Latch Fittings, Powered Bolt Nuts, Alignment Guides, Shear Tie, and retains the berthing seals.

Originally, some of the passive berthing mechanisms on the Space Station were to include flexible bellows with actuators. Their purpose was to compensate for manufacturing and pressurization tolerance build-up around a module loop to allow it to be closed. After much investigation and testing, it was found that such a bellows system could not reliably be produced to meet all the requirements necessary to ensure mission success. Currently, the plan is to use a single compliance element to close a module loop if such a configuration is desired. The single compliance element will have fewer restrictions on it (e.g. weight, operational envelopes) allowing for a reliable mechanism to be produced using current technology without impacting the CBM design for the earlier module flights.

### Capture Latch Fitting

The Capture Latch Fitting (Figure 8 and 9) provides the hook on the PBM to receive the Capture Arm. The fitting, made of 7075 aluminum, is bolted on the passive ring in four places. The reason for the use of the capture latch assembly is explained in the Active Berthing Mechanism section.

## Alignment Guides

The eight Alignment Guides on the PBM (Figure 6), meshing with the four on the ABM, ensure proper orientation of the berthing halves relative to each other allowing the Powered Bolts to engage. Originally, all alignment guides were to be identical, but in an effort to save weight, the blades on the passive side were changed, retaining only the necessary surfaces. The design of the two alignment guides on the PBM are identical; they are simply mirror images. Again, the reasoning behind the use of these alignment guides is explained in the Active Berthing Mechanism section.

## Powered Bolt Nuts

The Powered Bolt Nut (Figures 10 and 11) is designed to float to compensate for manufacturing, pressure and temperature distortions so the Powered Bolt can still engage with misalignments between the mating berthing flanges. The nut is made of Nitronic 60 (UNS S21800) and sits on a spherical washer to accommodate the floating movements. A spring is mounted behind the nut to allow it to move backward in case the first thread was not grabbed. It should be noted that only a minimal temperature gradient can be tolerated between the berthing flanges during berthing operations because of the Class 3 thread requirement.

## Berthing Mechanism to Berthing Mechanism Seals

The current configuration uses a set of Gask-O-Seals<sup>1</sup> (Figure 14) with three seal beads to provide two-fault tolerance across the gap between the berthing flanges. The Gask-O-Seal consists of a retainer plate with machined grooves into which an elastomer is molded to create the seal element. O-ring seals were considered, but were not chosen because they were not easily maintainable. The Gask-O-Seal is maintainable because it comes in sections, allowing much easier handling during cumbersome EVA. Metal seals were also considered, but were not selected due to the high seating forces inherent in this type of seal. More importantly, the metal seals could not accommodate pressure distortions (particularly those oval in nature) between the berthing flanges.



## CONCLUSION

Currently, development testing is being performed on the aforementioned hardware at both the component and system levels to refine the design. The tests have been formulated to cover a broad range of design scenarios which require confirmation and/or validation of current design approaches and analysis techniques, as well as to test attainability of imposed manufacturing complexities. The planned development tests will:

- Provide data on the ability of mechanisms to withstand static and vibrational launch loads;
- Demonstrate reliable mechanism performance in a thermal vacuum environment;
- Test the Berthing Mechanism Actuator and Control System performance;
- Evaluate the integrated performance of the Alignment Guides, Capture Latch and Powered Bolts;
- Evaluate the effects of capture and berthing dynamics on the seals and seal surface;
- Evaluate the ability of a fully berthed assembly to withstand proof and ultimate pressurization of the vestibule; and
- Evaluate the effects caused by on-orbit loads resulting from Logistics Module berthing, station reboost and Orbiter docking.

It is believed that the current configuration will meet all program requirements with minor modifications and will be ready for flight in May 1997 when Node 2 is launched.

