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ABSTRACT

This report describes in detail the mechanical design of a multipurpose cryostat system for nonencapsulated Ge(Li) and Si(Li) semiconductor radiation detectors. We have attempted to provide a standardized system that will accept many styles and sizes of detectors, and that lends itself to many kinds of experiments.

INTRODUCTION

A laboratory novelty four years ago, lithium-drifted germanium detectors are now a reliable tool in gamma-ray spectroscopy. Lithium-drifted silicon detectors, too, are now widely used in electron, gamma- and x-ray spectroscopy. The demand for these detectors is growing rapidly, and many new applications are being found. For most applications, both Ge(Li) detectors and Si(Li) detectors must be housed in cryostats. The demand for cryostats is proportional to the demand for detectors. The requirements that cryostats must meet are related in a similar way to detector quality and style, to the quality of available electronic systems, and to the needs of the experimenter.

Four styles of Ge(Li) detectors and two styles of Si(Li) detectors are now produced and used at this laboratory:

<u>Ge(Li)</u>

1. Conventional, planar-drift, or planar-geometry detector, Fig. 1(a).
2. Thin-entrance-window detector[1]), Fig. 1(b).
3. Double planar-drift detector, Fig. 1(c).
4. Slice detector[2]), Fig. 1(d).

<u>Si(Li)</u>

1. Conventional mesa-type detector[3]), Fig. 1(e).
2. High-voltage mesa-type detector[4]), Fig. 1(f).

Most of these detectors vary considerably in size and shape within any one style. Without even considering experimental requirements, it quickly becomes evident that a wide variety of cryostats or a highly variable cryostat system is required to accommodate these detectors. Since the cost of design and development of a variety of cryostats

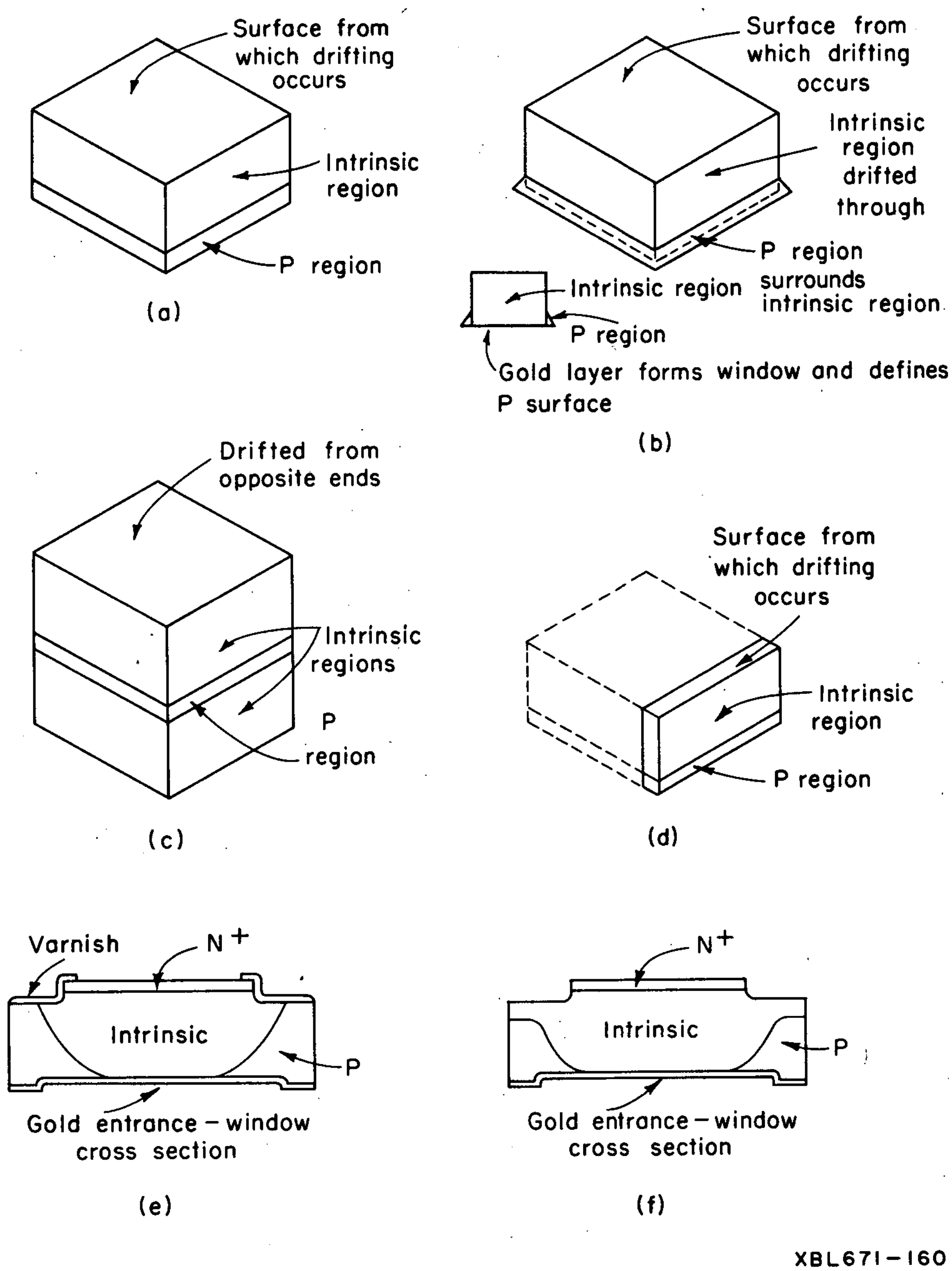

Fig. 1. Detectors produced and used at this laboratory. (a) Conventional, planar-drift Ge(Li) detector. (b) Thin-entrance-window Ge(Li) detector. (c) Double planar-drift Ge(Li) detector. (d) Ge(Li) slice detector. (e) Conventional mesa-type Si(Li) detector. (f) High-voltage mesa-type Si(Li) detector.

soon becomes prohibitive, we attempted to produce a standardized cryostat system that would accept many styles and sizes of detectors, would be easy to modify, and would be consistent with experimental needs. Although Si(Li) detectors often lend themselves to much simpler systems than Ge(Li) detectors, we feel that it is consistent with standardization to use the same cryostat design for both Ge(Li) and Si(Li) detectors. Much of the development work that led to this design is described in detail in Ref. 5.

Figure 2 is a photograph of a typical cryostat. Figure 3 is a photograph of the same cryostat with the end cap removed to display the detector mount assembly.

DESIGN FEATURES

Welded or Vacuum-Furnace Brazed Construction

We believe that in order to achieve optimum resolution with a nonencapsulated detector, contaminants that could affect the surface states of the detector or introduce current leakage across the detector surface must be excluded from the vacuum environment. We are unaware of any systematic effort to determine the effects of various contaminants on detectors. Since we lack knowledge in this area, we have attempted to control the environment of the detector by using materials and techniques that we know, or have reason to believe, will not harm the detector. We have adopted welding and vacuum-furnace brazing techniques of fabrication to provide high-integrity joints and to eliminate possible sources of solder flux and chemicals and solvents commonly associated with soldered fabrications. Final cleaning of parts

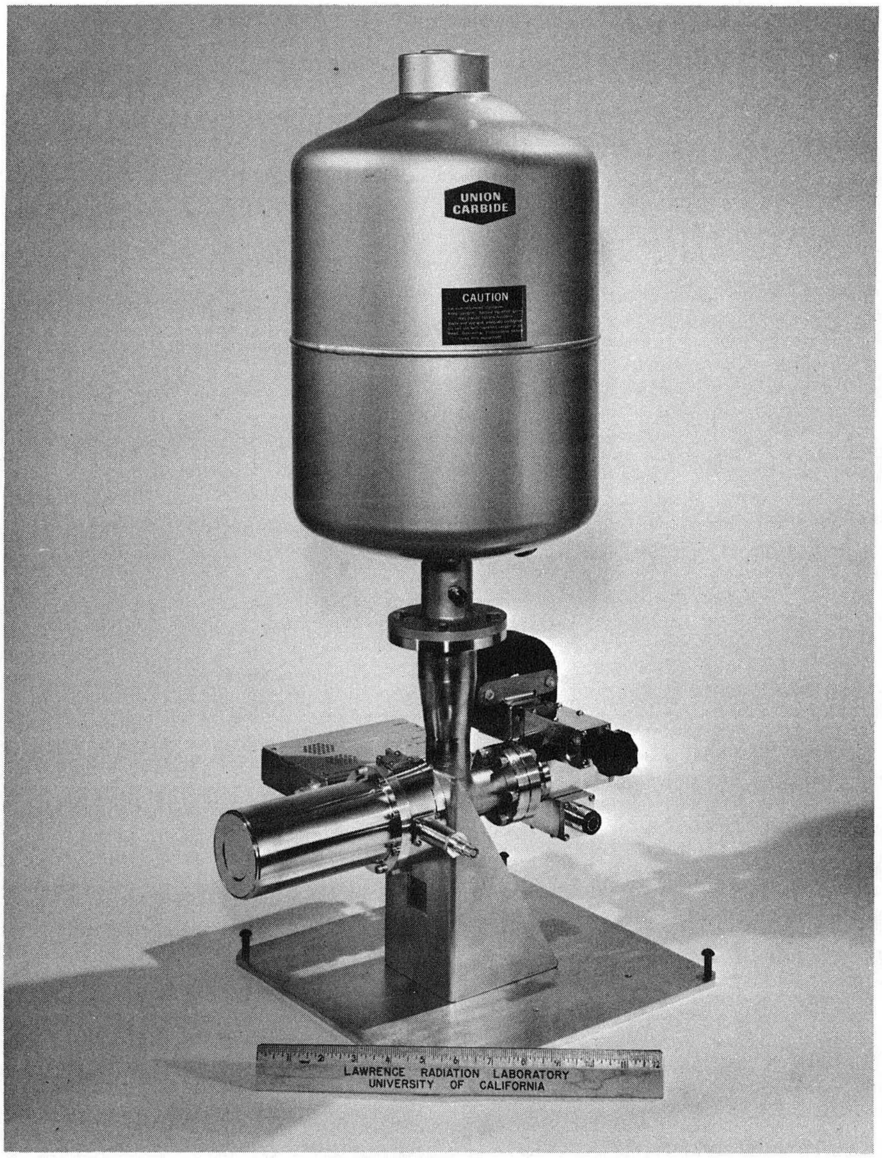

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Fig. 2. Typical cryostat assembly. The LN reservoir is shown at the top, the ion pump at right rear, and the preamplifier at left rear.

