PNEUMATIC PRELOADED SCANNING SCIENCE LAUNCH LATCH SYSTEM*

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ABSTRACT

Sophisticated spacecraft science payloads mounted to scanning or pointable platforms required preloaded platform launch latches with a low shock release. Brainstorming and trade studies conducted by JPL and Northrop Aerospace resulted in a relatively simple system using a preloaded pneumatic piston latch with a pyrotechnic valve release. The system was the only candidate that met all the imposed requirements utilizing reliable state-of-the-art components. This paper traces the development of the latch system from its first use on JPL's Mariner '69 Mars Flyby Spacecraft through its most recent use on the Voyager Spacecraft that will fly to Jupiter and Saturn.

INTRODUCTION

A pneumatic preloading latch system has successfully met the need for a high-reliability, low-shock launch latch for science instrument scanning platforms on JPL spacecraft for all missions since Mariner '69. The increasing size, weight and complexity of scanning payloads on interplanetary spacecraft demands special attention to launch load transfer to stationary structures. The load transfer must consider the control of instrument launch environment and releases the platform on command after the boost phase of the mission. Special problems were preloading of joints, control of pyro shock, cleanliness of release, reliability and testing of the system. Studies conducted during the first design of the pneumatic latch showed non-preloaded joints, rapid release of strain energy and close coupled structure borne pyro shock were the contributors of environmental conditions that needed to be eliminated in a science latch. Several devices, such as pyro actuated release nuts, explosive bolts and pinpullers, failed to meet at least one of the criteria established for an acceptable system. A gas pressurized preloading cylinder type of latch met all launch load requirements. The release event using a pyrotechnically actuated valve to bleed off the nitrogen gas resulted in a soft release with low shock levels at the instruments.

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This paper presents the history and evolution of the pneumatic latch system. Some of the testing and flight application information are also presented. Several test problems and pieces of information relative to challenges of the design are also discussed.

BACKGROUND INFORMATION

Scanning science platforms in excess of 50kg have been flown on several JPL spacecraft. The normal boost vehicle induced environment on such a platform is usually in excess of the load carrying capability of the support bearings or structure needed for other phases of the mission. A structural mount in parallel to cruise load path is required for launch. The device used to latch the platform to the structure must meet a long list of constraints and desirable traits to be selected for use. The specific requirement used in selection of a pneumatic latch were:

1. ability to carry the launch loads to the latch points;
2. latch joints must be linear through the load range;
3. release should be slow to minimize shock from stored energy;
4. electrical power for latch release should conform to pyro-type pulse;
5. contamination and release effects on spacecraft should be minimized;
6. device should have a relatively long shelf life;
7. maintenance should be simple for successive uses;
8. latch up and monitoring of preload should be simple and continuous;
9. reliability and failure modes should be understood;
10. flight telemetry should be built-in and simple;
11. weight and cost should be compatible with aerospace technology.

Initial studies and a later reevaluation of available release deivces considered four devices as prime candidates for the job. They were: 1) pyro release nuts; 2) pyro pinpullers; 3) ball detent locks (Quantic Industries type); and 4) preloading pneumatic latch devices. All of these devices are used in todays spacecraft for various functions and a strong case can be made to use each one as a platform latch. Trade studies determined that the pneumatic latch was able to meet all requirements and was definitely superior to other latches in two major areas. First, the pneumatic latch gave the best controlled release with little or no pyro shock effects. Second, the pneumatic latch had better reuse capability. The only drawback seemed to be in the area of weight required to make a personnel safe pressure vessel for the preloading cylinder. In summary, the pneumatic latch was chosen and has been used in various configurations on scan platforms on all JPL interplanetary spacecraft since 1969.

DETAIL DESCRIPTION

Stress related details of the design of the pressure vessel and latch components is all state-of-the-art technology and will not be discussed except in relation to philosophy of the configuration. The first pneumatic scan platform latch designed at JPL contained a single acting piston and return spring, a torsion spring pivoted tee-bar latch, interconnecting plumbing, pyro release valve, pressure transducer and various load and tie-down hardware. The cross-section of a typical Mariner spacecraft cylinder and the pneumatic schematic are shown in Figure 1.