## ACKNOWLEDGEMENTS

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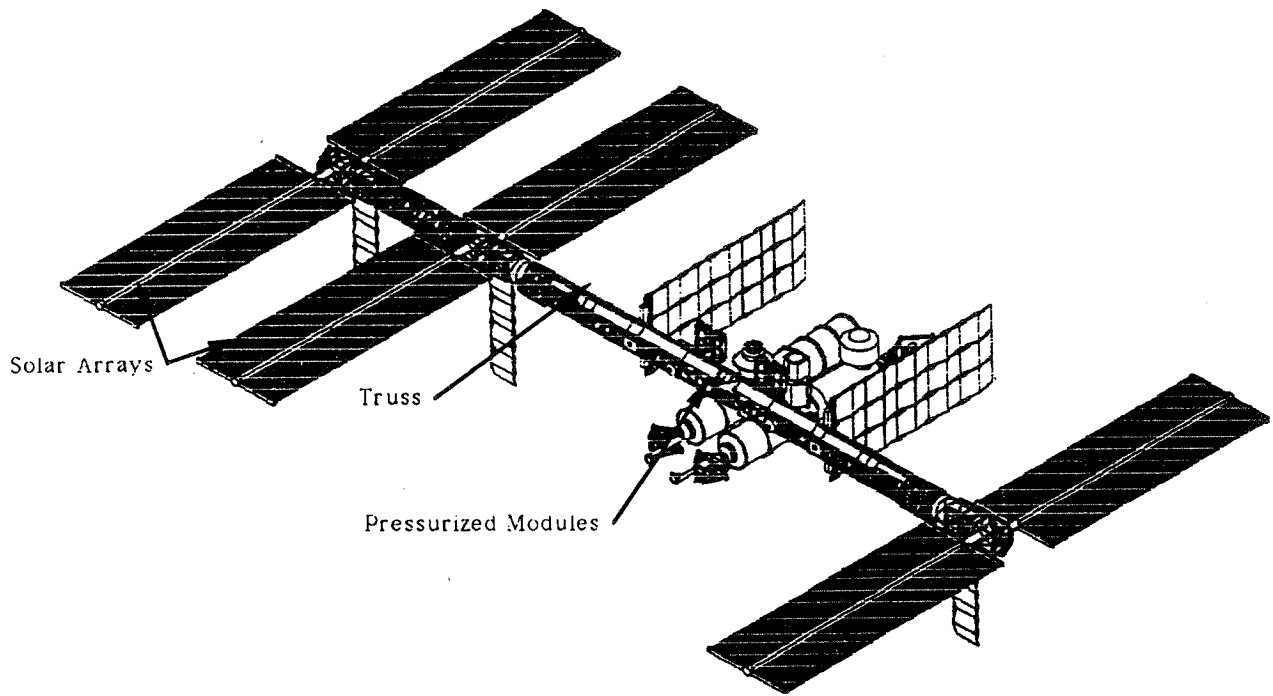