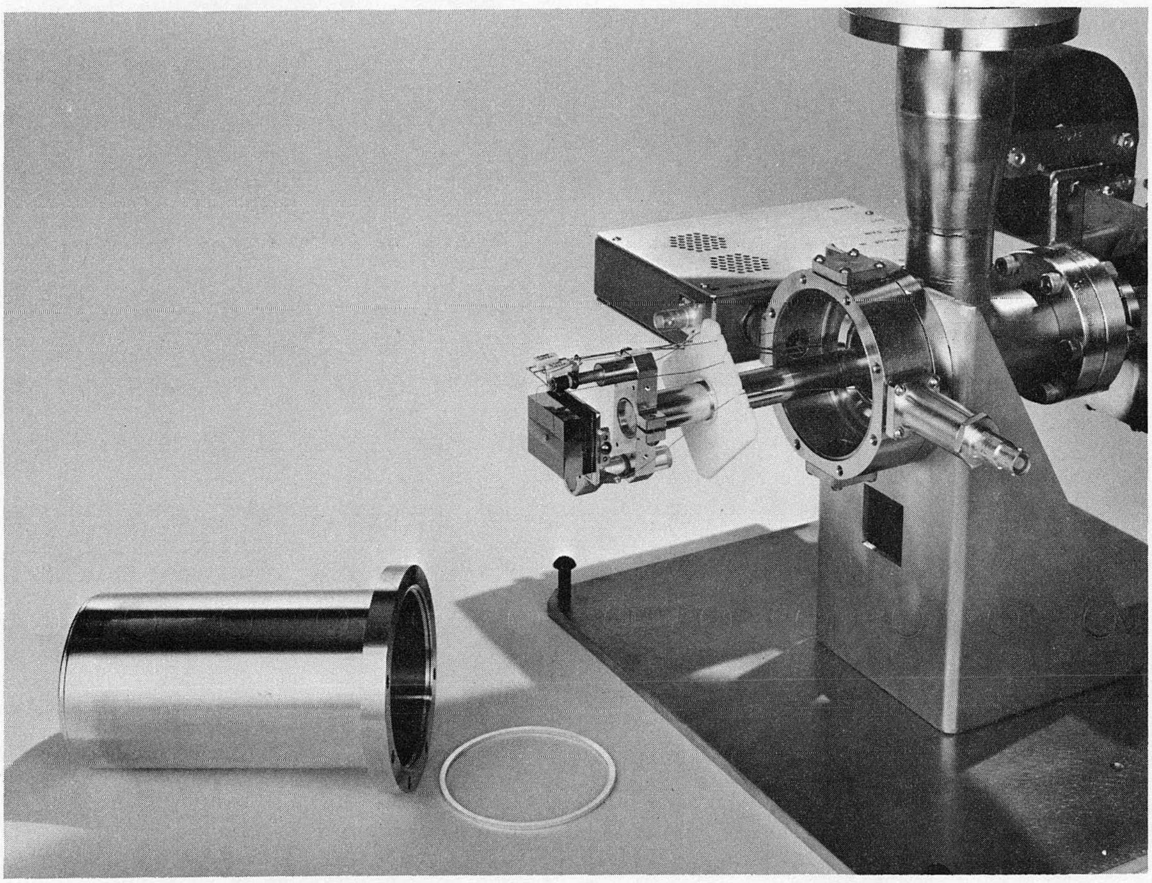

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Fig. 3. Cryostat assembly with end cap removed to display detector-mount assembly.

is done only in solvents such as those used by the detector production group in making detectors.

Metal-Gasketed Demountable Vacuum Joints

The noncommercial flanges used throughout the vacuum enclosure are made to be sealed with metal, Teflon, or Kel-F gaskets, or with Viton "O" rings. This flanging system is described in detail in Ref. 6. Our practice is to use aluminum-alloy gaskets in all of these demountable joints in order to standardize on one gasket material. Soft aluminum-alloy gaskets seal effectively with flanges of aluminum alloy, stainless steel, or brass. Copper gaskets are entirely satisfactory in joints using stainless steel flanges.

Several advantages are gained in using metal-gasketed joints in the cryostat. They are clean in that they harbor neither materials that will contaminate the detectors nor high-vapor-pressure materials that will contribute to the vacuum load. By limiting the vacuum load we are able to maintain the vacuum environment with a 1-liter/sec sputter-ion pump which adds little weight to the system, occupies little space, and is relatively inexpensive. Because the permeability of metal gaskets to helium is far lower than the sensitivity of a mass-spectrometer leak detector, they do not interfere with leak testing as do dry Viton "O" rings and Teflon and Kel-F gaskets. Since the flange knife-edges bite into the gasket material, they assure high integrity, continuous grounding, and high-frequency noise shielding throughout the cryostat assembly. When initial seals are made, the flanges are tightened only enough to ensure sealing. They are not pulled up metal-to-metal. This allows for subsequent tightening if a leak should appear and also permits as many as 20 reseals with the same gasket. Knife-edge seal surfaces of this type are less dependent on surface finish and integrity than are "O" ring seal surfaces. Consequently, the effort and time ordinarily expended on surface preparation and polishing in order to assure initial seals, particularly with ungreased (dry) "O" rings, is saved. Since the knife-edge surfaces are recessed from the flange face, they are well protected against nicks and scratches, and much less vulnerable to damage than are "O" ring seal surfaces.

Easily Replaceable Ion Pump

Vacuum is maintained in the cryostat at an average pressure of 3×10^{-7} torr by a 1-liter/sec sputter-ion pump. The operating lifetime of the sputter-ion pump is limited by the amount of titanium available for pumping. Operation at relatively high pressures for long periods, or frequent exposures to room air, will accelerate titanium consumption. We have experienced an occasioanl ion-pump failure caused by prolonged operation at pressures above 10^{-6} torr. Evidence of this type of failure is that the pump stops pumping, although it continues to register an ion current that is proportional to pressure. Another type of pump failure which we have experienced a little more frequently from prolonged operation at high pressure is a short circuit between the anode and ground. This type of failure is indicated by a very high pump current which is not proportional to pressure and little, if any, voltage drop between the anode and ground. We believe that these short circuits are usually produced by sputtered titanium bridging the gap between the anode and the cathode or between the anode and the pump casing. It is also possible that a short circuit can be caused by the presence of conductive foreign material inside the pump.

Since pump failures can occur, at least three advantages are gained by being able to replace pumps easily and quickly. Once a detector has been cooled and is operating satisfactorily, it is preferable to avoid disturbing its thermal and vacuum environment. This is particularly true for calibrated systems that have produced considerable data. Nothing may occur to change the characteristics of the system, but the process of warming, removing, and replacing a detector risks changes that should be avoided. It seems that when pumps fail, they often do so during the course of a critical experiment. Down time, rescheduling, and rerunning are always costly in experimental time and money; in some cases, delays might prevent an experiment from being done at all. Manpower consumed in replacing pumps can always be used to better advantage elsewhere.

Cooling by Gravity-Feed Liquid Nitrogen Supply

Liquid nitrogen (LN) is supplied to the tip of the LN finger by a commercially available, well-insulated, gravity feed reservoir. Since this reservoir is small and is located above the cryostat, the cryostat can be used conveniently on table tops, can be located very close to other equipment such as in coincidence and angular-correlation arrays, and can be easily enclosed in radiation shielding. A desirable characteristic of this cooling method is that the liquid level remains constant within the cryostat and maintains a highly stable, fixed thermal environment.

Detector Mount Readily Accessible and Easy to Change

Removal of the end cap permits complete access for installation or removal of detectors and wiring. Interchangeable detector-mount assemblies permit relatively quick changeovers from one style of detector to another.

Aluminum and Other Low-Z Materials Near Detector

The structural parts of the detector-mount assembly, the LN finger, and the end cap are made of low-Z materials, usually aluminum, in order to limit nuclear scattering. Aluminum was selected for this portion of the cryostat because it is a good vacuum material, has a low neutron-capture cross section, and has a low scattering cross section for gamma rays. Some gamma-ray experiments, for example, are performed at this laboratory in the presence of a moderate neutron flux. It is essential to this type of experiment that the materials near the detector have a low neutron-capture cross section in order to minimize production of background gamma radiation accompanying neutron capture in these materials.

Detector Mount Electrically Isolated

Insulation of the detector mount from the remainder of the cryostat allows the cryostat to accept a variety of electronic circuits including those requiring the entire detector to be above or below ground potential.

Field-Effect-Transistor Temperature Adjustment

The operating temperature of the internal field-effect-transistor (FET) input stage of the preamplifier can be externally adjusted between -160°C and -80°C to optimize the performance of the FET.

COMPONENTS

Figure 4 is a cross-sectional drawing of the cryostat assembly.

Liquid Nitrogen Container, Fig. 5

The liquid nitrogen container is designed to provide a hollow, LN-filled finger that lies in the horizontal plane and can be exposed to provide ample access for mounting detectors, electronic components, etc. As shown in Fig. 5(b), the exposed portion of the finger is a 5/8-in.-o.d. × 0.020-in.-wall aluminum-alloy-to-stainless steel transition tube[7]). The finger tip is capped by a thin, cup-shaped aluminum-alloy plug. The plug is inserted and electron-beam welded into the aluminum-alloy end of the transition tube to provide a low-Z tip on the finger. The stainless steel end of the transition tube is adapted and Heliarc-welded to a 3/4-in.-o.d. × 0.065-in.-wall stainless steel elbow[8]). The elbow is Heliarc-welded to the small end of a 1 1/4-in.-o.d. × 3/4-in.-o.d. stainless steel concentric reducer[8]). The large end of the reducer is Heliarc-welded to a 1 1/4-in.-o.d. × 0.065-in.-wall stainless steel tube. Except at the ends, which are kept thick to facilitate welding, this tube is machined to a 0.020-in.-thick wall to provide a heat transfer barrier between LN temperature and room temperature. The upper end of this tube is Heliarc-welded to a 4-in.-o.d. stainless steel flange which mates with the mounting flange on the LN reservoir. Also Heliarc-welded to this flange is a jacket which surrounds the vertical portion of the LN finger. This jacket consists of a 2-in.-o.d. × 0.065-in.-wall stainless steel tube Heliarc-welded to the large end of a 2-in.-o.d. × 1 1/2-in.-o.d. stainless steel concentric reducer[8]). The small end of the reducer is

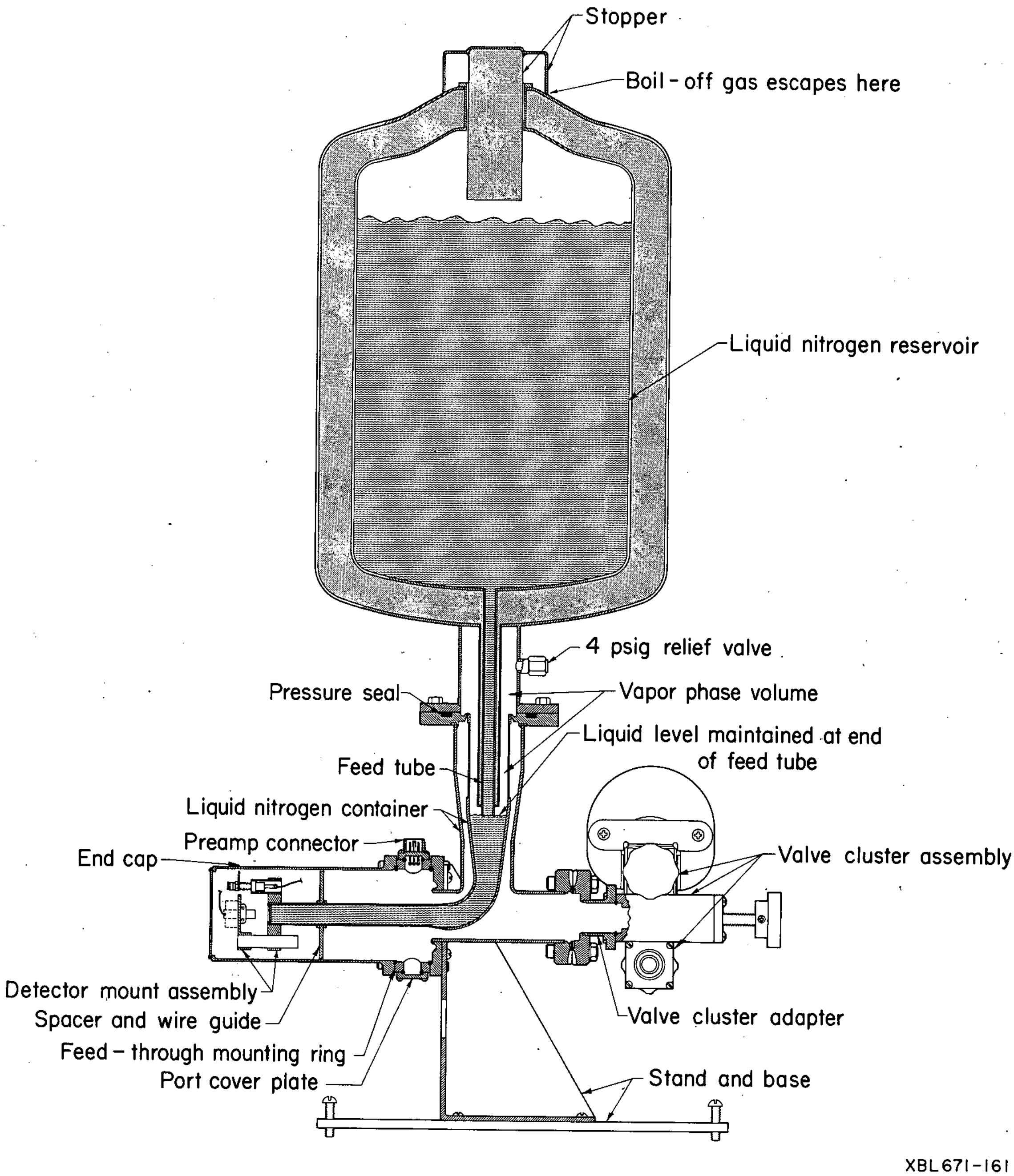
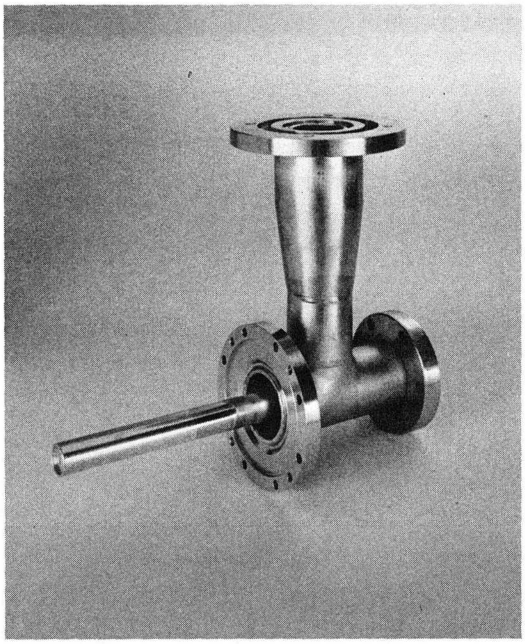


