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INSTALLING SCIENTIFIC INSTRUMENTS INTO A COLD LHe DEWAR — THE GRAVITY PROBE B APPROACH

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ABSTRACT

Gravity Probe B is an orbital test of Einstein's general theory of relativity using gyroscopes. The precession of the gyroscopes will measure both the geodetic effect (6.6 arc sec/yr) through the curved space-time surrounding the Earth and the motional effect (0.042 arc sec/yr) due to the rotating Earth dragging space-time around with it. To achieve the extraordinary accuracies needed to measure these small precessions, it is necessary to have the gyroscopes operating in the following environments: a vacuum of $< 10^{-10}$ torr; an acceleration level of $< 10^{-10}$ g's; a magnetic field of $< 10^{-7}$ gauss; and a temperature near 2 K. This paper discusses designs that allow scientific instruments to be installed into a dewar at 4.2 K. Methods for structurally supporting the instruments, transferring heat across joints at low temperature in vacuum and excluding air during the insertion process are discussed. The structural support method is designed for Shuttle launch loads. The separable heat transfer joints are needed for cooling the instruments through the four cool vapor cooled shields and structural support in the dewar. Both structural and thermal resistance test data for the joints are presented. A design of a helium purged air lock is discussed that allows the insertion or removal of the instruments into or out of the dewar. The design permits multiple insertions and removals without refurbishment.

INTRODUCTION

This paper is an update of work reported previously.[1] The precession of the gyroscopes is measured with highly sensitive magnetometers, DC SQUIDS, using the London moment. To achieve the extraordinary accuracies needed, the magnetic field background has to be lowered from 0.6 gauss (Earth's field) to $< 10^{-7}$ gauss. This reduction is achieved by expanding a series of folded lead bags immersed in liquid helium. The lead traps the magnetic field it sees as it cools and passes through its superconducting transition temperature of 7.2 K. Succeeding folded bags are inserted inside the previously expanded bag. The expanded bag is removed and the new folded bag is then expanded. This process is repeated as many times as required.

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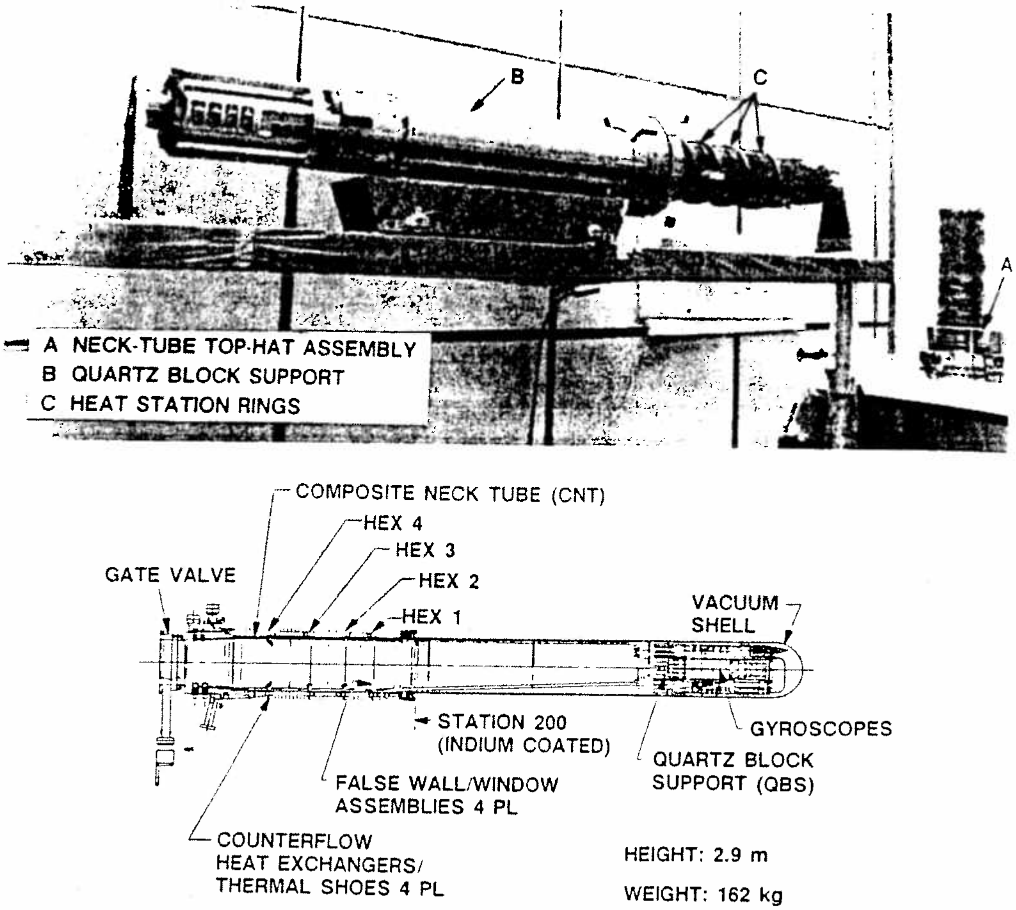

