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MEMORANDUM REPORT ARBRL-MR-03056

PRESSURE REGULATION IN A REDUCED
PRESSURE CHAMBER USING A CRYOGENIC
TEMPERATURE CONTROLLER

Mark A. Dewilde

August 1980

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) srf A cryogenic temperature controller, invented at the University of Virginia, is adapted for use as a pressure regulator in a reduced pressure flame studies system. Designed for use in a dynamic flow system, the regulator will hold a pressure within worst limits of 5 mm Hg throughout a flow range of 0.1 lpm to 40 lpm, in a pressure range of 2 to 760 mm.		

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I. INTRODUCTION

In cryogenic studies, temperatures below 4.2°K are routinely required and are attained by reducing the pressure over a liquid helium bath. For temperature control, this pressure must be kept constant within a few mm Hg, at flow rates which vary with heat flow to the liquid helium bath. Our requirements for pressure regulation in a reduced pressure chamber containing a flat flame burner were similar, and with modifications, the regulator has been used to provide the required degree of precision.

In Figure 1, the major components of the regulator are shown. Gas from the system to be regulated enters the regulator at the connection on the left, passes through the regulator intake tip (1) into the tubular diaphragm (2) through the regulator outlet tip (3) and on to the vacuum pump (not shown) which must be able to maintain the desired pressure at the desired flow. The main flow of gas is not permitted to enter the regulator chamber (4), which is sealed with O-rings to the aluminum backplate (5) and the plexiglass faceplate (6). The flow of gas through the regulator is permitted only so long as the pressure inside the tubular diaphragm (2) exceeds the pressure in the regulator chamber (4) so that the diaphragm does not cover the holes in the exhaust regulator tip (3). When the pressure inside the diaphragm (2) is less than that in the regulator chamber, the diaphragm collapses and closes off the holes in the exhaust regulator tip (3). The regulator chamber pressure is reduced by briefly opening valve (7), and increased by opening valve (8).

The strict on-off action described above is not desirable for most applications, so the regulator tips (1) and (3) are tapered. When the diaphragm begins to collapse, it closes off more and more of the holes in the tip (3) providing a variable-area orifice to pump through, and thus, proportional control.

II. DESIGN STANDARDS

For flame gases, the spacing and the diameters of the regulator tip holes is different than that for helium gas, which has much lower viscosity and requires less aperture for proper operation. If the diameter of the holes are made too large, the diaphragm will be sucked into them and will rupture, or will be too tightly held for the gas to push away from the holes. The same holds true for the spacing of the holes. The angle of the taper also helps to determine the opening and closing pressures of the regulator. It is possible to calculate what the pressure on the diaphragm is at a given pressure difference, angle of taper and elastic constant of the diaphragm material, but such calculations serve only to give a starting point. For a given gas mixture, several sets of tips may have to be made in order to reach desired performance, each with different hole spacing and taper angle.