Fig. 4. Cross-sectional drawing of a typical cryostat assembly.



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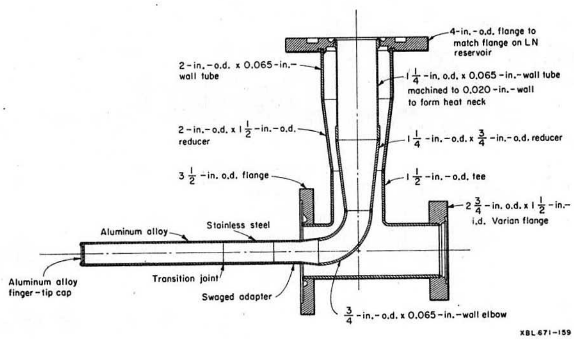


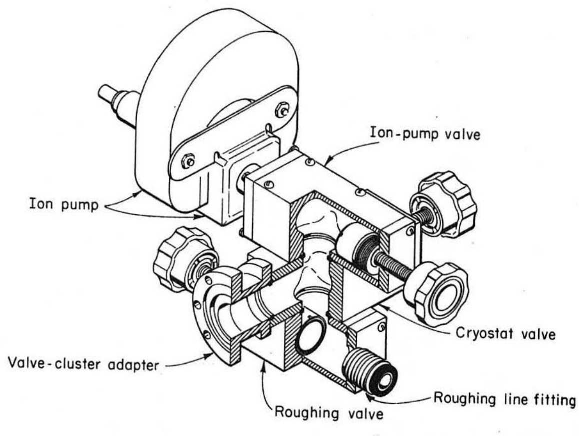
Fig. 5. Liquid nitrogen container.
(a) Elevation view showing exposed LN finger.
(b) Cross-sectional view showing fabrication details.

Heliarc-welded to the branch of a 1 1/2-in. -o.d. stainless steel tee[8]. One end of this tee facilitates continuation of the jacket around the elbow section of the finger. This end is Heliarc-welded to a 3 1/2-in.-o.d. stainless steel flange which is designed to form a sexless, metal-gasketed, vacuum-tight seal when mated with a similar flange[6]. Four tapped holes in this flange facilitate mounting the cryostat on a suitable stand. To the opposite end of the tee is Heliarc-welded a 2 3/4-in. -o.d. × 1 1/2-in. -i.d. Varian flange[9] through which the cryostat is evacuated.

Valve Cluster Assembly, Fig. 6

This assembly is a complete vacuum system which consists of pump, pressure gauge, pump valve, system valve, and roughing valve. The pump is a 1-liter/sec Varian sputter-ion pump[10] to which has been Heliarc-welded a 1 3/8 in.-square stainless steel flange[6]. After welding, the pump is ultrasonically cleaned in 1, 1, 1-trichloroethane followed by ethyl alcohol and is oven-dried at 300°F for about 30 min. The pump is then mounted and sealed with an aluminum gasket to the seat port of a 3/4-in. bellows-sealed brass angle valve[10,11]. The pump valve is mated by its side port to one of two opposed side ports of a similar tee valve. The roughing valve, which is identical to the pump valve, is mated by its side port to the second side port of this tee valve. The tee valve is the main valve to the cryostat. It is mated to the 2 3/4-in.-o.d. flange on the LN container by the valve-cluster adapter. The valve-cluster adapter consists of a 2 3/4-in.-o.d. Varian flange[9] and a flange similar to that on the ion pump.

As shown in Fig. 6(b), the valves mutually communicate by means of their side ports; hence the internal volume of the cluster assembly is



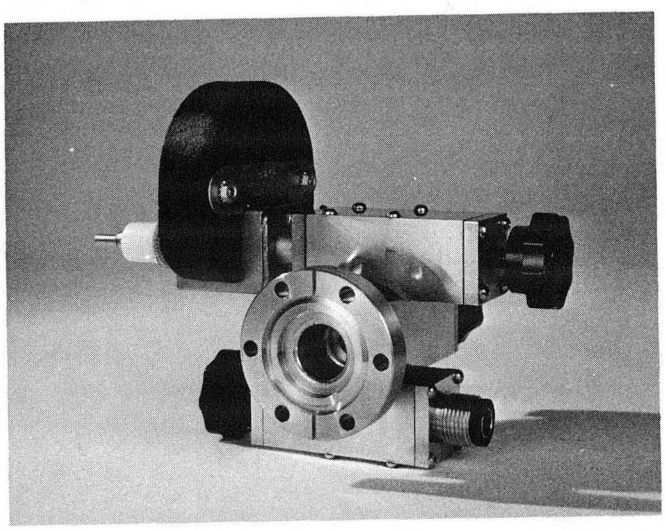


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Fig. 6. Valve-cluster assembly.
(a) Elevation view showing ion pump at top left side and roughing valve at bottom.
(b) Partial sectional view showing common porting of valves.

common to all three valves. When it is arranged in this way, the valve-cluster assembly permits roughing of the cryostat without interfering with the operation of the ion pump and permits roughing of the ion pump without interfering with the operation of the cryostat. This arrangement also permits removal and replacement of the ion pump without affecting the vacuum in the cryostat. Hence, the ion pump can be replaced without warming the detector. Additional pumping, if required, can be obtained during time the ion pump is inoperative by adapting an 8-liter/sec ion pump or a cryosorption pump to the roughing port.

The ion pump, operated with a metered control unit, serves as an adequate pressure indicator.

After the valve cluster is assembled and leak-tested, it is evacuated by a cryosorption pump and the ion pump is baked at 220°C for approximately 24 hours. The ion-pump valve is then closed and the pump is allowed to cool to room temperature. When the pump has cooled, it is started with its valve remaining closed, and is then kept in continuous operation.

The baking process facilitates fast starting of the ion pump and helps it to achieve a low base pressure (below 5×10^{-7} torr) in a short period (approximately 30 min). Baking is not an absolute necessity. Without baking, the pump will start in a reasonable time, but it will pump slowly at first and will be less responsive to pressure loads.

<u>Feed-Through Mounting Ring, Fig. 7</u>

This component is made from a 1 in. length of 3 1/2-in.-o.d. × 0.437-in.-wall stainless steel tubing. Four ports spaced around the

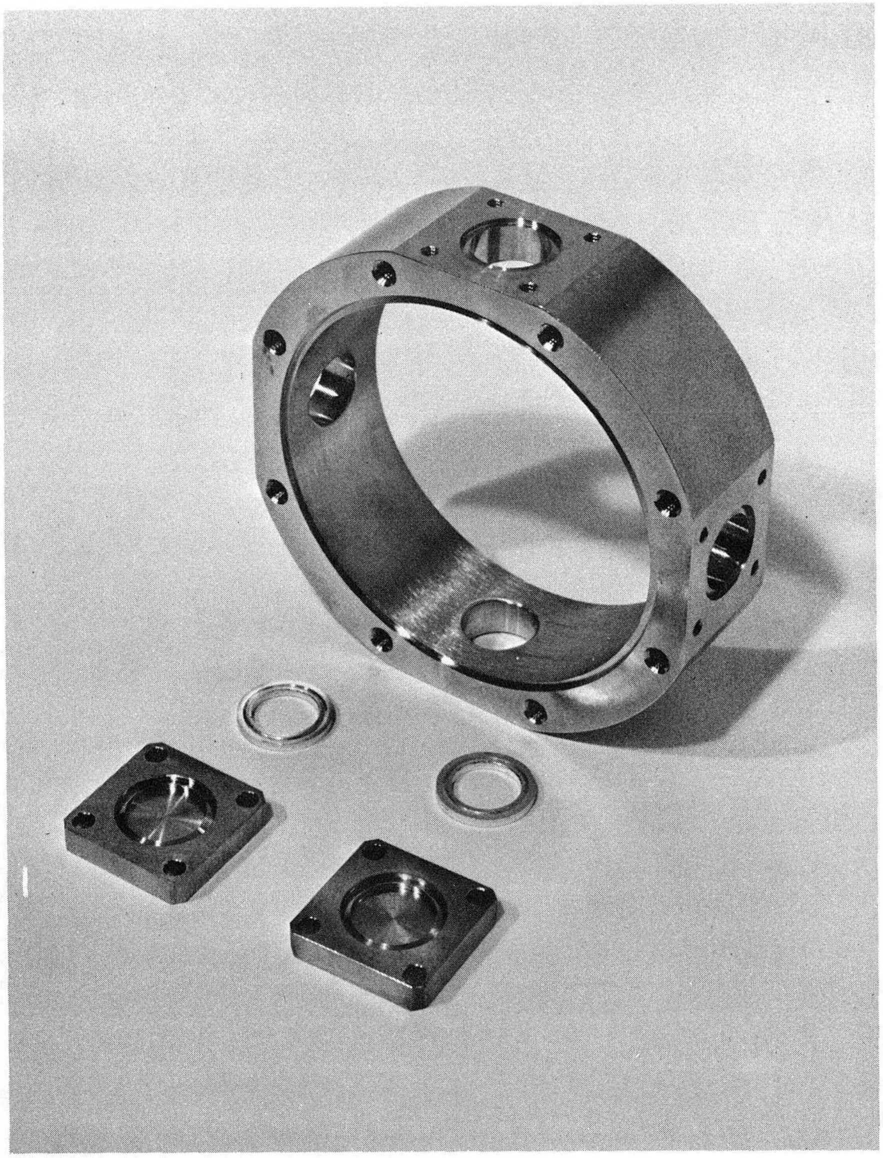

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Fig. 7. Feed-through mounting ring with port cover plates.

periphery of the ring accept a variety of feed-throughs, connectors, and cover plates. The cover plate, also shown in Fig. 7, is a 15/16-in.-square × 3/16-in.-thick blank flange designed to seal with a metal gasket[6]). The mounting-hole spacing of the cover plate is that of a size-10 shell of the MS box-mounting connector series. The feed-through mounting ring is attached and sealed to the 3 1/2-in.-o.d. flange on the LN container.