This unit was used satisfactorily on Mariner '69, '71 and '73. System tests performed during the development program proved that the performance was exceptional. Leakage of nitrogen gas past the viton piston seals was so small that it could not be measured in a 30-day pressure monitoring test. Two items of interest showed up in the test program that caused further development effort. First, the restrictor used to release the gas to control the unlatch rate would have to be dual function; one, trap debris from blow-by of the pyro valve piston without clogging; two, control flow. This was accomplished by using a sintered porous plug of 25-50 micron filter material in the line in front of the 5-10 micron plug used to produce a controlled pressure drop. This approach was successfully tested and has been used in all the systems to date. The second item of interest was the pressure fill valve, shown as part of the pyrotechnic valve in Figure 2, did not seal reliably if torqued to specification on successive uses. To cure the problem, the ball valve seat was lapped to renew the sealing surface and an O-ring sealed cap was added to the fill port. These measures combined with a procedure to reduce the torque on the ball valve any time it was closed except during final prelaunch pressurization eliminated the problem. One peculiarity that showed up in flight was a delayed tee-bar withdrawal after bleeddown. The flight telemetry data provided by an event switch on the rotating tee-bar did not trip for a few minutes after the pressure bleed-off. Testing at JPL to check this phenomenon showed the cause to be long-time cold flow of the O-ring seals into the machining imperfections of the mating surface. The breakout force was not overcome immediately by the piston return spring resulting in a delayed release of up to two mintues. No corrective action was taken to change the design once the situation was understood but the event time was increased to allow sufficient time for operation.

For the Viking Program, a complete redesign was undertaken resulting in the cross-section and schematic shown in Figure 3. The items of special note were the double acting piston design that eliminated the time delay phenomenon noted above and weight reduced components that used light metal alloy parts in place of all steel construction. A further departure from previous designs was the use of elastomer sealed bolted connections between the tubing and the cylinders instead of an all welded design. This reduced the cost of parts and made system cleaning and maintenance much easier. The seal in the joint was a special viton face seal washer "Gaskoseal" provided by Parker Seal Company used as shown in Figure 4. It should be noted that although seven of these seals were used in the system, no leakage problems were ever encountered. The double acting piston approach provided extra margin for unlatch because the differential area of the piston developed considerable unlatching force as pressure approached equalization on both sides of the piston. A typical blow down event is shown in Figure 5 where the reduced data indicated a 200-pound (890 N) additional force to move the piston. In the event of a piston bind, the pressure would tend to increase on the large area side of the piston and raise the total unlatching force to approximately 800 pounds (3560 N).

The evolutionary process of the scan platform latch was ongoing for the Voyager spacecraft. In this case a swingout boom mounted scan platform was used that required an axial withdrawal of a collet latch instead of the previously used rotating tee bar. This change was made because the spring deployed boom could introduce forces that prevented a gap from developing between the tee bar and its mating part preventing its movement. The system made use of all the previous developments. The Voyager latch cross-section is shown in Figure 6. Development of this system was uneventful and modifications of the operation were minimal. An item of interest for the mechanism designer is the collet made from titanium with some interesting manufacturing innovations. It was manufactured as a turned part, the nine finger slots were made by a single electro discharge machine pass and it was shotpeened on the inside to open the fingers of the collet to allow easy stud withdrawal. The Voyager spacecraft launched in 1977 unlatched its platform according to plan and all platform mounted science worked successfully.

SAFETY RELATED PROBLEMS

As mentioned earlier in the paper, the methods of calculating stresses in pressure vessels is well known but complications arise when pressurized units are used around personnel. One of the big problems of weight reduction of the pneumatic latch is that it is often under full pressure when the spacecraft is being worked on. Safety requirements are therefore enforced on the design. The latches shown for Viking and Voyager in this paper are admittedly heavy since they met ASME boiler code requirements, i.e., Proof Test to twice working pressure with burst capability of four times working pressure. This seems an undue penalty but if ignored the operational approvals to use the equipment may be a greater problem than the extra weight. No specialized equipment is required to support a pneumatic latch since JPL fills from standard "K" bottles of clean nitrogen.

CONCLUDING REMARKS

The penumatic latch concepts presented in this paper give the mechanism designer a versatile tool for use as a launch latch in space applications. The concepts involved contain no statistical qualification requirements or shock tests as is often the case with direct acting pyro devices. Careful design builds in reliability and functional margin that assures successful operation.