Figure 1--Space Station Freedom

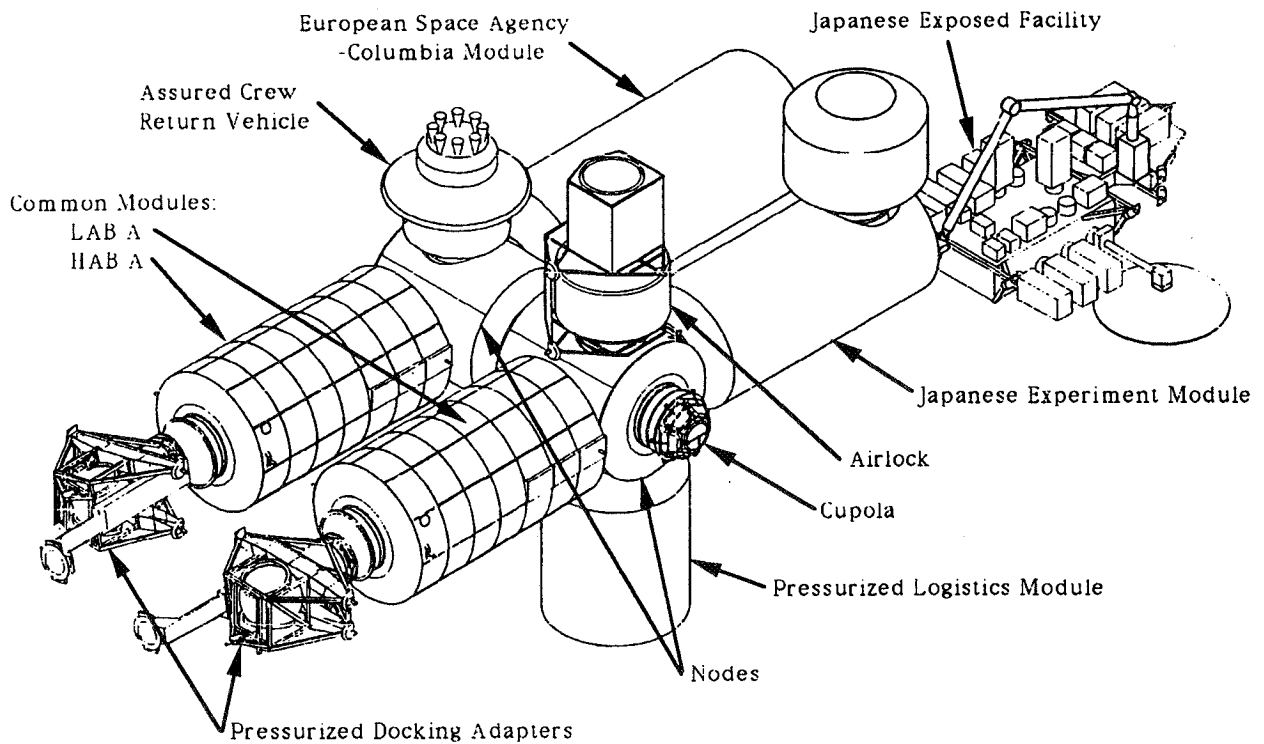
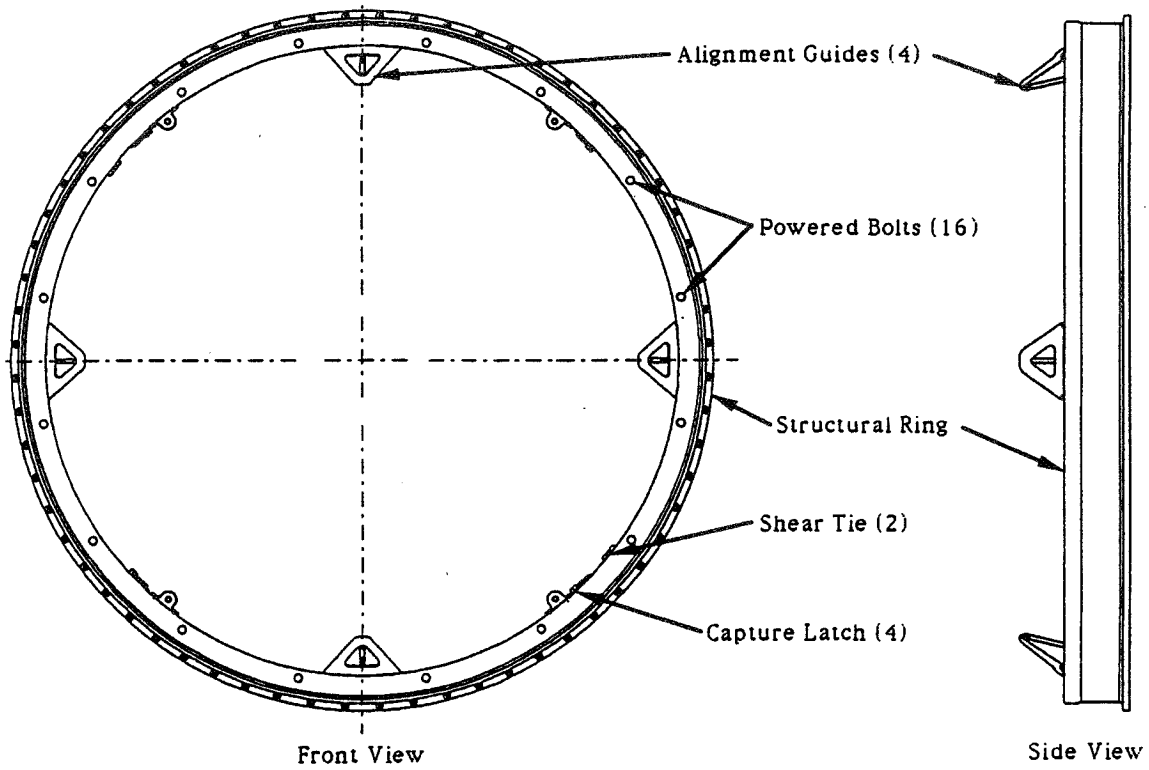
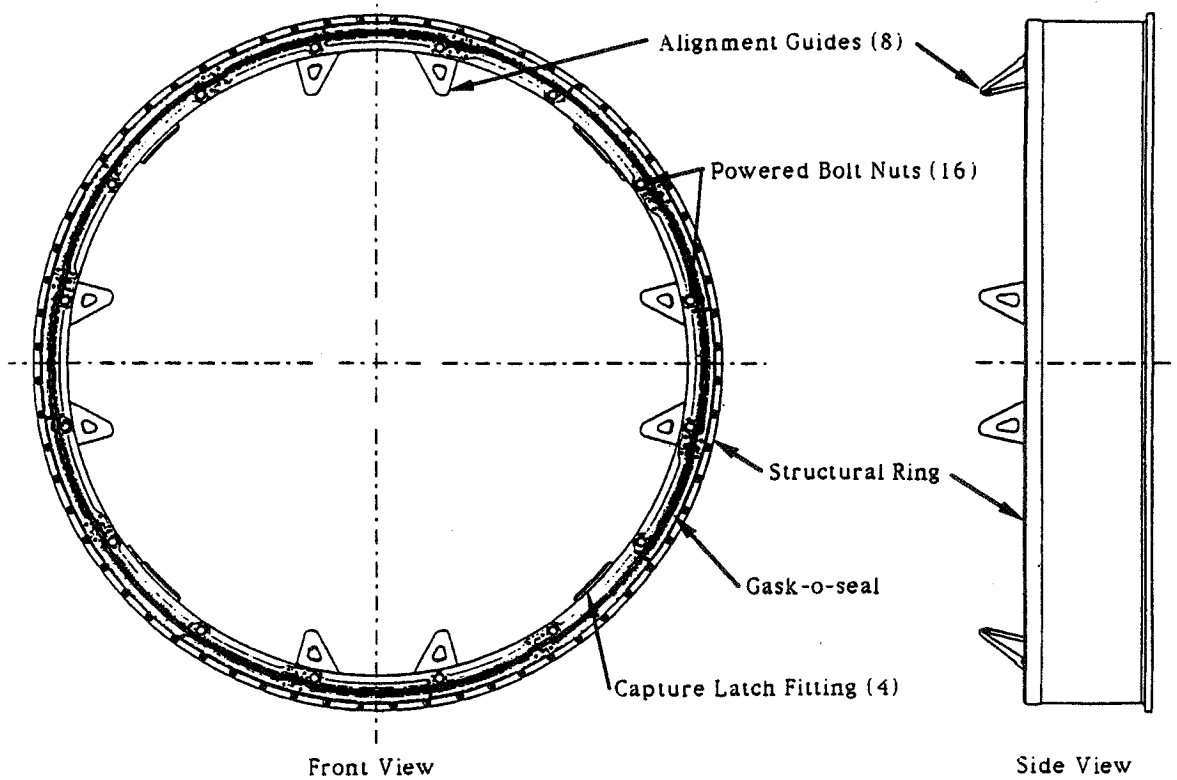