Fig. 1. Probe.

The magnetic field can thus be "pumped" down to the low value required. This requirement drives the design of the 2.9 m long probe (Figure 1) in which the gyroscopes are mounted and the bucket dewar design in which the probe is mounted (Figure 2). Features are discussed which allow the lead bags to be expanded in the dewar well while immersed in liquid helium and the probe to then be inserted without introducing air or allowing the lead bag to warm above its superconducting transition temperature. The probe can also be removed for servicing without warming up the dewar. The approach or portions of the approach may be applicable to other projects where it is necessary to insert or remove scientific instruments into cold dewars for servicing, repair etc. without having to warmup the dewar.

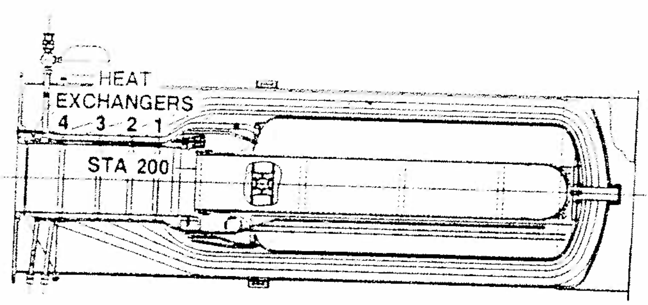

Fig. 2. Engineering development dewar.

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An Axial Lok design
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APPLICABLE FEATURES OF THE DEWAR AND PROBE DESIGNS

The first dewar built for ground testing of the gyroscopes has a well (Figure 3) in which the probe is inserted. The well design has the same features for both the ground test dewar and the flight dewar[1] to be built later. The top half of the dewar well consists of a gamma alumina/epoxy necktube for thermal isolation reasons. Four bonded copper rings in the composite neck are used for transferring heat out from the vacuum sealed, probe necktube through 6 thermal shoes at each of four heat stations. The lower half of the well is part of the 6061-T6 aluminum helium tank. In the composite/aluminum joint area (Sta 200), the major structural support and heat transfer occurs for probe cooling to 2 K.

An Axial Lok design shown in Figure 4 and reported previously[1] uses three dog clamps which are rotated in and clamp the indium coated probe surface to the dewar aluminum surface with a total force of 26,400 N. Details of the Axial Lok operation are reported in reference 1.

THERMAL SHOE TEST RESULTS

The thermal shoe shown in Figure 5 consists of a removable beryllium copper spring attached to a pivot, and a pure copper heat conduction strap attached to a shoe, which conforms to the seat area of the dewar stop ring. The contact area of the strap is plated with indium which cold flows to provide optimum contact. The dewar stop ring contact area is rhodium coated to prevent copper oxidation and diffusion bonding of the indium. The radial force on each shoe (Figure 6) is generated by bending the spring as the Axial Lok clamps pull the probe into the dewar. This force plus the indium coating minimizes the thermal resistance at each of the 24 shoes. Upon removal of the probe, the indium remains bonded to the strap, ready for another insertion.