Liquid Nitrogen Container Spacer and Wire Guide

This part is designed for a snug fit both on the finger portion of the LN container and inside the end cap in order to keep the LN finger centered in the end cap as shown in Fig. 4. It is made from a 1/8-in.-thick Teflon sheet and has several slots or holes that can be used to support and separate wires leading from the detector to the feed-through mounting ring. It is retained on the finger portion of the LN container by two aluminum-alloy spring clips.

End Cap, Fig. 8

The end cap is machined from a 3 1/2-in.-o.d. × 0.500-in.-wall aluminum-alloy tube to form a 2 3/4-in.-o.d. × 0.040-in.-wall tube with a 3 1/2-in.-o.d. flange at one end. This flange mates with and seals to the feed-through mounting ring to complete the vacuum envelope. In the tubular end of the end cap is welded a 0.050-in.-thick disk in which is machined a 0.010-in.-thick × 1 1/2-in.-diam window. This disk is made of either aluminum alloy or beryllium, depending on transmission requirements. It is electron-beam welded to the body of the end cap.

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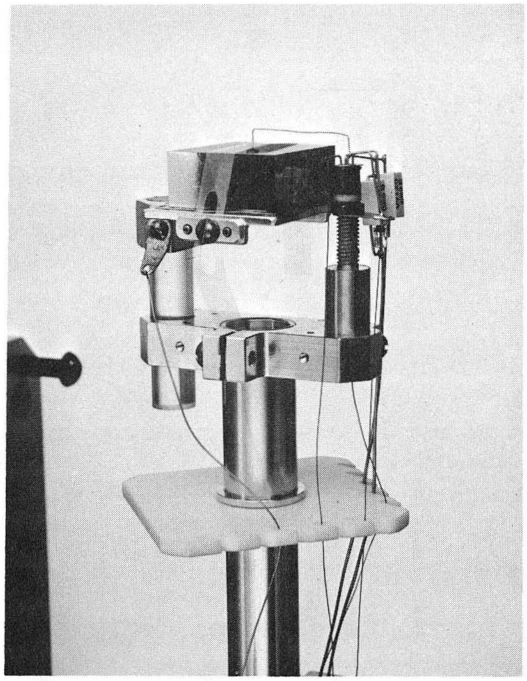
Fig. 8. End cap. A cross-sectional view showing fabrication details is included in Fig. 4.

Detector Mount Assembly, Fig. 9

This mount is used with the conventional, planar-drift Ge(Li) detector. The end-assembly mount adapts the detector-mount assembly to the tip of the finger portion of the LN container. It consists of a 5/8-in.-diam single-screw clamp on either side of which is a 3/8-in.-diam single-screw clamp. The bores of these clamps are ultrasonically tinned with indium about 0.001-in.-thick to provide cushioning and large-area thermal contacts when the clamps are tightened. The 5/8-in.-diam clamp is slipped over the tip of the finger portion of the LN container and is tightened in place by tightening its screw. Into one of the 3/8-in.-diam clamps is inserted a 3/8-in.-diam × 1 3/4-in.-long sapphire rod[12]. This rod electrically insulates the detector mount from the rest of the cryostat while maintaining high thermal conductivity[13] between the detector mount and the LN container. The detector mount is attached to the end of the sapphire rod by means of a similar 3/8-in. single-screw clamp. The detector mount is a 1 5/8-in. × 1 3/16-in. rectangular aluminum-alloy table, 0.060-in.-thick, with clamping tabs centrally located along the 1 3/16-in. edges. The 3/8-in. single-screw clamp is centrally located on one of the 1 5/8-in. edges of the rectangle. The clamping tabs and the single-screw clamp all protrude from the same side, leaving one surface flat and unobstructed. The detector is mounted against this surface. A layer of indium foil is placed between the detector and the mounting surface to permit relative slippage in order to compensate for differential thermal expansion between the detector and the mount. The indium foil also provides a relatively large electrical and



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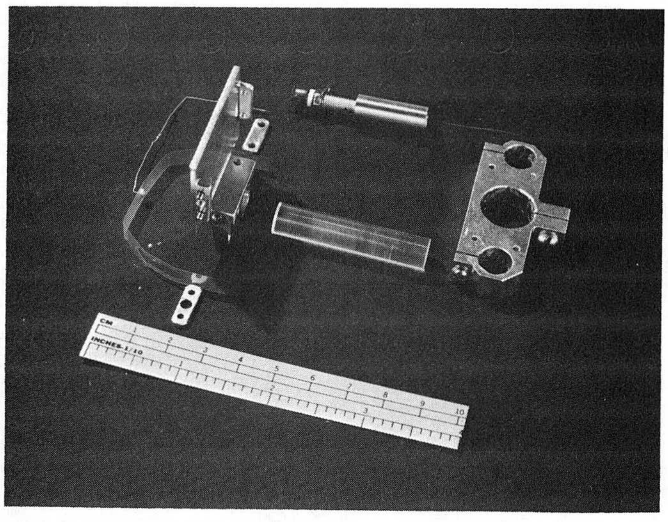

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Fig. 9. Conventional detector-mount assembly.
(a) Complete assembly including wiring.
(b) Exploded view showing, from left to right, Mylar strap with contact, detector mount with strap clamp piece, sapphire rod, FET mount assembly (above), and end-assembly mount.

thermal contact area between the detector and the mount.

A 1/4-in. -wide × 4 1/4-in. -long × 0.002-in. -thick Mylar strap is tightly clamped approximately 1-in. from the end to one of the clamping tabs on the detector mount. A 1/8-in. -wide, 3/4-in. -long slot centered 1-in. from the free end of the Mylar strap secures the strap loosely to the other clamping tab on the detector mount. The clamp piece used at this end is retained by a center screw which passes through the slot in the Mylar strap. It is guided and prevented from rotating by two 1/16-in.-diam × 1/8-in.-long Rollpins[14]) pressed into the clamping tab and located so that the Mylar strap fits between them. The clamp piece is made with two clearance holes which allow it to slip freely along the Rollpins. This clamping arrangement prevents the Mylar strap from twisting when the clamp is tightened.

The detector signal contact consists of the slug obtained from punching a 3/32-in. -diam hole in a 0.020- to 0.030-in. -thick sheet of copper. A 0.010-in. -diam wire is hard-soldered to the center of the concave side of this slug. The wire is inserted in a pin hole in the Mylar strap. This hole is located so that the contact will be centered on the face of the detector when the strap is pulled tight. When the detector is installed, the strap is pulled tight, forcing the contact against the detector and the detector against the mount. The strap is locked in place by tightening the clamp screw. The Mylar strap supports the detector and holds it firmly in place.

The wire from the signal contact is soldered to the gate of a field effect transistor (FET)[15]). The FET is plugged into a stud-mounted

TO-18 heat sink[16]). The heat sink is mounted in the stud end of an 8-V zener diode[17]). The hexagonal portion of the base of the zener diode is machined to fit tightly inside one end of a 0.373-in.-o.d. × 0.010-in.-wall × 7/8-in.-long stainless steel tube. The open end of this stainless steel tube is inserted and locked in the second 3/8-in.-diam single-screw clamp of the end-assembly mount. The stainless steel tube provides cooling for the FET and the zener diode provides heating for the FET. Power is supplied to the zener diode through the preamplifier from the 12-V circuit of the amplifier. The operating temperature of the FET is maintained by a calibrating resistor in the premaplifier. The power dissipated in the zener diode permits elevation of the temperature of the FET within a range extending from -160°C to -80°C.

With this mount arrangement the position of the detector mount can be varied by repositioning the sapphire rod with reference to its clamp on the end-assembly mount. This mount assembly, then, accepts detectors from 1 mm to 15 mm thick while allowing the spacing between the detector and the end of the end cap to remain constant, and without modifying or replacing any parts. Similarly, the position of the FET can be varied with respect to the detector mount. This permits minimization of the length of the signal wire between the detector and the gate of the FET, thus minimizing noise introduced by the capacitance of this wire.

Preamplifier Connector, Fig. 10

The wires leading from the FET to the preamplifier are connected to appropriate pins of a 6-pin, flanged connector[18]). This

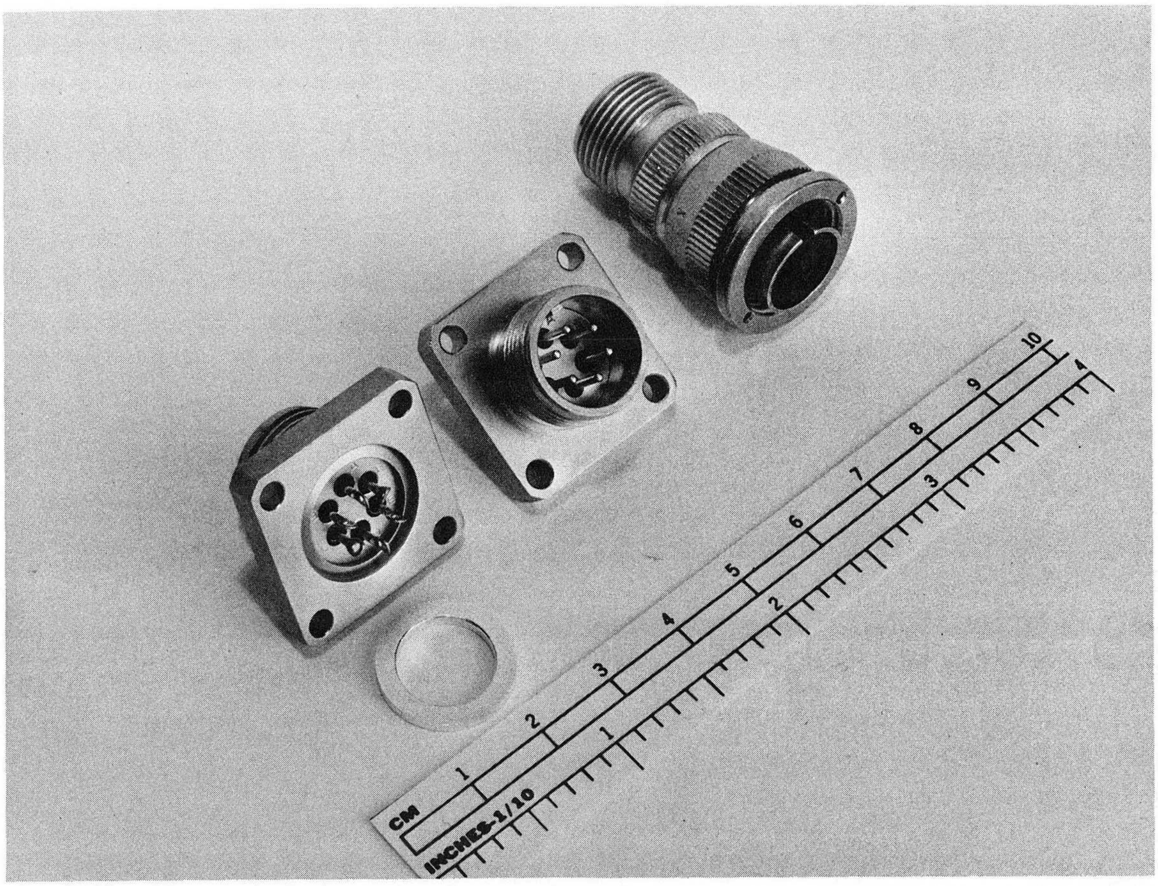

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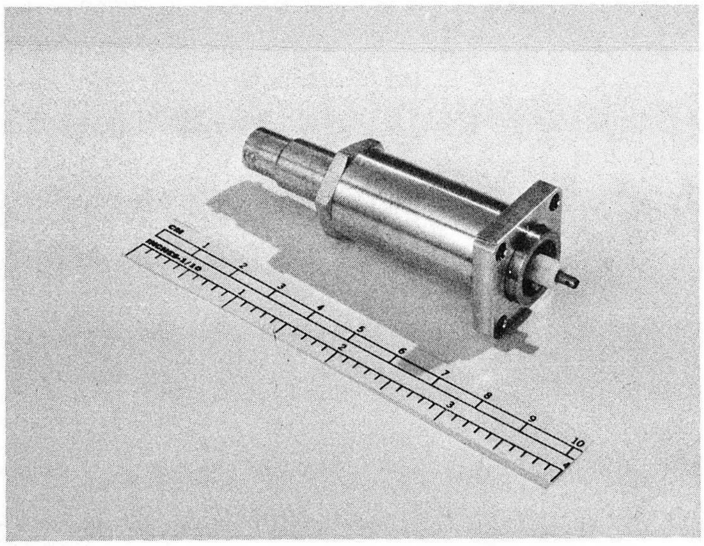
Fig. 10. Preamplifier connector. Rear view with aluminum gasket shown at left. The mating connector is shown at right.