Figure 2--Space Station Freedom Pressurized Module Pattern



**Figure 3--Active Berthing Mechanism**



**Figure 4--Passive Berthing Mechanism**

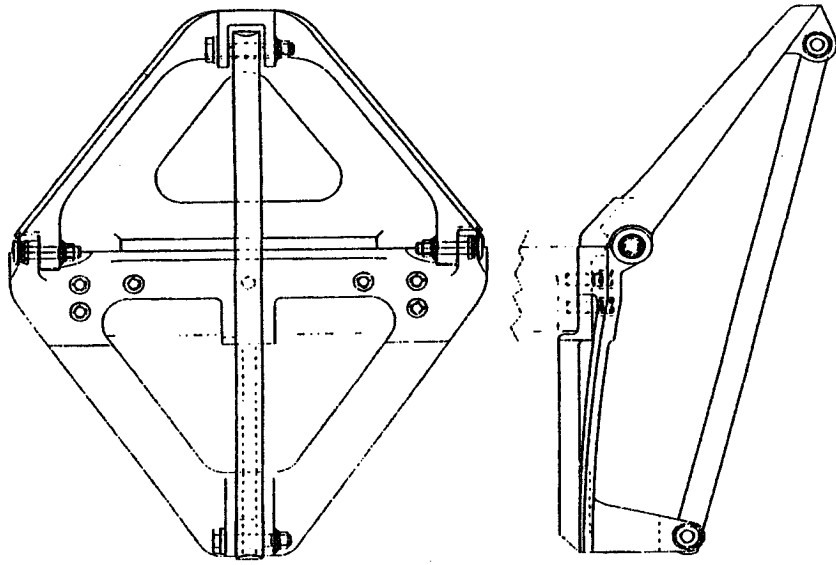