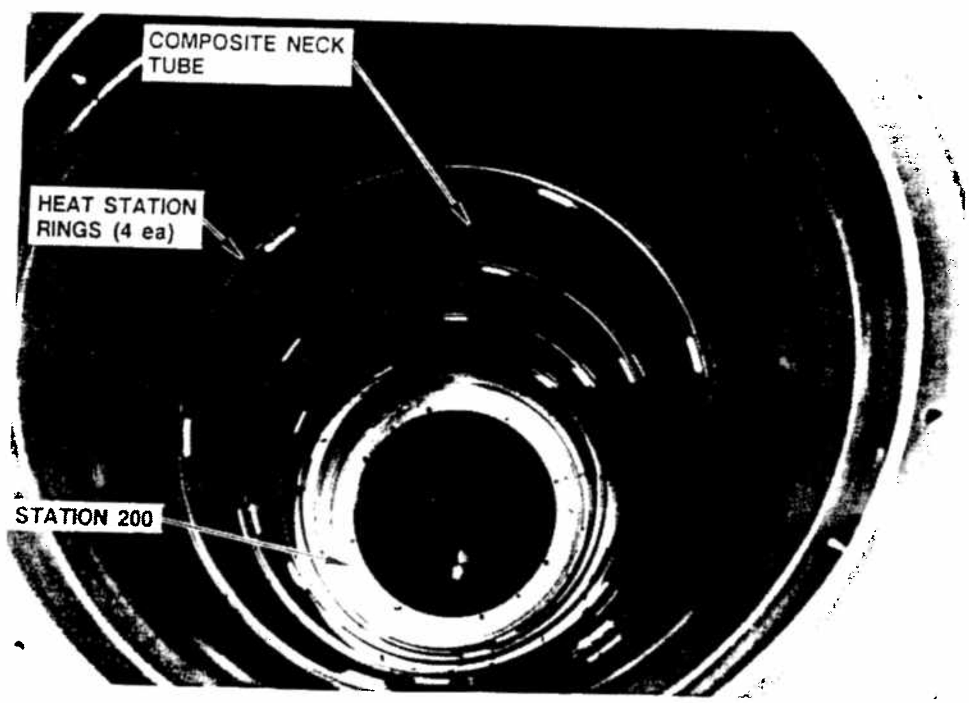


Fig. 3. Dewar well.

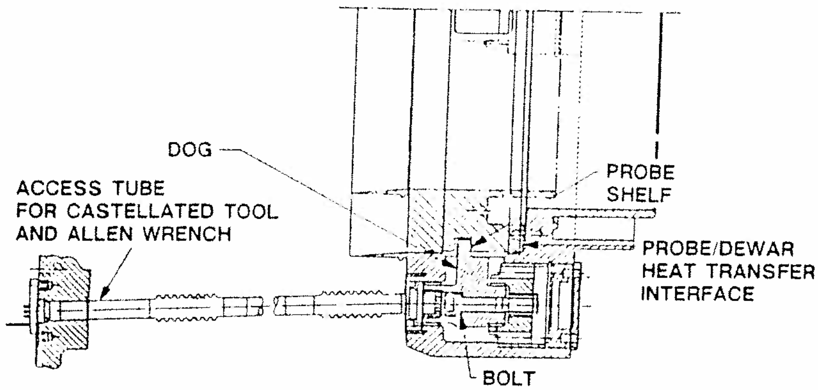


Fig. 4. Axial Lok.

AXIAL LOK TEST RESULTS

Thermal resistance measurements were made at the indium coated 6061 aluminum probe to an uncoated 6061 aluminum dewar interface shown in Figure 4. The area of contact is 0.0142 m^2 and average force per unit area is 1.8 MPa. The surface roughnesses were ~ 32√ and the surfaces flat to within .003 cm.

Tests were made both with and without the indium coating on the probe to see how the .008 cm-thick coating enhanced heat transfer. The results (Figure 7) show some improvement using the soft indium. Also, the joint was broken and remade 3 times. Note the results are repeatable. There was no evidence of indium transferring to the uncoated aluminum dewar surface.