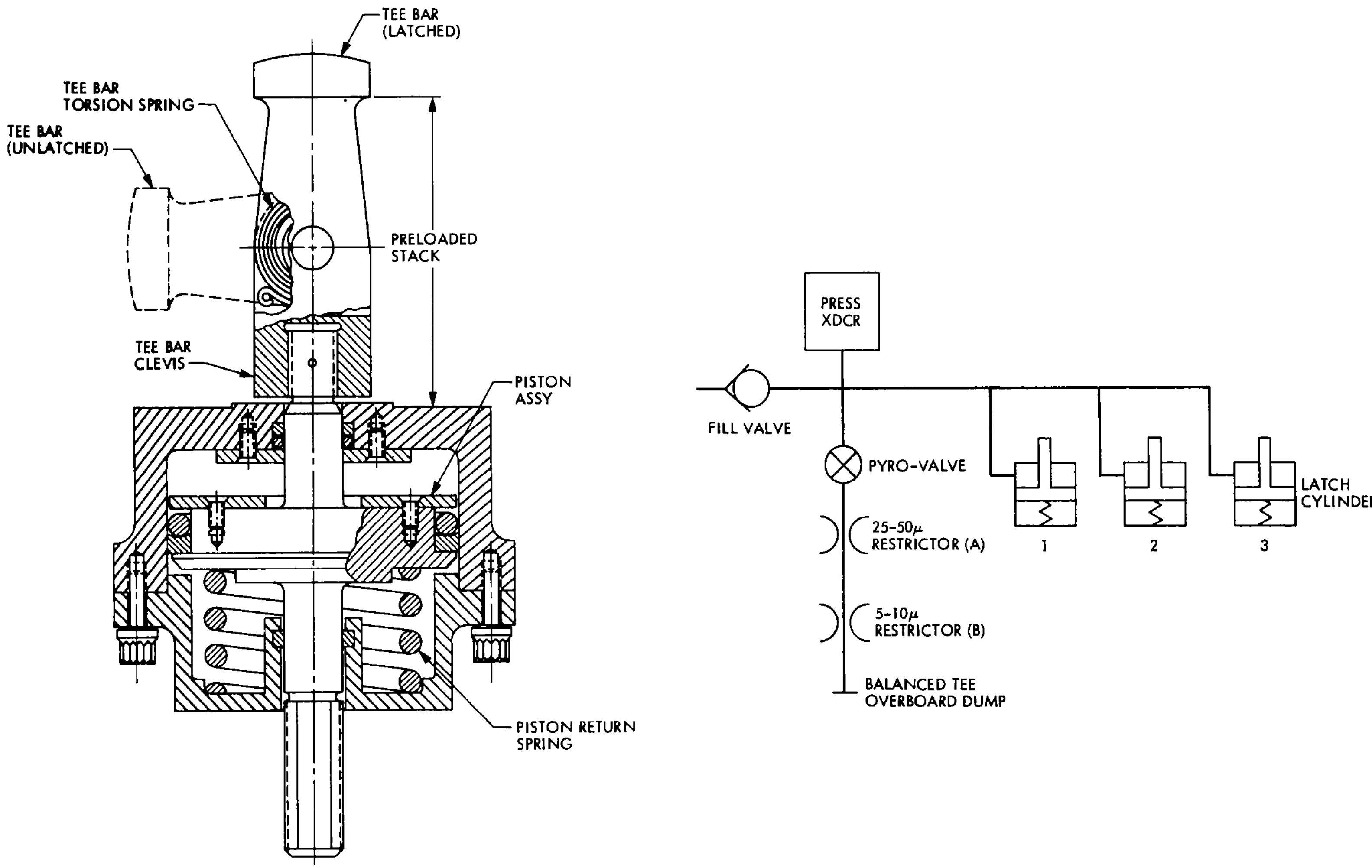

Figure 1. Mariner Pneumatic Latch System and Schematic