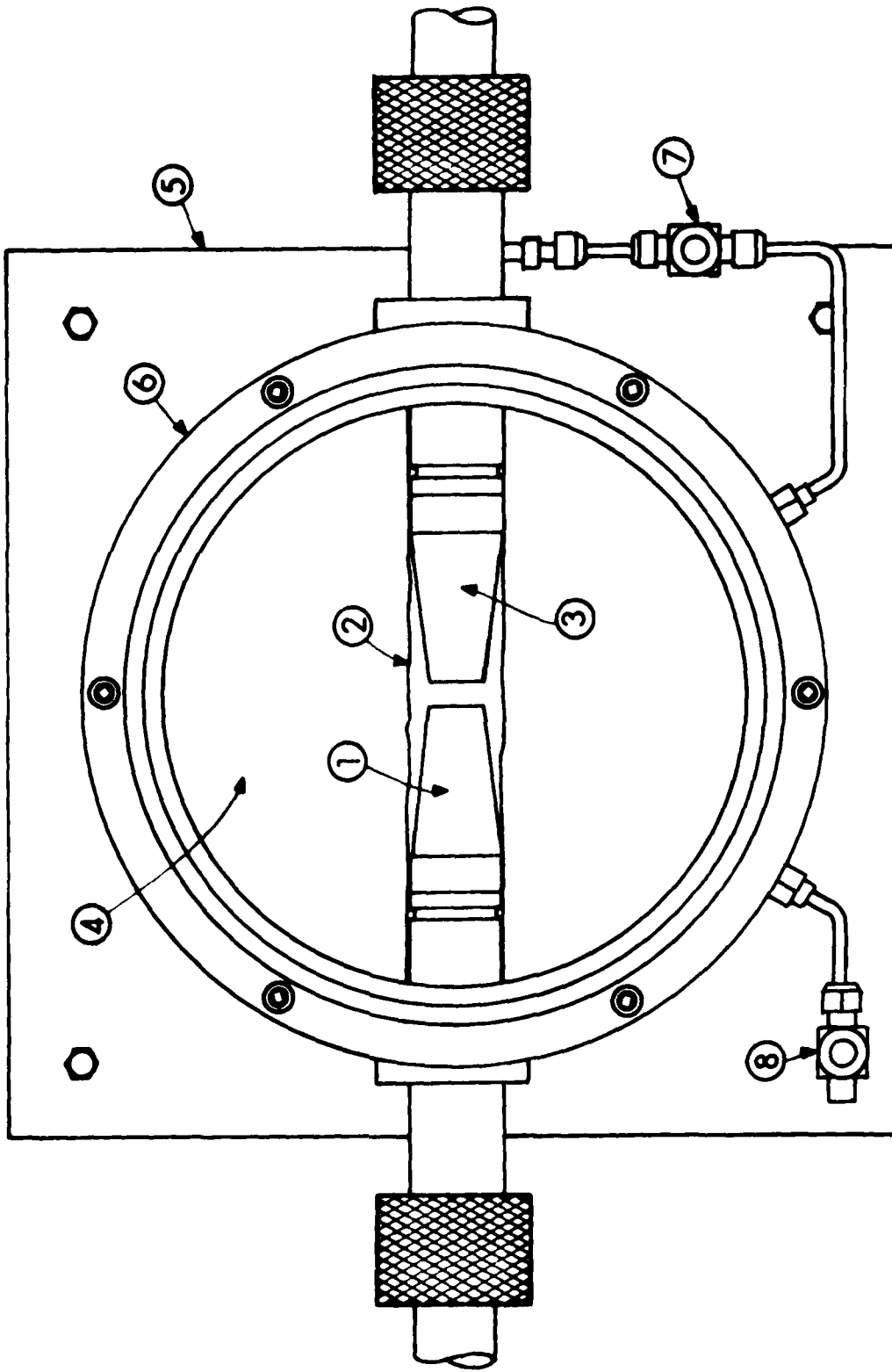


Figure 1. Regulator in TOTO

Ideally, the sum of the areas of the holes in a regulator tip should at least equal the area of the pipes bringing gas to and from the regulator.

III. DIMENSIONS AND CONSTRUCTION OF A REGULATOR FOR FLAME EXHAUST GASES

Figures 2 and 3 contain the dimensions of the pressure regulator couplings and gas channels. The couplings were designed for standard one inch (nominal) copper tubing. The material used was aluminum, although brass or stainless steel are equally suitable. Stainless steel is preferred for more corrosive gases. O-rings provide the seals between the coupling/gas channel pieces and the pressure regulator shell, Figure 4. Figure 5 shows the dimensions of the back and front plates for the pressure regulator shell. Figure 6 shows the pressure regulator tips. The holes are .025 inch in diameter and placed on the intersections of a .15 inch by .15 inch grid on the surface of the tips. The ends of the tips are closed by a press-fitted end cap.