AIRLOCK OPERATION

To prevent air from freezing in the liquid helium filled dewar well, it is necessary to exclude air while inserting lead bags or the probe. A number of different sized

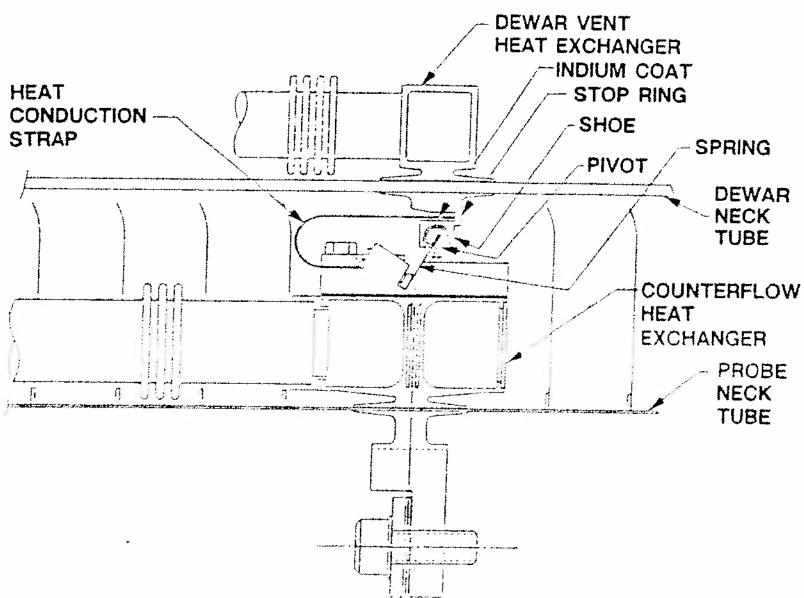
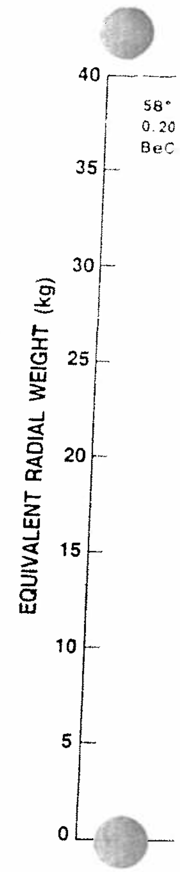


Fig. 5. Thermal shoe design.



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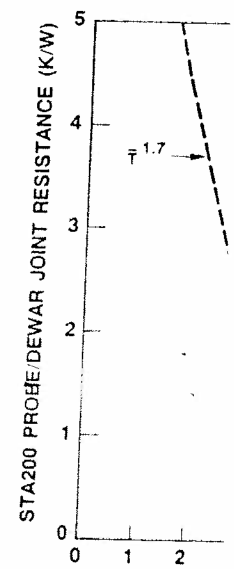
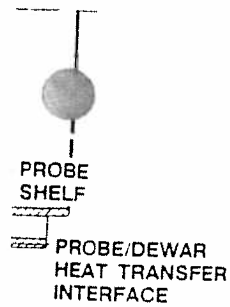


Fig. 7



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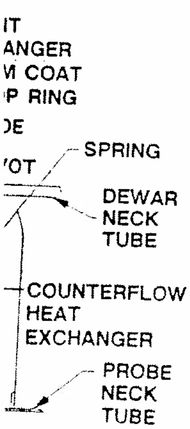