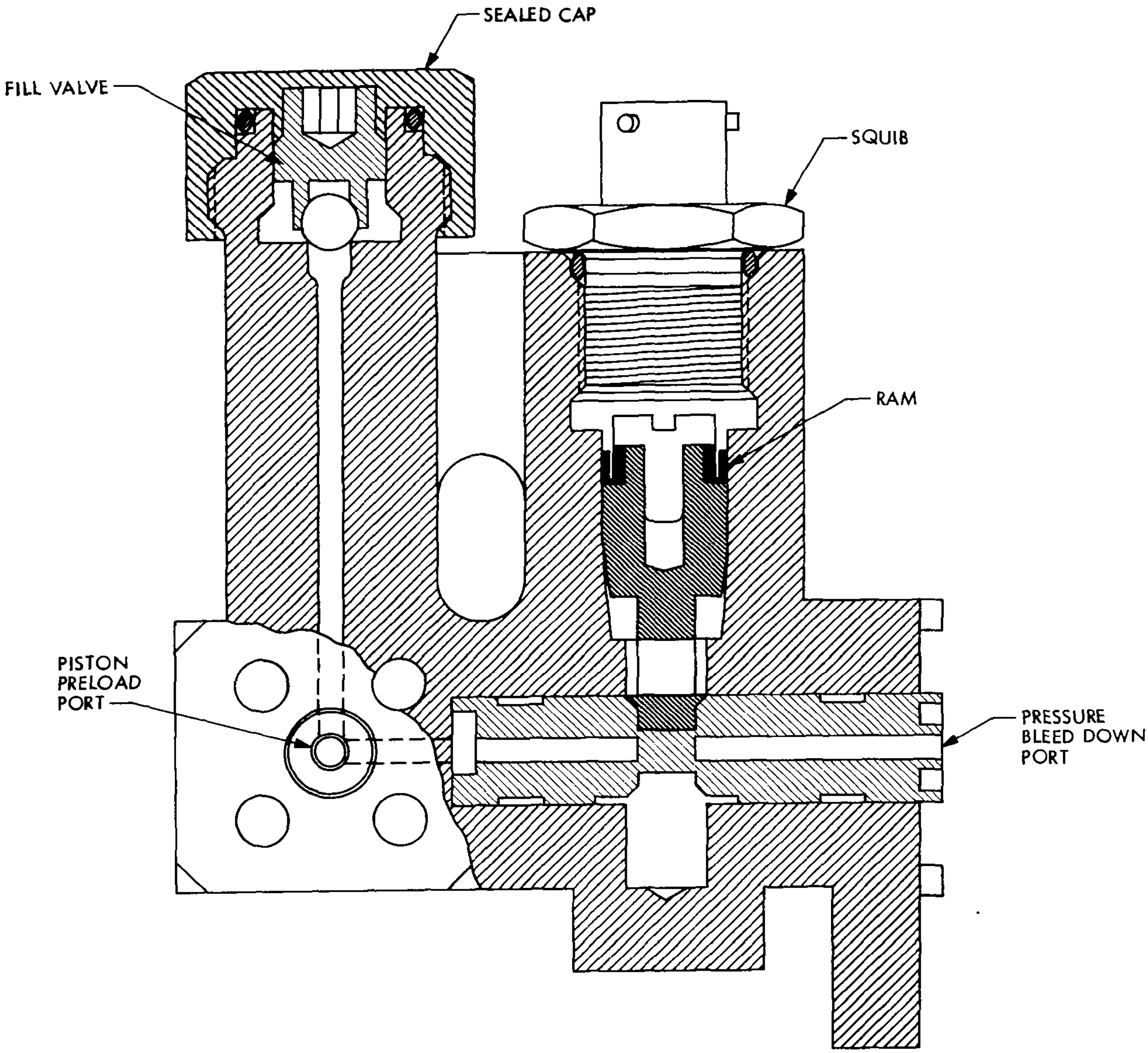

Figure 2. Normally Closed Pyro Valve Assembly

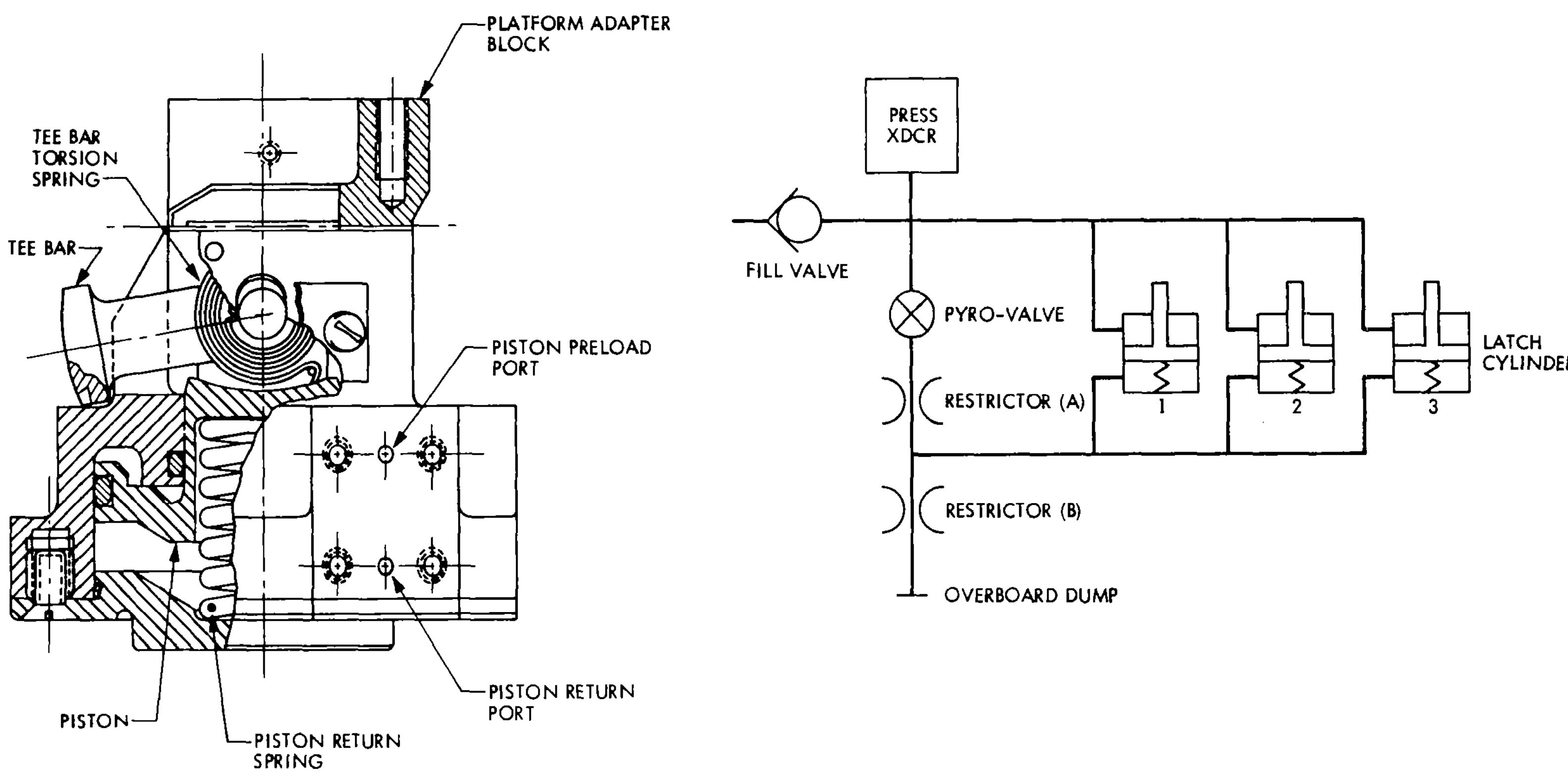