connector seals directly to one of the side ports on the feed-through mounting ring. The connector is a miniaturized size-10 MS stainless steel shell with a 0.180-in.-thick flange identical to a feed-through mounting-ring port cover plate. The pins are separately insulated to form a strain-free construction. They are made of stainless steel, are gold-plated on the air side, and are flattened and pierced on the vacuum side. The insulating material is a ceramized glass, capable of withstanding very high temperatures. This connector is mechanically rugged and will withstand severe mechanical and thermal shocks. It mates with a standard plug mounted on the case of the preamplifier. The preamplifier is connected directly to the cryostat, with no further adaptation required.

High-Voltage Connector, Fig. 11

The detector mount carries a negative bias voltage which varies from several hundred volts to several kilovolts depending on the thickness and quality of the detector. The bias wire is connected between the detector mount and the high-voltage connector, consisting of a ceramic-to-metal feed-through adapted to a high-voltage panel-mount connector. The feed-through[19]) is brazed to a copper gasket which fits the sealing gland of a second side port on the feed-through mounting ring. The pin on the glazed end of the feed-through is shortened to 9/32-in. above the ceramic and is machined to form a male connecting pin 0.043-in.-diam × 5/32-in.-long. The solder end of the pin of the high-voltage connector[20]) is cut off flush with the insulation. It is then machined back so that the pin terminates 1/64-in. inside the insulation, and is bored to form a female receptacle that will accept the male connecting pin on the ceramic-insulated feed-through. The adapter is a 3/4-in.-diam piece of stainless steel or brass, with a flange similar to a feed-through mounting ring



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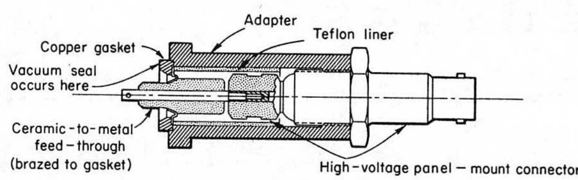

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Fig. 11. High-voltage connector assembly.
(a) Side view showing vacuum side of ceramic-insulated feed-through.
(b) Cross-sectional view.

cover plate at one end. This flange is counter-bored to index on the outside diameter of the gasket to which the feed-through is brazed. The opposite end of the adapter is tapped to accept the threaded shank of the high-voltage connector. The length of the adapter is chosen so that the feed-through and the high-voltage connector will engage with the insulated end of the connector almost touching the ceramic portion of the feed-through. The adapter is lined with a 33/64-in.-o. d. $\times$ 0.030-in.-wall Teflon tube to increase the dielectric strength of the air space inside the adapter. When tested, the total indicated leakage current of this high-voltage connector assembly did not exceed 6×10^{-12} A at 6 kV dc.

Liquid Nitrogen Reservoir, Fig. 12

The LN reservoir is a Linde[21]) model CR-10 gravity-feed device which holds 10 liters of LN. It is mounted--and sealed against internal pressure--directly to the 4-in.-diam flange on the LN container. The feed tube of the CR-10 extends about 3 in. into the LN container. When the liquid level in the container rises to the end of the feed tube, a pressure--equal to atmospheric pressure plus the head produced by the depth of LN in the CR-10--is built up in the vapor-phase volume of the LN container. The vapor-phase volume, Fig. 4, is the volume enclosed by the liquid surface, the wall of the LN container, and the flanged outer wall of the CR-10. As boil-off of LN in the LN container causes the pressure to increase within the vapor-phase volume, the liquid level is depressed slightly, and gas is permitted to escape up the feed tube and out of the CR-10 until the pressure in the vapor-phase volume again reaches equilibrium with atmospheric pressure plus the liquid head in the CR-10. A simultaneous exchange of escaping gas and supply occurs

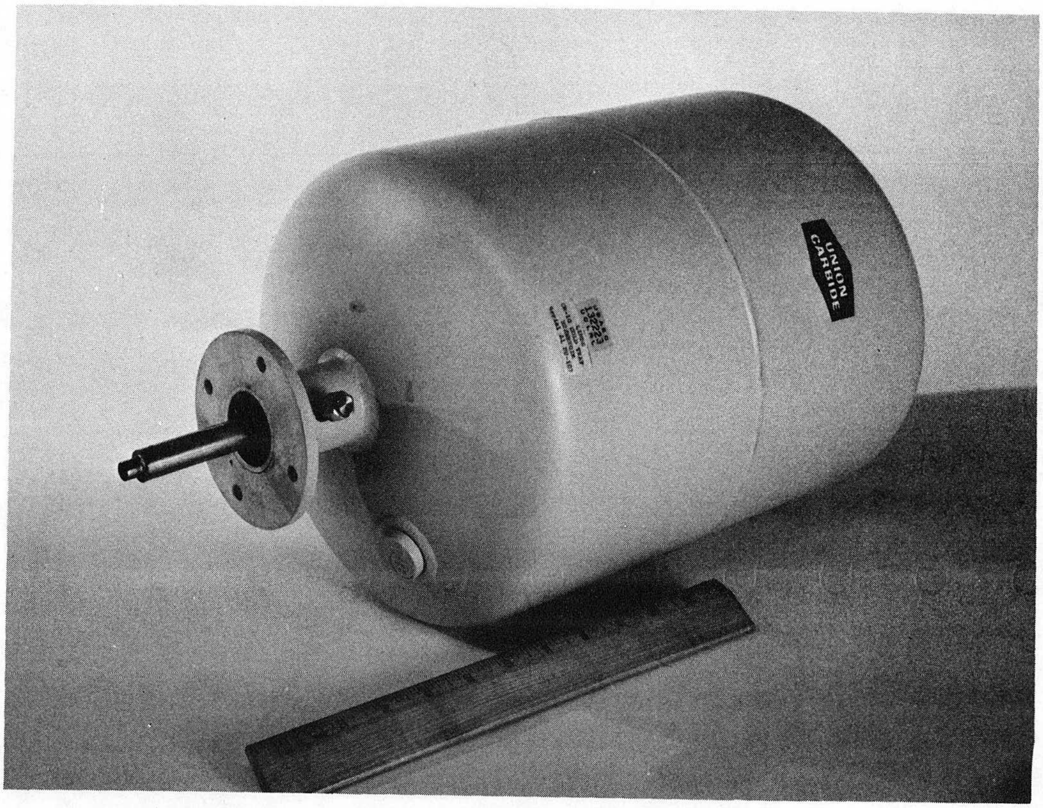

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Fig. 12. Liquid nitrogen reservoir showing feed tube and mounting flange. A cross-sectional view is included in Fig. 4.

in the feed tube of the CR-10. Consequently, the liquid level in the LN container is regulated and held relatively constant as long as liquid is being supplied from the CR-10. A 4-psig relief valve which communicates with the vapor-phase volume is an integral part of the CR-10. This relief valve protects the LN container from overpressure in case of plugging of the feed tube of the CR-10. With a reasonably good insulating vacuum surrounding the LN container, the CR-10 gives it a holding time of at least 5 days on one 10-liter filling of LN.

The LN reservoir should be filled from a Dewar that has been kept free of ice crystals in order to prevent clogging of the feed tube or filling of the LN container with ice rather than with LN. An unstoppered Dewar, partially full of LN, which has been allowed to sit for a period of time accumulates ice crystals by freezing water vapor from the air. It is equally important to keep the stopper in the LN reservoir whenever it contains LN. The stopper fits loosely and permits the escape of boil-off gas from the LN reservoir and from the LN container. The stopper[21] shown in Fig. 4 prevents back-diffusion of moisture into the LN reservoir and also protects the reservoir from icing at the fill port under rapid boil-off conditions.

Thin-Entrance-Window Detector Mount, Fig. 13

With two exceptions this mount assembly is identical to the conventional detector-mount assembly previously described. Two 5/16-in.-long × 1/16-in.-wide slots are located adjacent and parallel to the clamping tabs in the table surface of the detector mount. A hole, the size and shape of the intrinsic region adjacent to the P surface of the detector, is

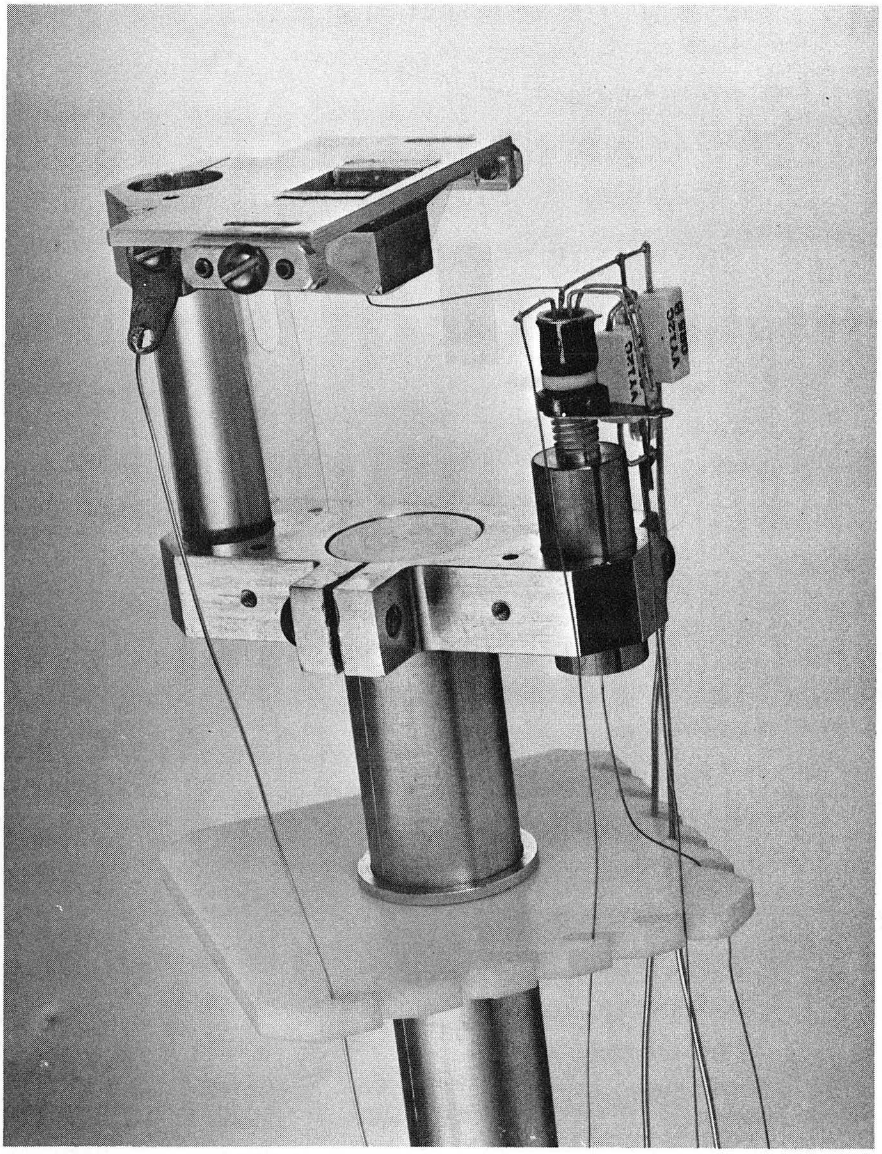

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Fig. 13. Thin-entrance-window detector-mount assembly.

centered in the table surface of the detector mount. The detector is installed with its P surface against the back side of the detector mount. The ends of the Mylar strap pass from the back side of the detector mount through the slots adjacent to the clamp tabs before being engaged in the clamps. This mount assembly will also accept detectors from 1 mm to 15 mm thick while allowing the spacing between the entrance window of the detector and the end of the end cap to remain constant.