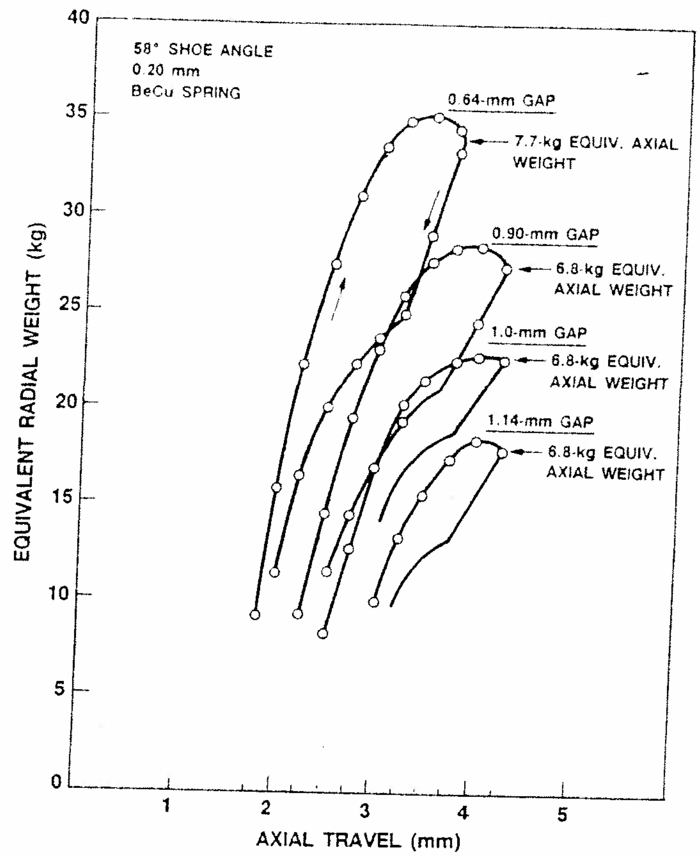

Fig. 6. Measured thermal shoe radial and axial loads.

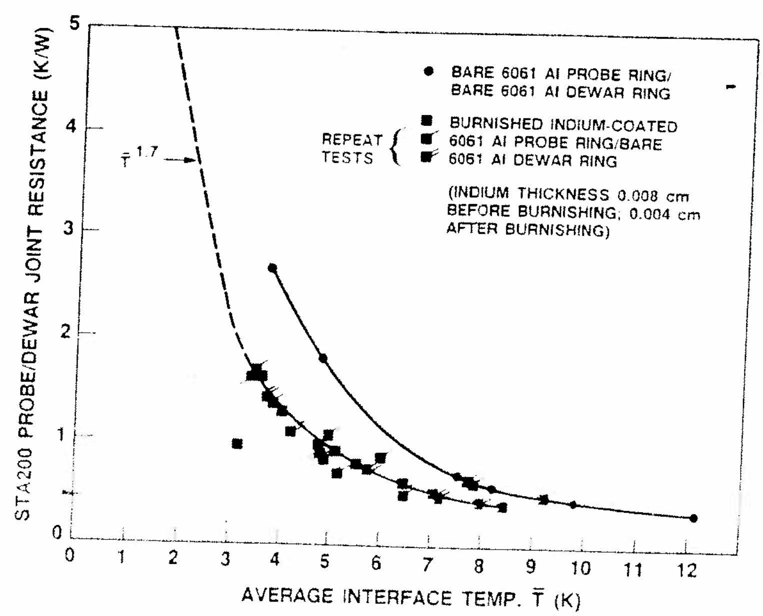

Fig. 7. Axial Lok thermal resistance test results.

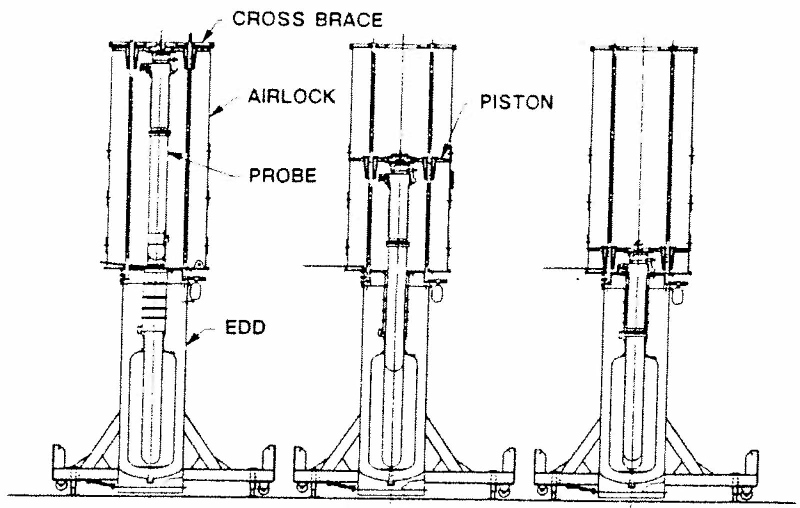

Fig. 8. Probe insertion into dewar.

airlocks were built and tested for inserting and expanding lead bags and inserting the probe. For illustration purposes, only the larger probe airlock is discussed here. The air locks are designed to be purged with gaseous helium to remove air during the insertion or removal operations. The airlock insertion process is illustrated in Figure 8.