Figure 5--Active Berthing Mechanism Alignment Guide

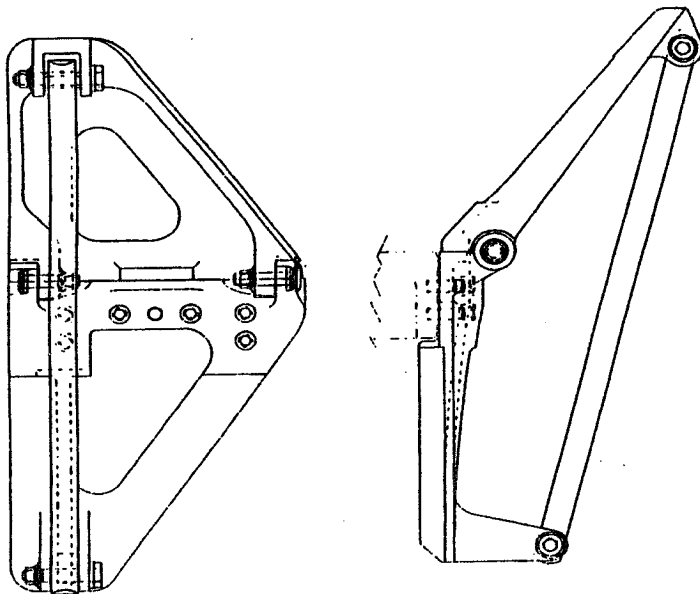


Figure 6--Passive Berthing Mechanism Alignment Guide

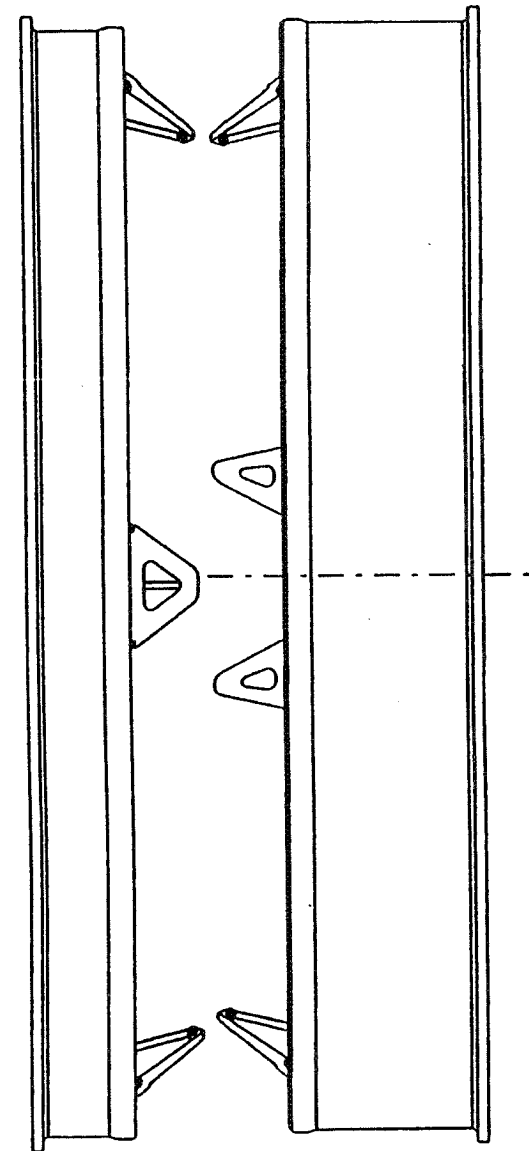