This same mount assembly serves also as the conventional mount for Si(Li) detectors, as shown in Fig. 14.

Double Planar-Drift Detector Mount, Fig. 15

This mount assembly is nearly identical to the conventional detector-mount assembly. A longer Mylar strap is used to accomodate the detector, which is usually about 3 cm thick. The wire from the contact on the face of the detector is connected to the detector mount, which is carried at a high positive bias. The wire to the gate of the FET makes spring contact against the side of the detector at the center of the P region.

Slice Detector Mount, Fig. 16

In this assembly the detector mount is replaced by a vise jaw clamp which grips the P region of the detector. The jaws are made of aluminum alloy and the surfaces that grip the detector are ultrasonically tinned with indium to provide large thermal-contact areas. The vise is carried at a high negative bias. The signal contact is made by spring-loading the wire to the gate of the FET against the intrinsic surface of the detector. The tip of this wire is tinned with gallium-indium alloy,

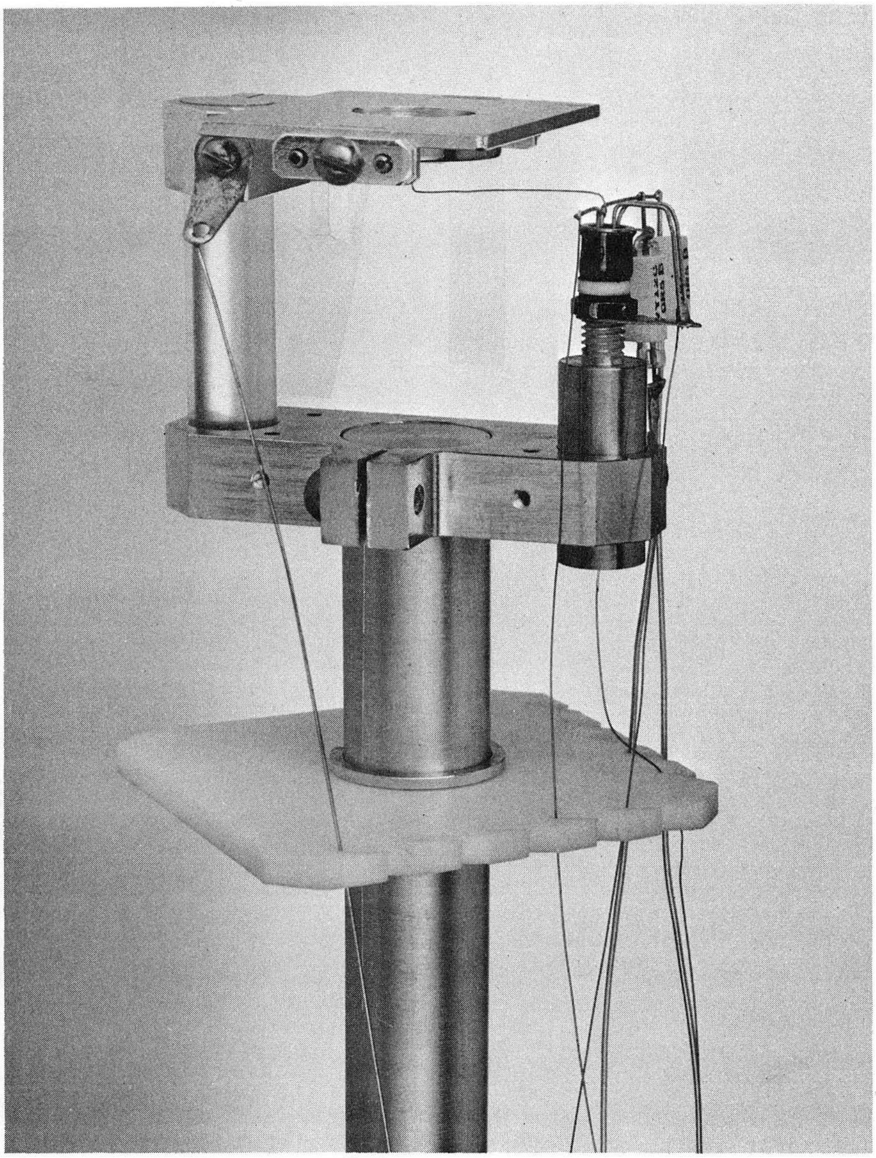

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Fig. 14. Conventional Si(Li) detector-mount assembly.

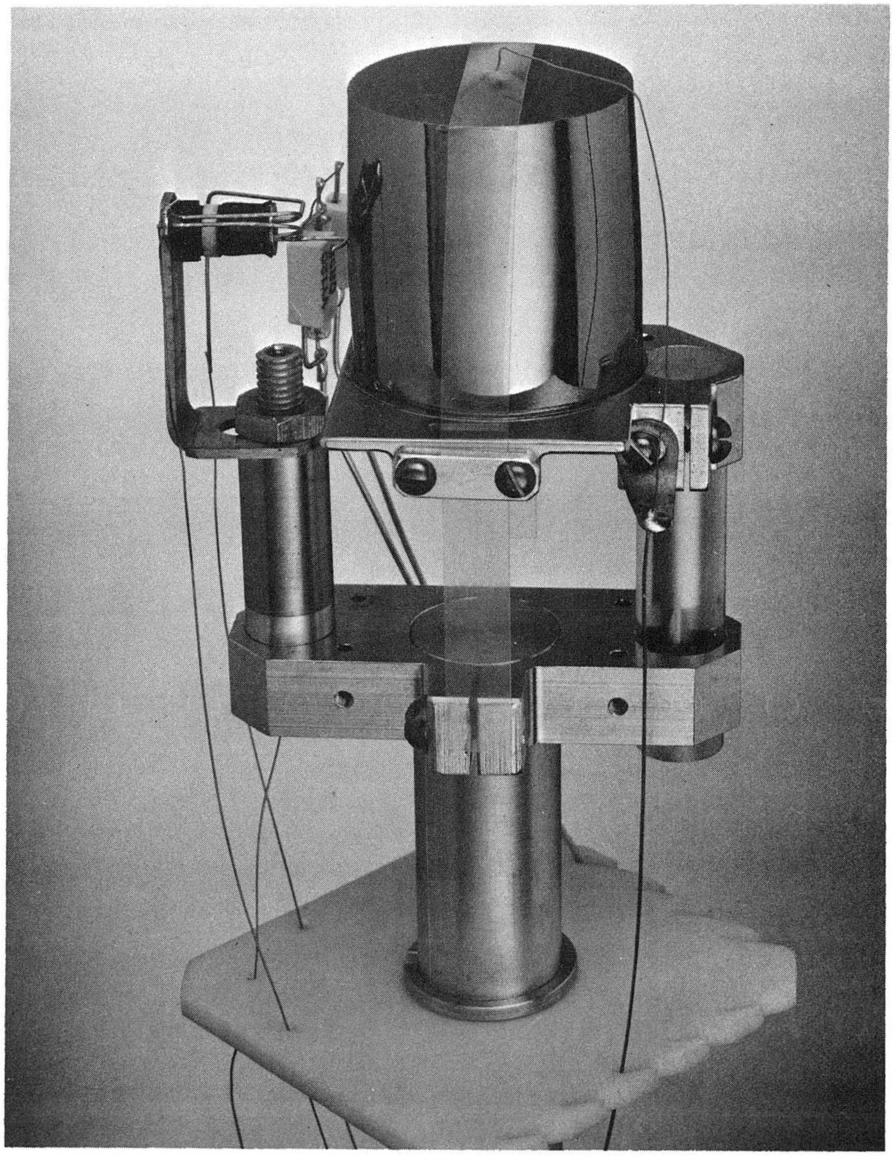

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Fig. 15. Double planar-drift detector-mount assembly.

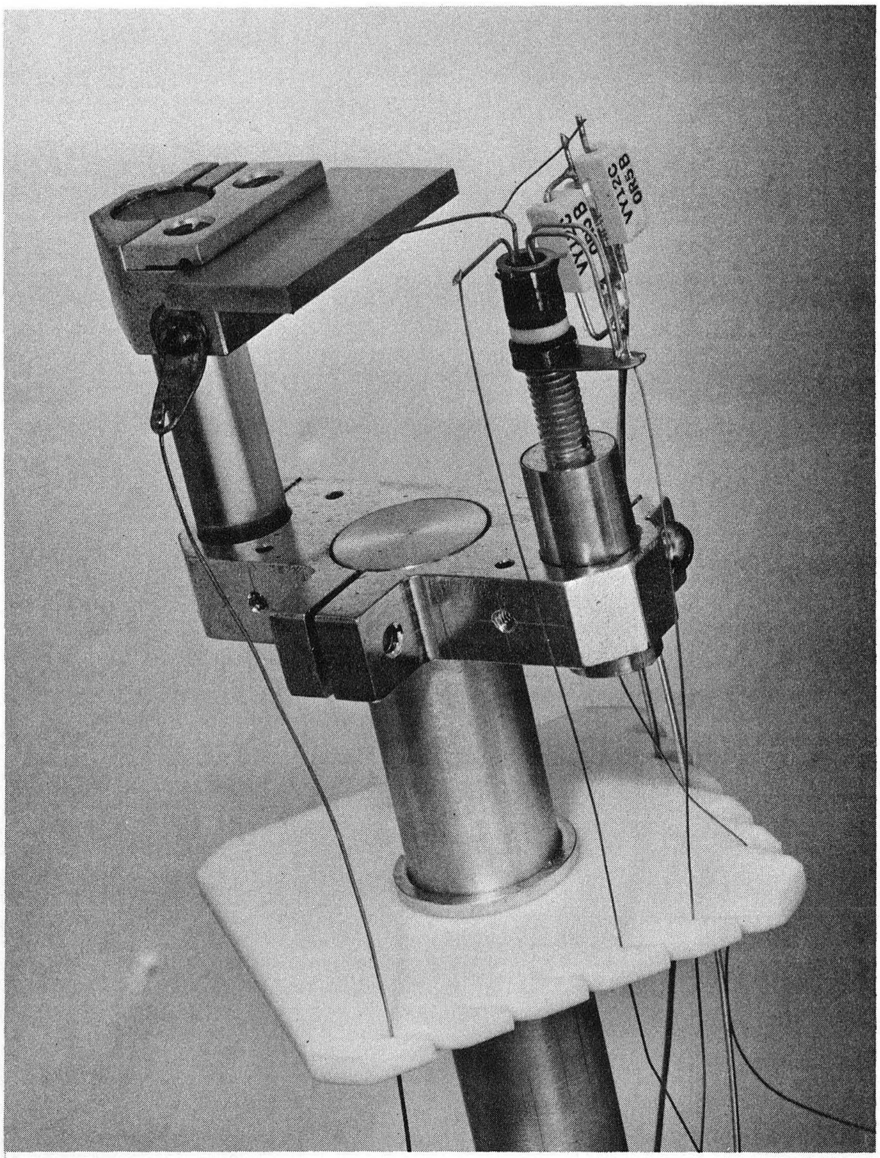

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Fig. 16. Slice detector-mount assembly.

which wets the detector surface and forms a soldered joint when the detector is cooled.