The airlock consists of a metal cylinder precision machined on the inside surface (Figure 9). A piston with an inflatable seal (Figure 10) provides the moving seal inside the cylinder as the probe is lowered. Two centerless ground guide rods accurately

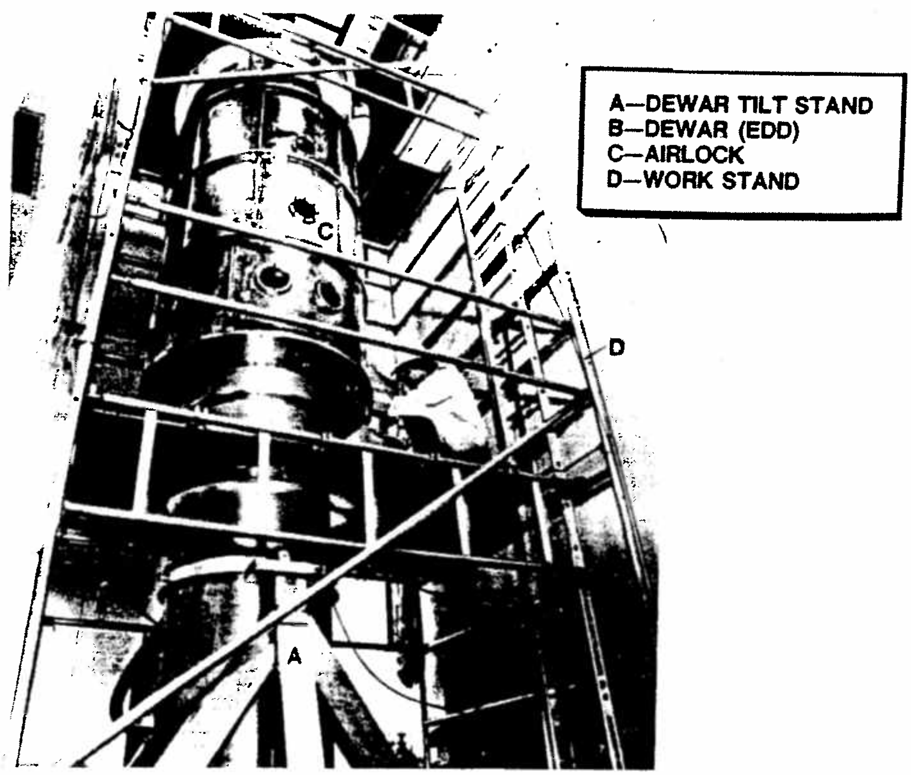

Fig. 9. Airlock/dewar.

Fig. 10.

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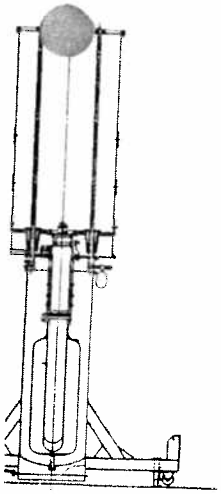

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B—DEWAR (EDD)
C—AIRLOCK
D—WORK STAND