Figure 7--CBM Connectivity

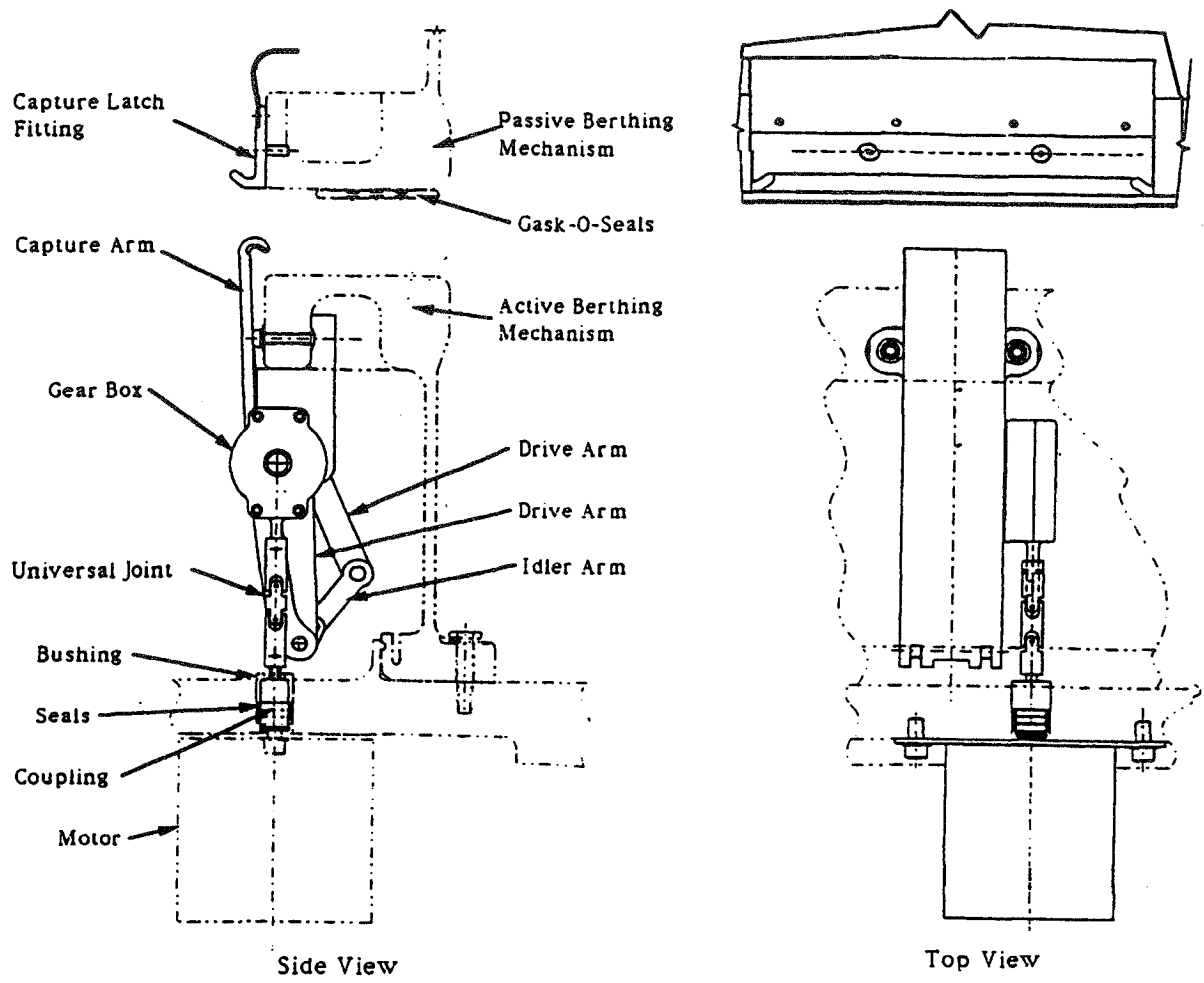


Figure 8--Capture Latch Assembly

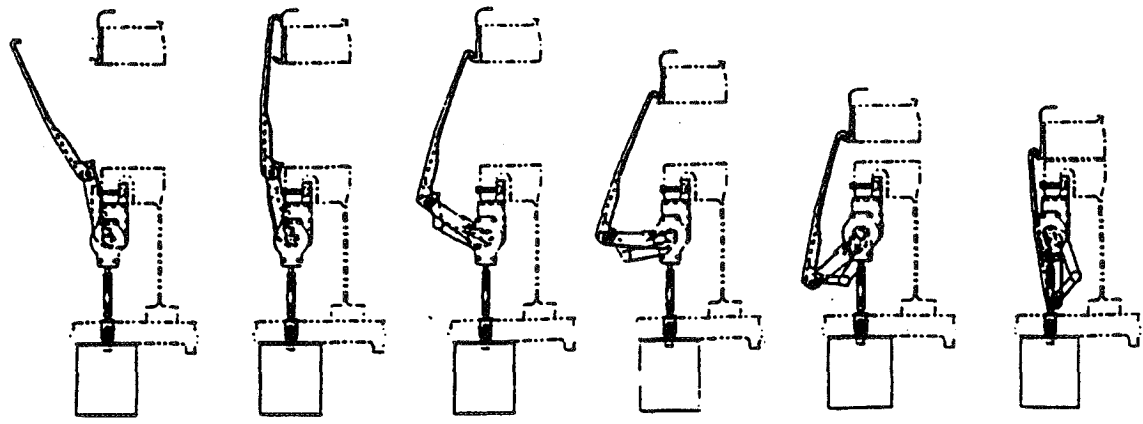


Figure 9--Capture Latch Motion