Symmetrical Detector Mount, Fig. 17

This mount assembly is designed specifically for round detectors and is arranged so that the bulk of its mass is distributed symmetrically about the detector. The FET is centrally located behind the detector on the tip of a 3/8-in. -diam boron nitride[22]) rod which extends from a 1 3/8-in. -diam internally-threaded cap. Several holes in this cap facilitate evacuation, accommodate wires, and provide for mounting to a simple end-assembly mount. One end of a 1 1/4-in. -o. d. × 1/8-in. -wall boron nitride tube with external threads at both ends is screwed into this cap. The other end is counterbored to receive the detector mount. A longitudinal slot is cut into the shoulder of this counterbore to accept a guide pin. The detector mount is a disk of Teflon or of boron nitride sized to fit the counterbore in the boron nitride tube, and notched on the outside diameter to permit insertion of the guide pin. A shallow bore, sized for a snug fit on the outside diameter of the detector, is cut in the disk and is relieved to form a narrow shoulder which supports the back of the detector. Four 1/8-in. diam holes through the disk within the relieved portion facilitate evacuation of the back side of the detector. A narrow slot is cut from the edge of one of these holes to the center of the disk. When the detector mount is installed in the end of the boron nitride tube, the detector signal contact, which is connected to the gate of the FET, is passed through this hole and centered in the mount by sliding the contact wire in the slot. Bias voltage is applied to the window surface of the detector by a thin aluminum alloy ring. The inside diameter of this ring is the

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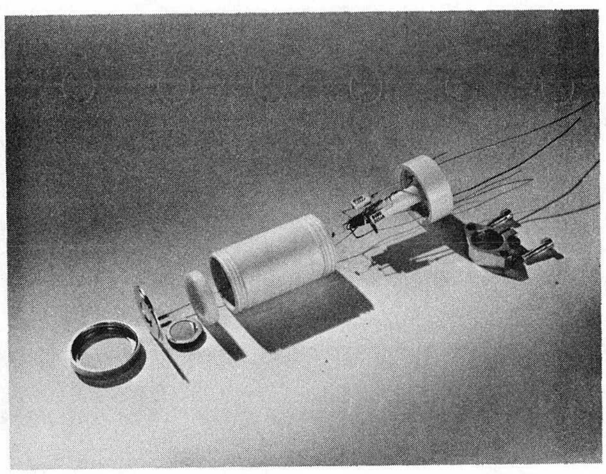

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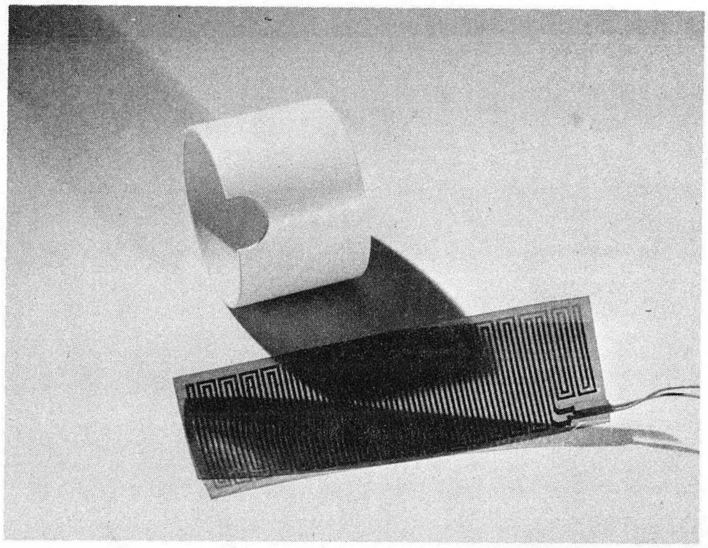
Fig. 17. Symmetrical detector-mount assembly.
(a) Side view.
(b) Exploded view showing, from left to right, clamp ring, bias ring, Si(Li) detector, detector mount, boron nitride tube, contact and FET with wiring mounted on boron nitride rod extending from cap, and simplified end-assembly mount.

same size as the window in the detector. One side of the bias ring is counterbored for a snug fit on the outside diameter of the detector and the opposite side is relieved to form a shallow boss that indexes with the bore of the clamp ring. A 1/16-in.-diam × 7/16-in.-long beryllium-copper Rollpin is press-fit into the surface of the ring near the outside edge. This Rollpin serves as a soldering post for the bias wire and is the guide pin that indexes the ring and detector mount to the boron nitride tube. The bias ring, detector, and detector mount are held firmly in place by an internally threaded aluminum alloy clamp ring, which is bored to fit over the shallow boss on the bias ring. The guide pin prevents rotation of the bias ring and of the detector when the clamp ring is tightened.

This mount assembly lends itself well to angular-distribution experimentation and is especially useful with thin-entrance-window Si(Li) detectors in x-ray emission spectrography[23]).

To achieve optimum resolution with Si(Li) detectors, some experimenters prefer to operate the detector at temperatures above that of LN (-196°C). Watson[24]) has found that in systems using the LN-cooled (internal) FET, the optimum temperature for the Si(Li) detector may be as high as -90°C. Temperatures in this range are achieved with the symmetrical detector mount assembly by wrapping a noninductive thermofoil[25]) heater around the boron-nitride tube. The heater is retained by a snug-fitting boron nitride sleeve that has been slotted to accomodate the electrical leads of the heater as shown in Fig. 18. The heater leads are connected to a 6-pin connector identical to that described earlier and



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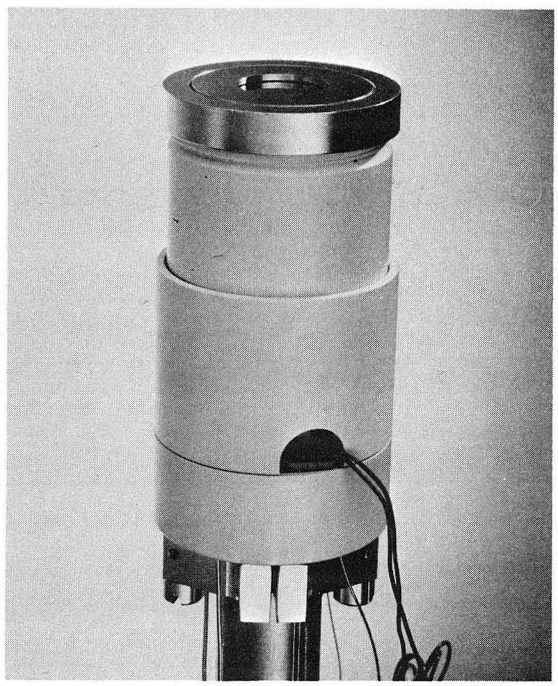

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Fig. 18. Detector heater for symmetrical detector-mount assembly.
(a) Heater and slotted retaining sleeve.
(b) Heater and sleeve installed on detector-mount assembly.

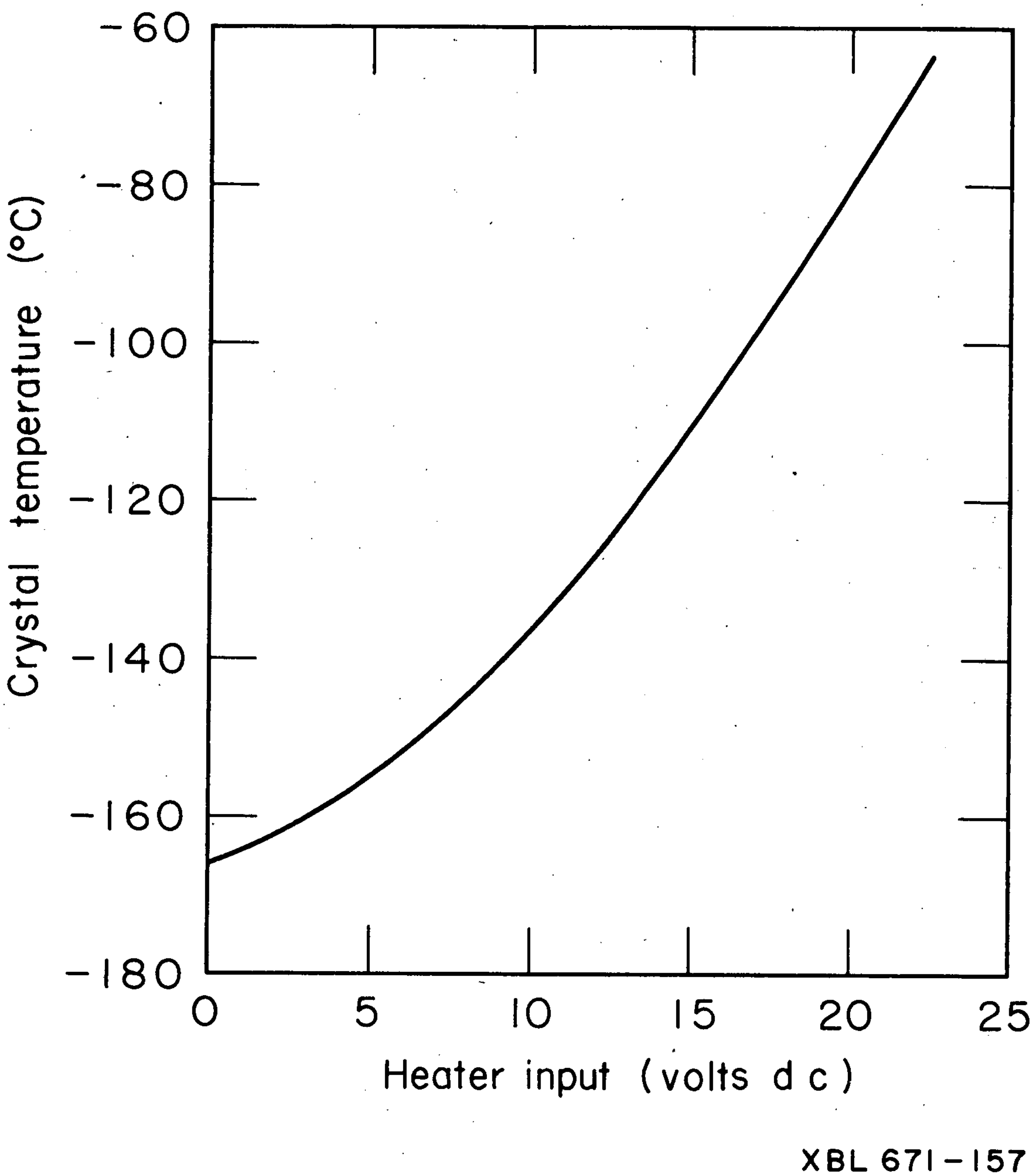


Fig. 19. Temperature measured at clamp ring of symmetrical detector mount plotted against heater input voltage.