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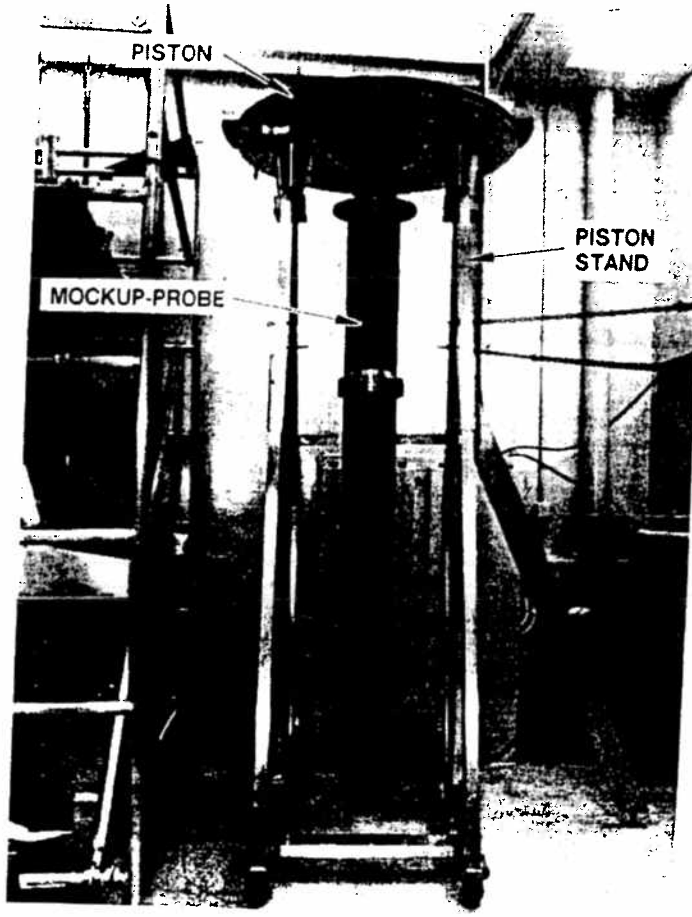

Fig. 10. Mockup probe installed in airlock piston.

clock and locate the probe with respect to the dewar well as the probe is lowered into the dewar. A removable Plexiglas tube is installed around the probe vacuum shell to duct cold gas over the probe.

The sequence of operations shown in Figure 8 is as follows. The probe and Plexiglas cylinder are mounted in a support stand. The stand is rolled underneath the piston and cross brace temporarily supported in a separate stand for this purpose. The Plexiglas cylinder is not shown in Figure 10. The two guide rods are also installed in their bushings. The piston/probe/Plexiglas cylinder/guide rods are lifted by an overhead crane and placed inside the cylinder. The cross brace is attached to the cylinder and the entire assembly is lifted on top of the cold dewar (Figure 9). The airlock is O-ring sealed to the dewar top through an intermediate plate. The interior of the probe is purged with GHe to 3 cm positive water pressure. The temporary cover over the well is removed through a glove port exposing the LHe in the well to the helium environment. The piston is unbolted from the cross brace and the piston slowly lowered into the well to allow controlled cooldown of the quartz block and gyroscopes and controlled topping of the well with liquid helium. During this period, the lead bag temperature can not exceed 7K.

Features of the design that compensate for slight misalignments include spherical bearing bolts in oversize holes holding the probe to the piston for tilt adjustment and tapered guide rods that "release" the piston/probe as the probe enters into the well.

Due to dimensional differences, the probe's aluminum vacuum shell protrudes above the top of the dewar well when the probe bottom is entering the liquid helium. To duct the cold vapor over the vacuum shell, a Plexiglas tube surrounds the probe vacuum shell above the dewar. As the probe goes deeper into the dewar, the Plexiglas tube is disassembled in pieces through the glove ports. The Plexiglas parts stay in the air lock until the air lock is removed. This procedure has been demonstrated using a mockup probe.

CONCLUSIONS

It is practical to insert and remove scientific instruments from a cold liquid helium dewar as long as the following conditions are met.

- Resistance across separable joints must be kept low using suitable loads and indium coated surfaces (one side only).

- Copper heat transfer surfaces must be rhodium coated to eliminate copper oxide formation.
- Surface finishes must be 32⁄ or better.
- Designs must allow intimate surface to surface contact by flatnesses less than the indium coated thickness or the ability of one surface to conform to the other surface, i.e. the thermal shoe design.
- Air must be excluded during instrument insertion or removal by using a helium purged air lock.

ACKNOWLEDGEMENTS

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1. R. T. Parmley, Unique cryogenic features of the Gravity Probe (GP-B) experiment, in "Advances in Cryogenic Engineering," Vol 33, Plenum Press, New York (1987), P 943.

DESIGN OF A PROTOTYPE
FOR THE SPACE INFRARED

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Sarma N. G
and Francis

Electro-Opt
Perkin-Elm
Danbury, Co

ABSTRACT

We describe the design
(PSMA) under development for
SIRTF assembly must operate be
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design employs a fused quartz mi
mirror/cruciform assembly is driv
pivot of unique design ar   ur
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INTRODUCTION

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