Figure 3. Viking Pneumatic Latch and Schematic

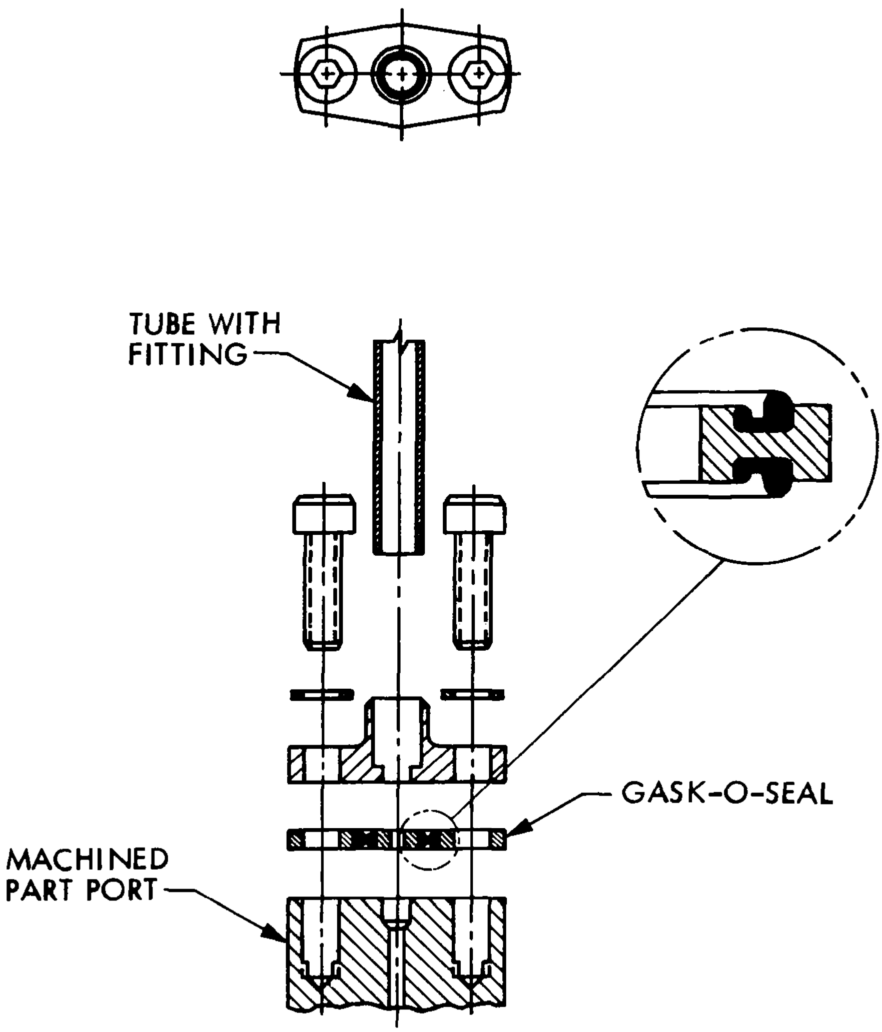