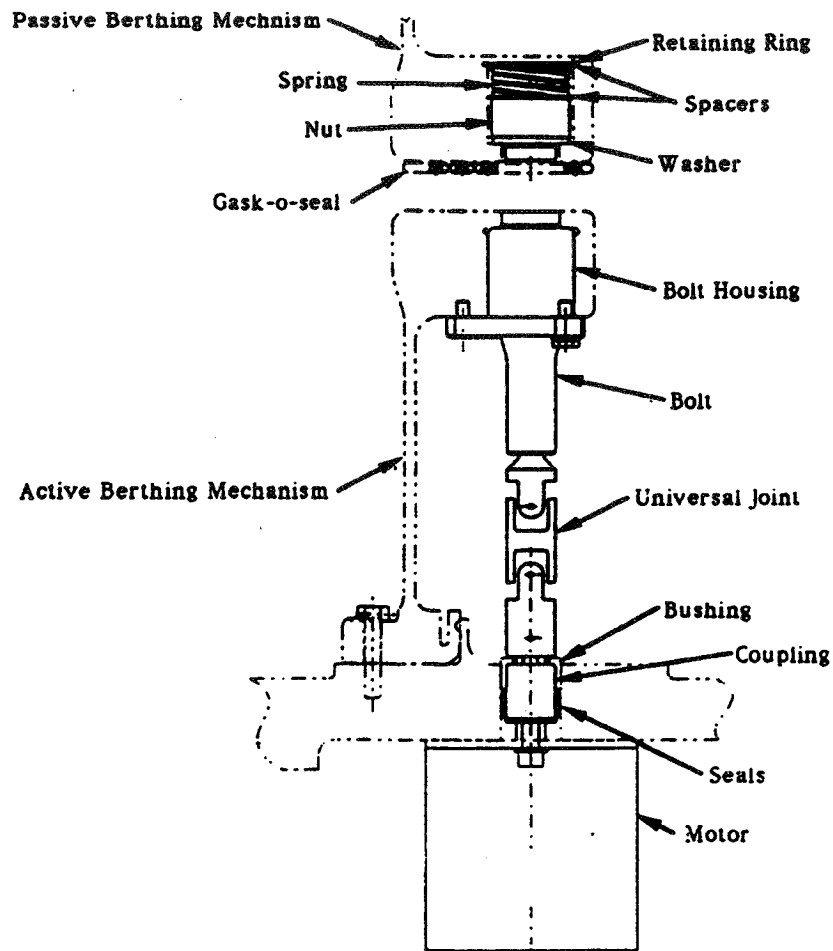


Figure 10--Powered Bolt

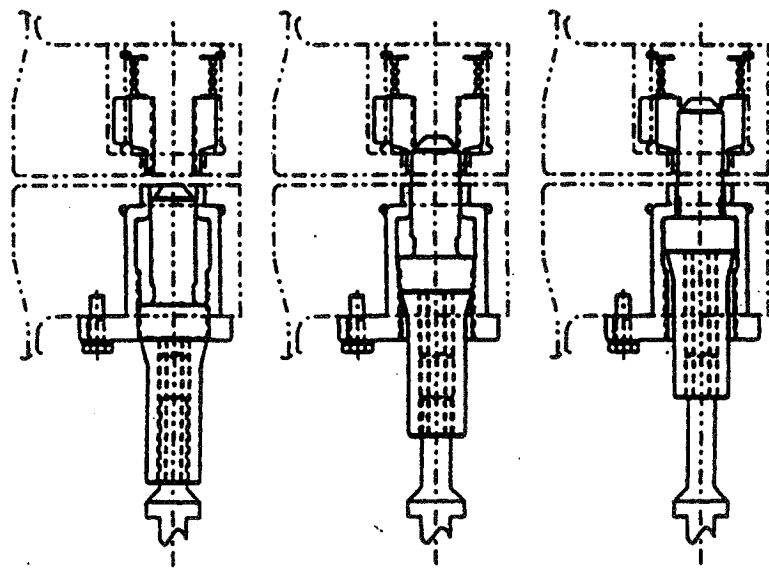
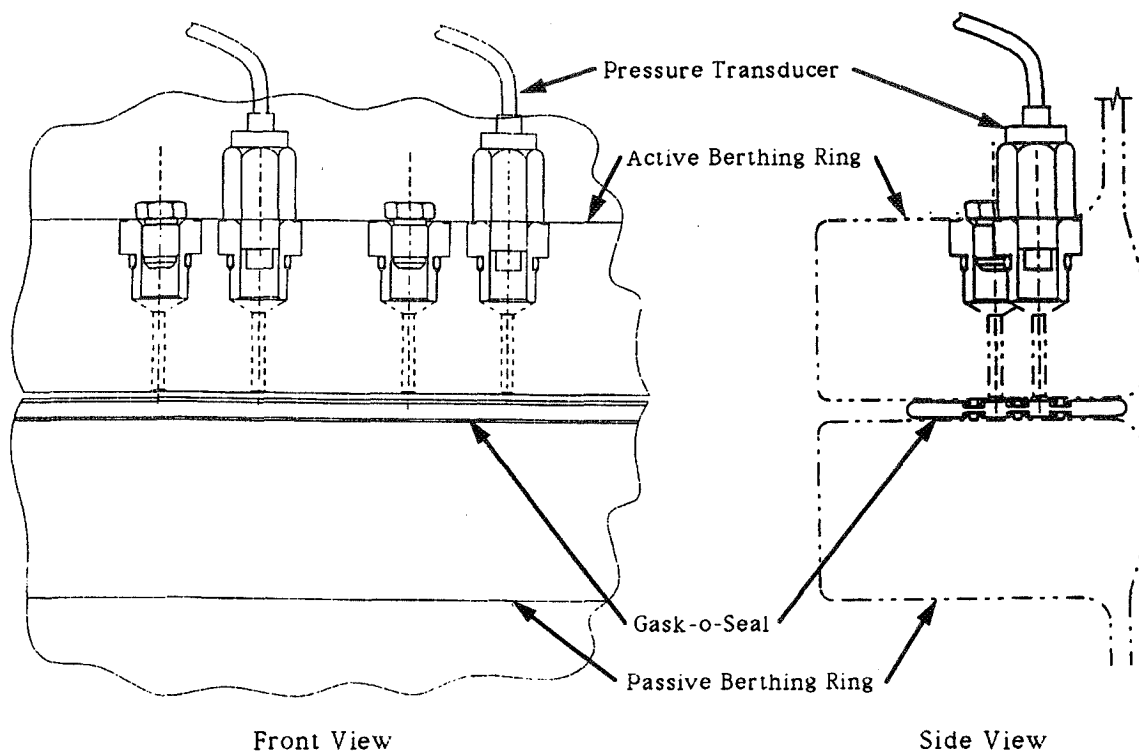
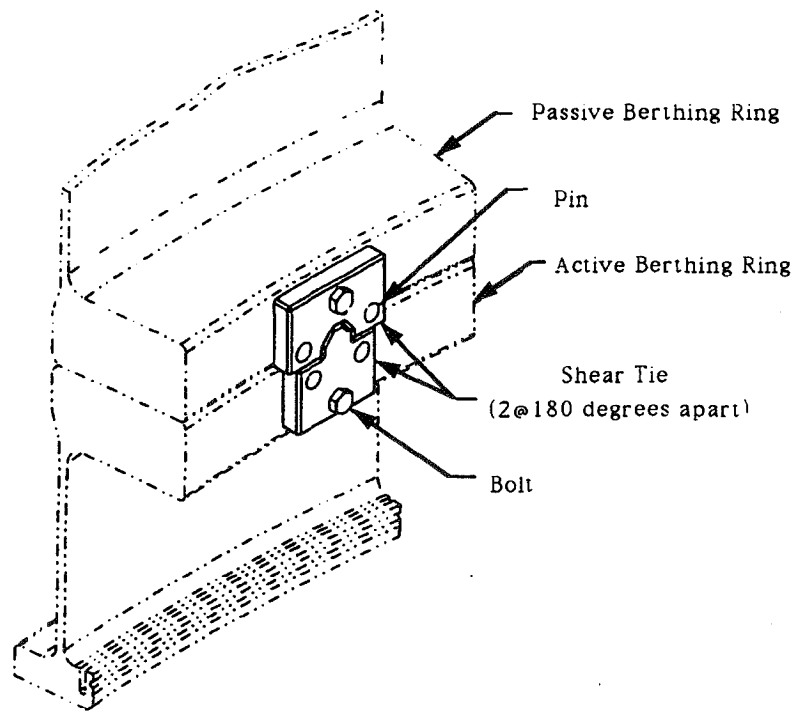