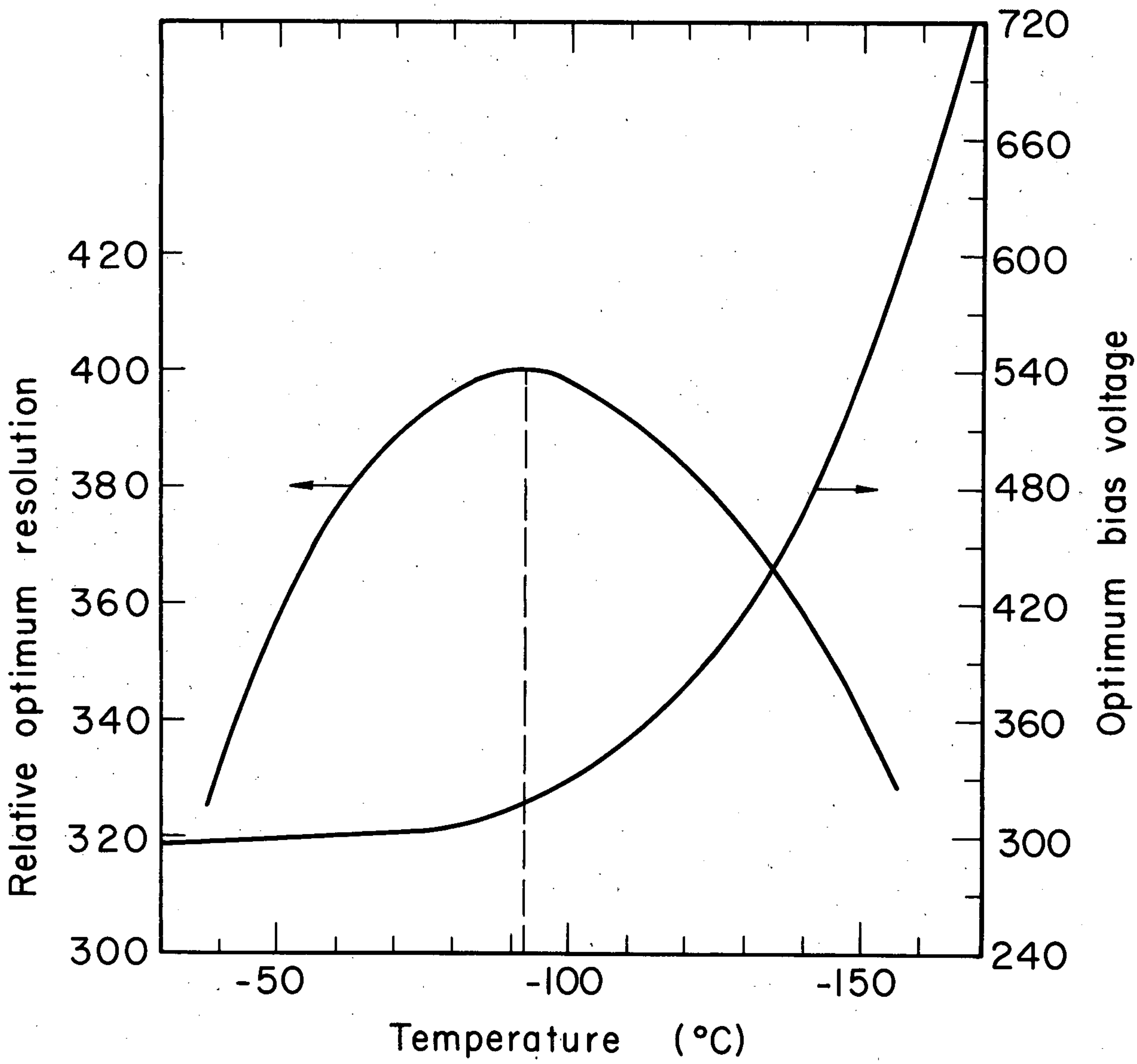
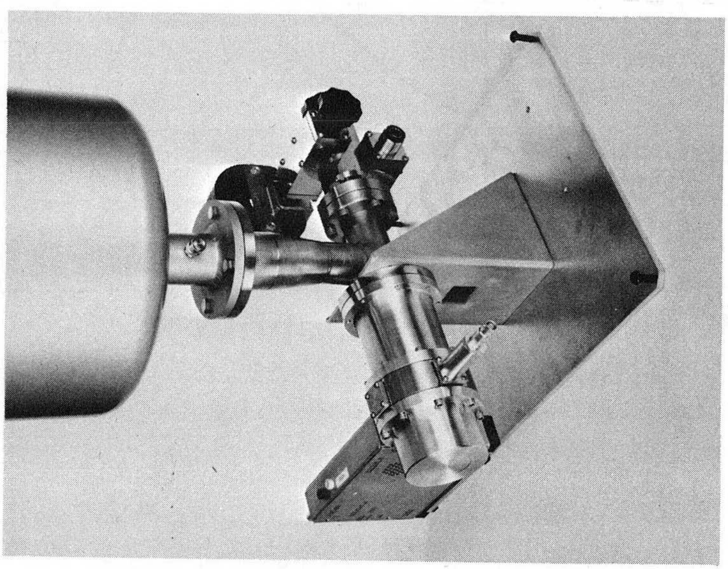


Fig. 20. Temperature and bias curves for the optimum operation of a Si(Li) electron detector.



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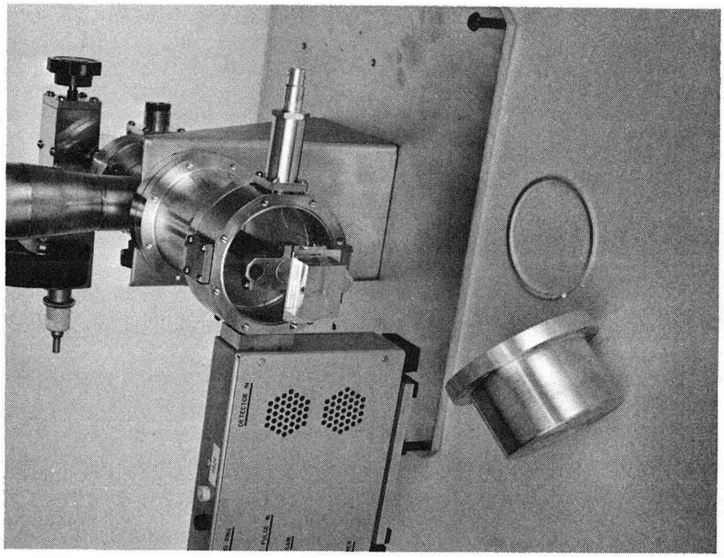

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Fig. 21. Cryostat assembly for use with external FET.
(a) Elevation showing short end cap and alternate location of feed-through mounting ring.
(b) Assembly with end cap removed to show detector, wiring, and method of mounting preamplifier.

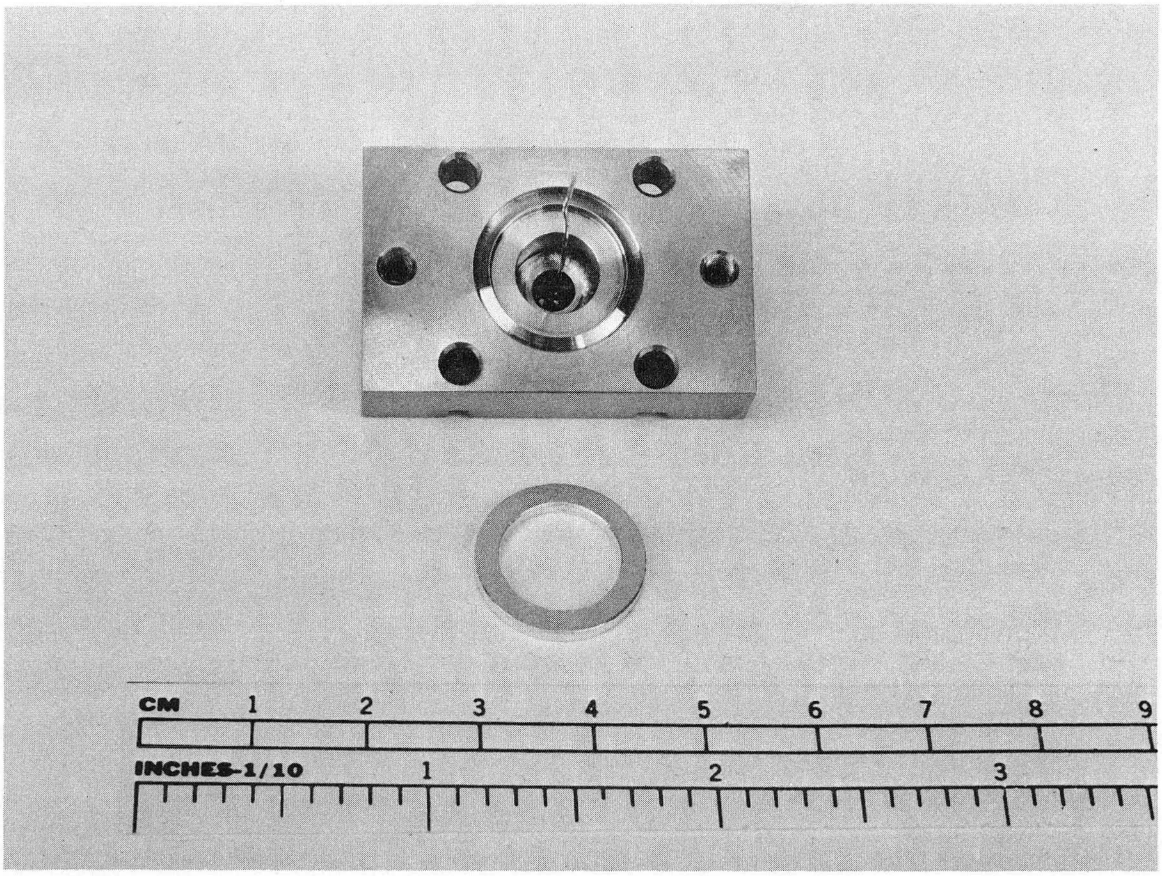

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Fig. 22. Signal feed-through for external FET assembly shown from vacuum side. The preamplifier case is mounted against the far side using the two tapped holes centered along the ends of this flange.

shown in Fig. 10. This connector is mounted on a third port on the feed-through mounting ring. A calibrating thermocouple, clamped to the clamp ring of the detector-mount assembly, is also attached to this connector. Heater power is supplied by a 1 1/2-A, 50-V, regulated dc power supply. Temperature indicated by the thermocouple is plotted versus input voltage to give a calibration curve; the thermocouple is then removed. Figure 19 is a typical temperature-calibration curve. Figure 20 is a typical curve showing resolution versus temperature[24].

External FET Assembly

In cases not requiring optimum resolution, the FET is included in the preamplifier case and is operated at room temperature. It is still necessary, however, to keep the signal wire between the detector and the gate of the FET as short as possible in order to minimize noise. This is done, as shown in Fig. 21, by dividing the end cap into a flanged spool and a short end cap. One end of the spool is mounted directly to the 3 1/2-in.-o.d. flange on the LN container. The feed-through mounting ring is mounted on the other end of the spool. The short end cap is then mounted to the feed-through mounting ring. The signal wire is brought out through a Kovar-glass, three-wire terminal[26] soft-soldered into a flange similar to a feed-through mounting-ring cover plate, shown in Fig. 22. The two outer wires of the terminal are clipped at both sides of the glass insulator as close as possible to the glass. In this application, the feed-through terminal replaces the 6-pin connector. The preamplifier case is attached to the same flange in which the feed-through is mounted.

CONCLUSION

Approximately 18 cryostats of this design are now in service at this laboratory. Approximately 12 more are in various stages of preparation. Those now in service have performed well, are relatively trouble-free, and are convenient to use.

In the near future we hope to provide FET temperature control in addition to Si(Li) detector temperature control in the symmetrical detector mount. We plan soon to develop a mounting system for coaxially drifted Ge(Li) detectors. If necessary, we shall also attempt to provide a means of raising the operating temperature of Ge(Li) detectors above LN temperature.

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19) Obtained from American Lava Corp., Chattanooga 5, Tennessee; part No. Y-31490.

20) Obtained from Reynolds Industries, Inc., 2105 Colorado Ave., Santa Monica, California; part No. 167-3555C. Mates with Reynolds cable connector; part No. 167-3554C.

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