Figure 4. Gask-O-Seal Joint

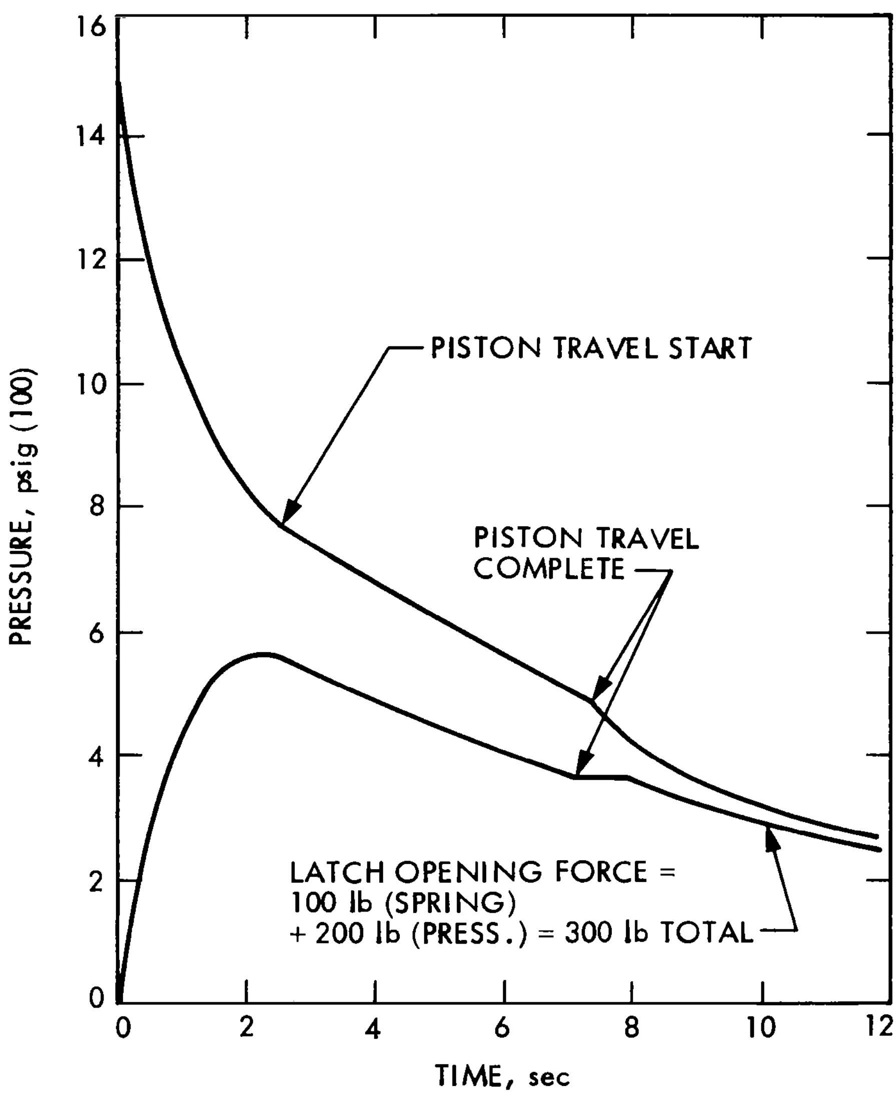

Figure 5. Viking Orbiter System - Struc/Sep Review