Figure 11--Powered Bolt Motion  
 (Note: Seal not shown for clarity)



**Figure 12--Differential Pressure Transducer**



**Figure 13--Shear Tie**

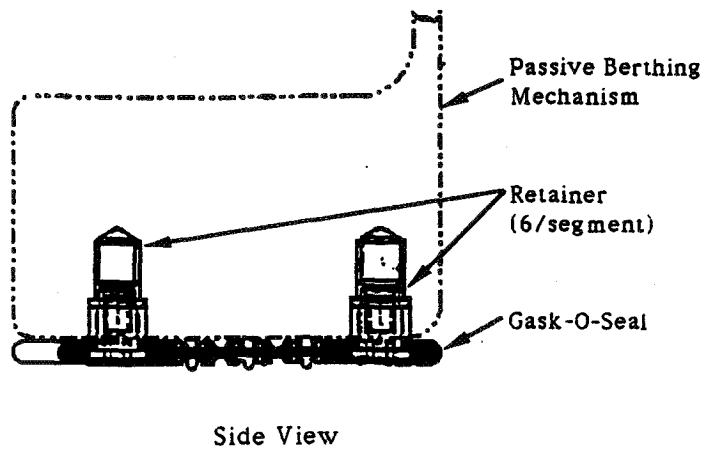
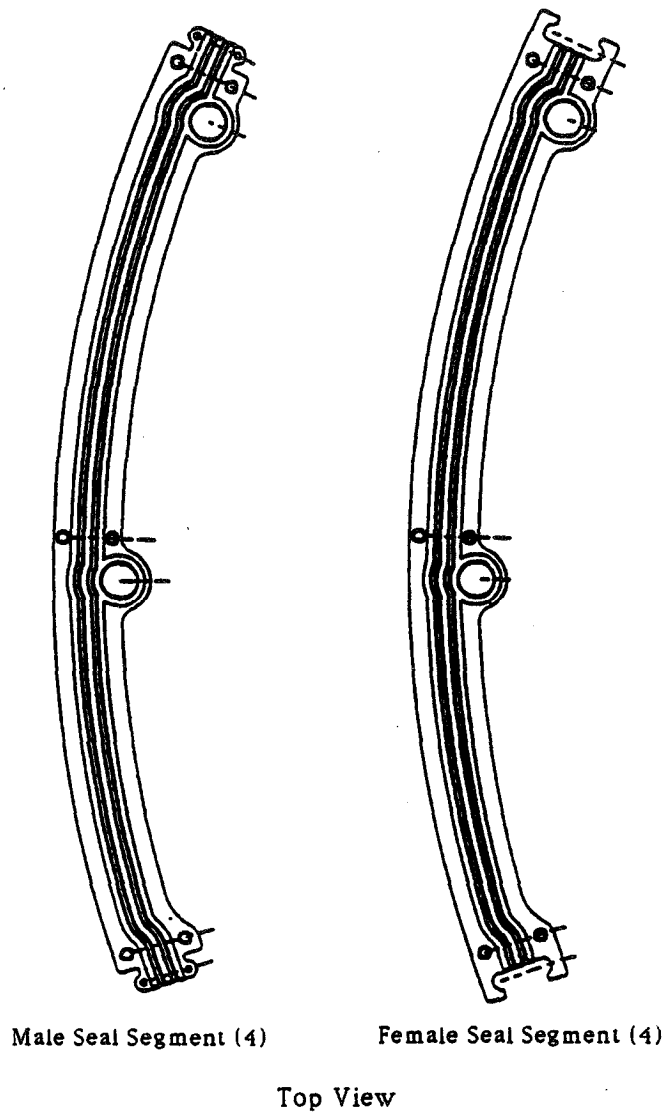


Figure 14--Gask-O-Seal