Scan Latch Blow Down Cycle

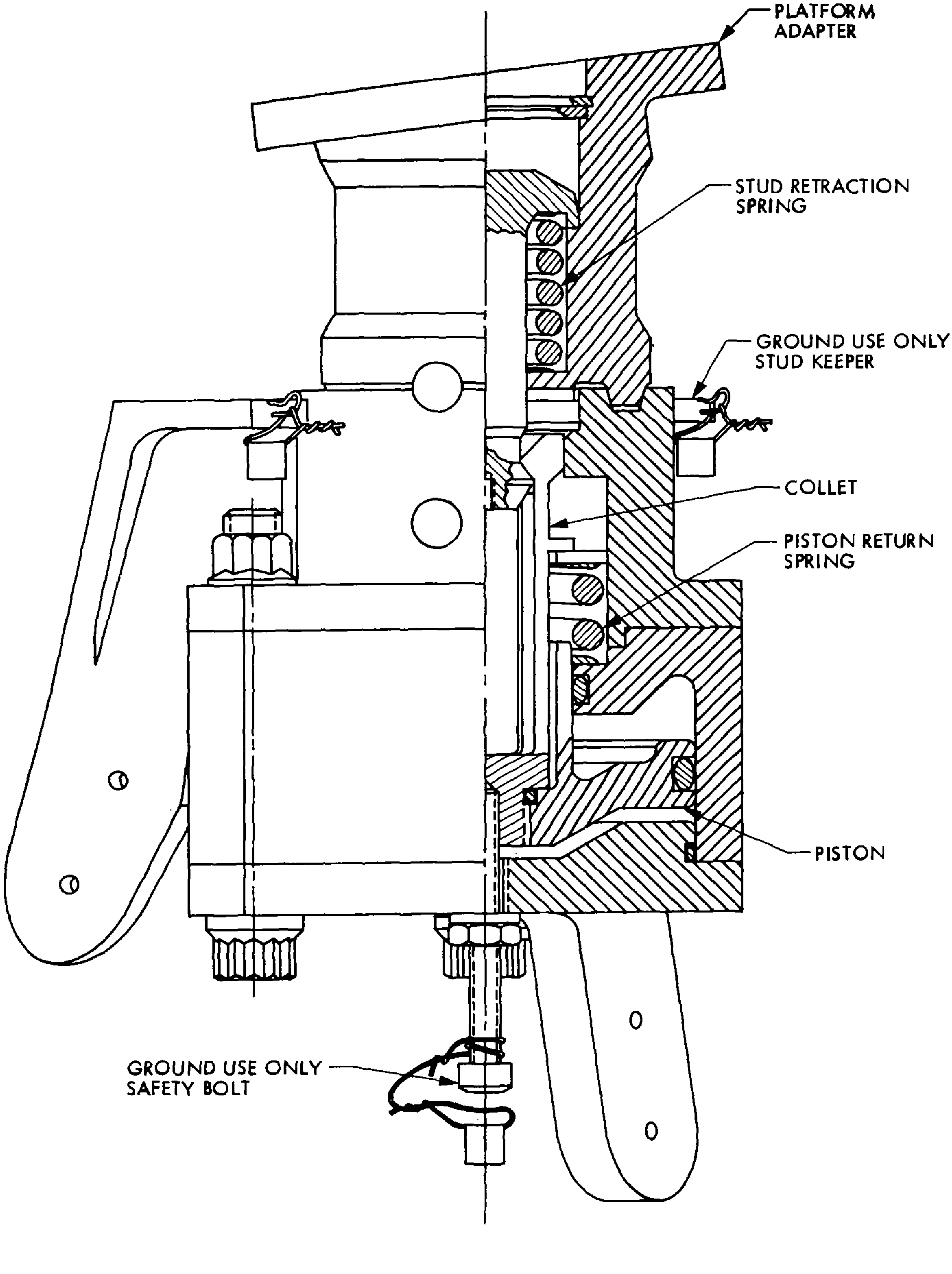

Figure 6. Voyager Scan Platform Latch