The tubular diaphragm is perhaps the most elegant part of the design. For maximum flexibility, resiliency, and convenience, an ordinary condom, with the closed end cut-off, provides an excellent solution to the problem. Once the not totally unexpected reluctance and mirth of the procurement system can be overcome, the immediate availability and low cost proves to be a hidden advantage, since few elastomers can stand up to the corrosive gases produced by certain flames, and replacement can become necessary daily.

IV. CONCLUSION

Although this design is certainly not the only or best one for pressure regulation in the fraction-of-an-atmosphere domain, it certainly has advantages over cartesian-diver types of devices, both in cost and in absence of the hazardous mercury metal required by most. For the volumes of gas that this regulator will pass, most other devices of this sort are large and cumbersome, or lack the degree of precision that is available.

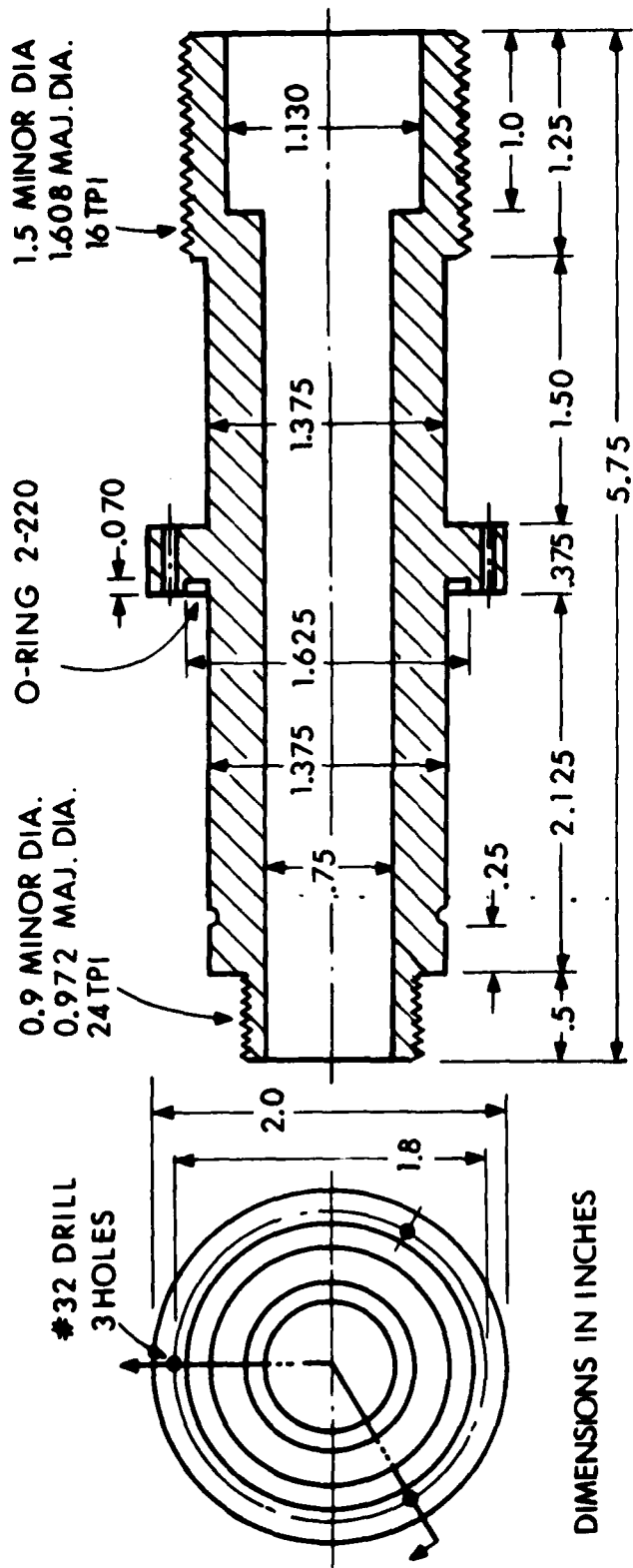


Figure 2. Gas Channel

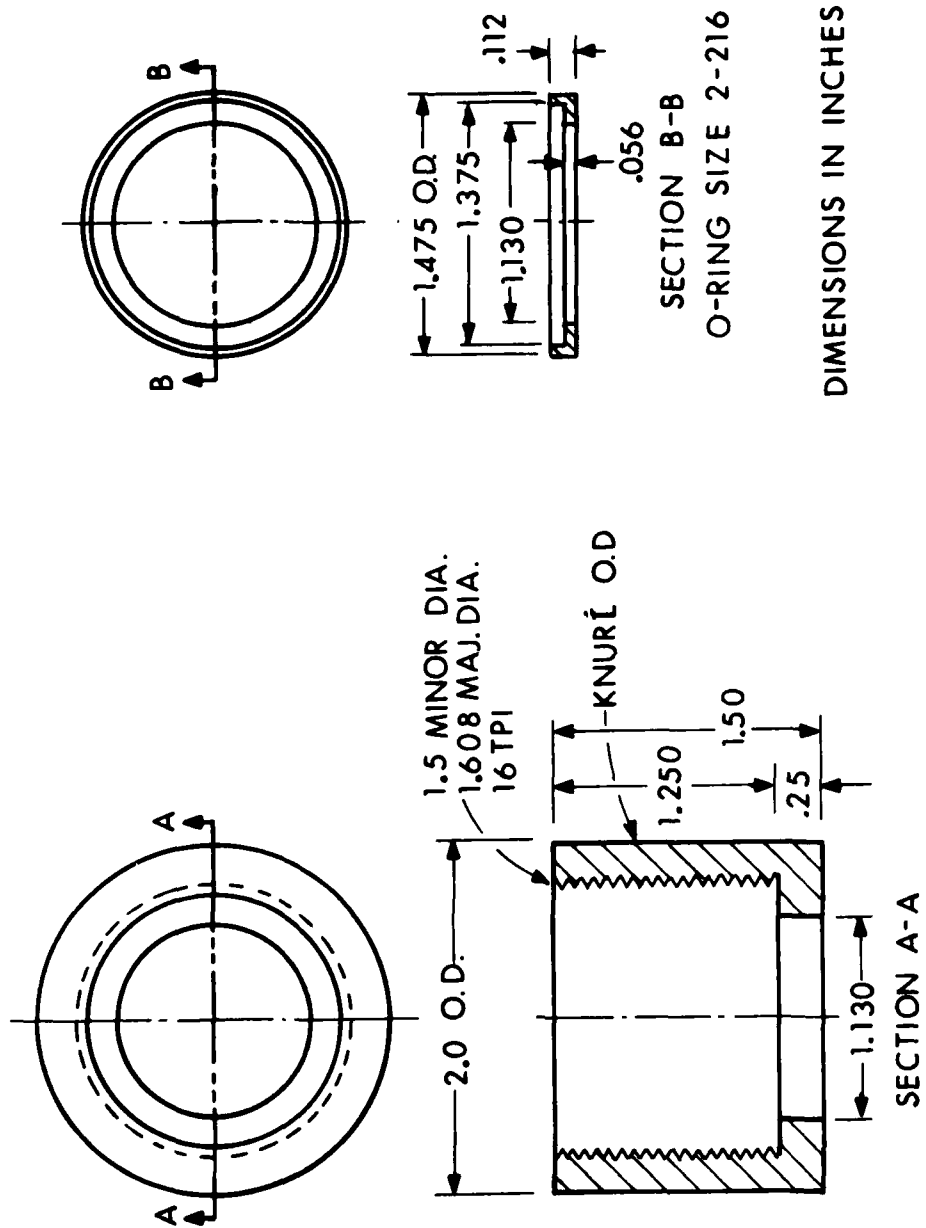


Figure 3. Coupling Nut and O-ring Retainer

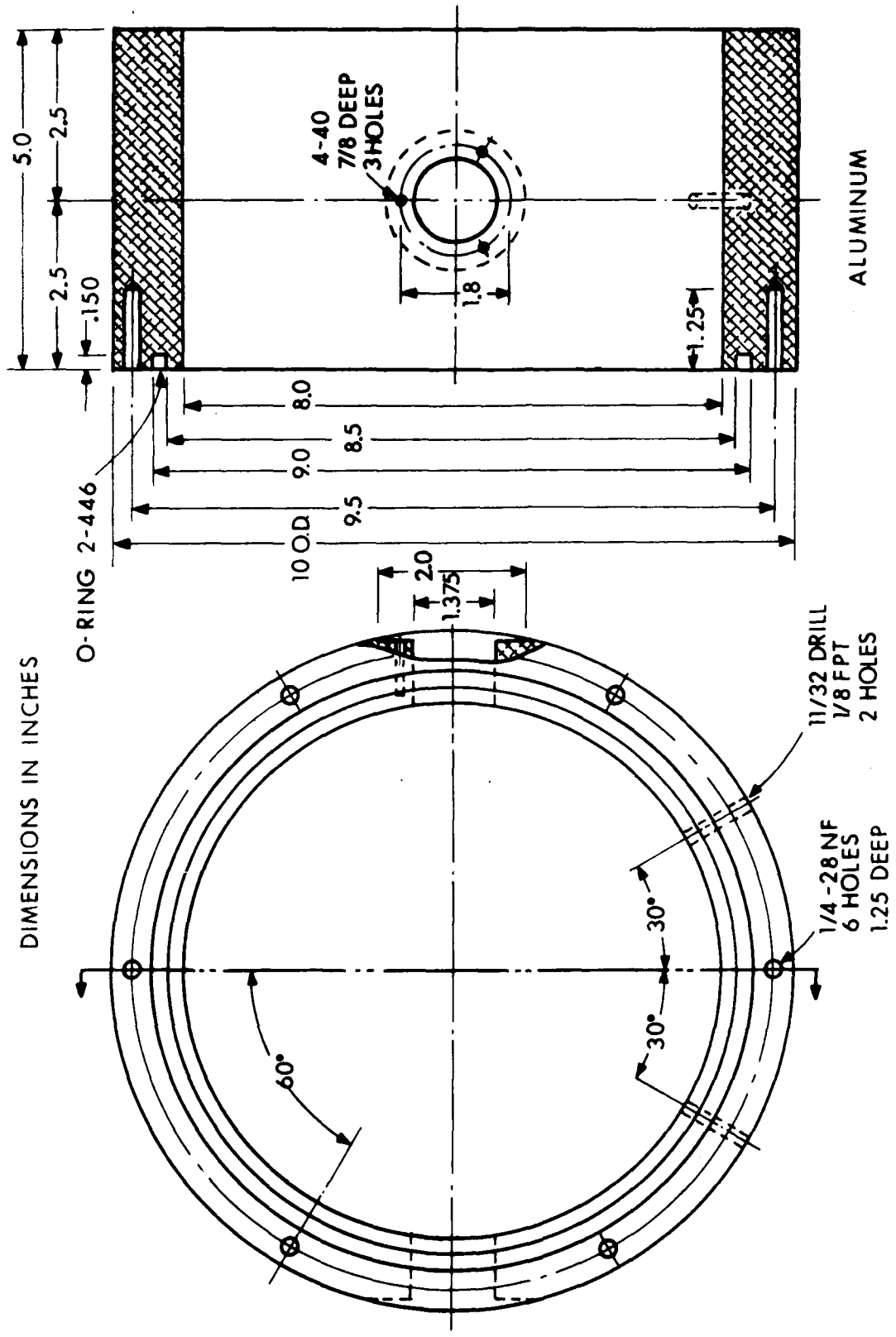


Figure 4. Chamber

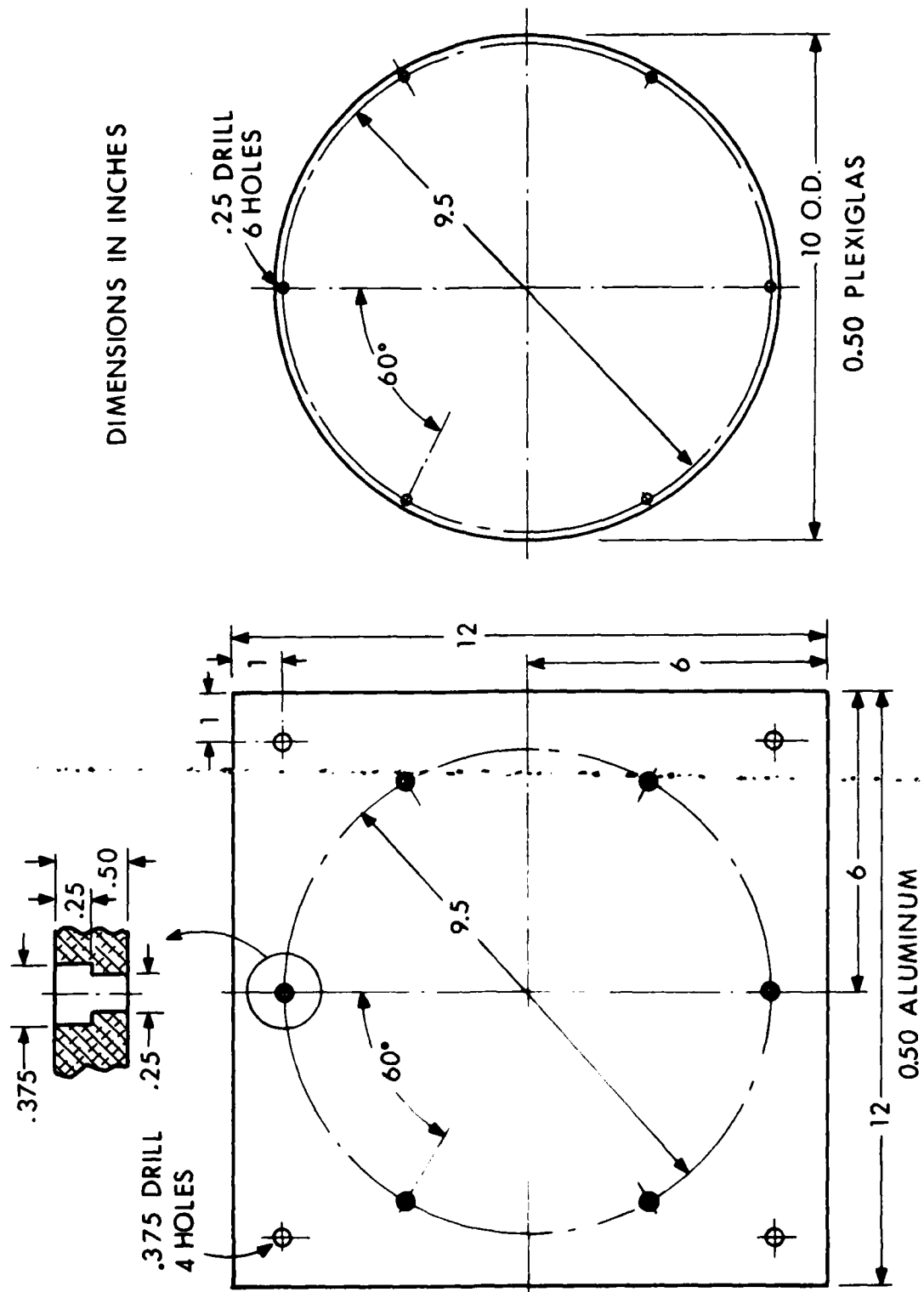


Figure 5. Front and Rear Chamber Cover Plates

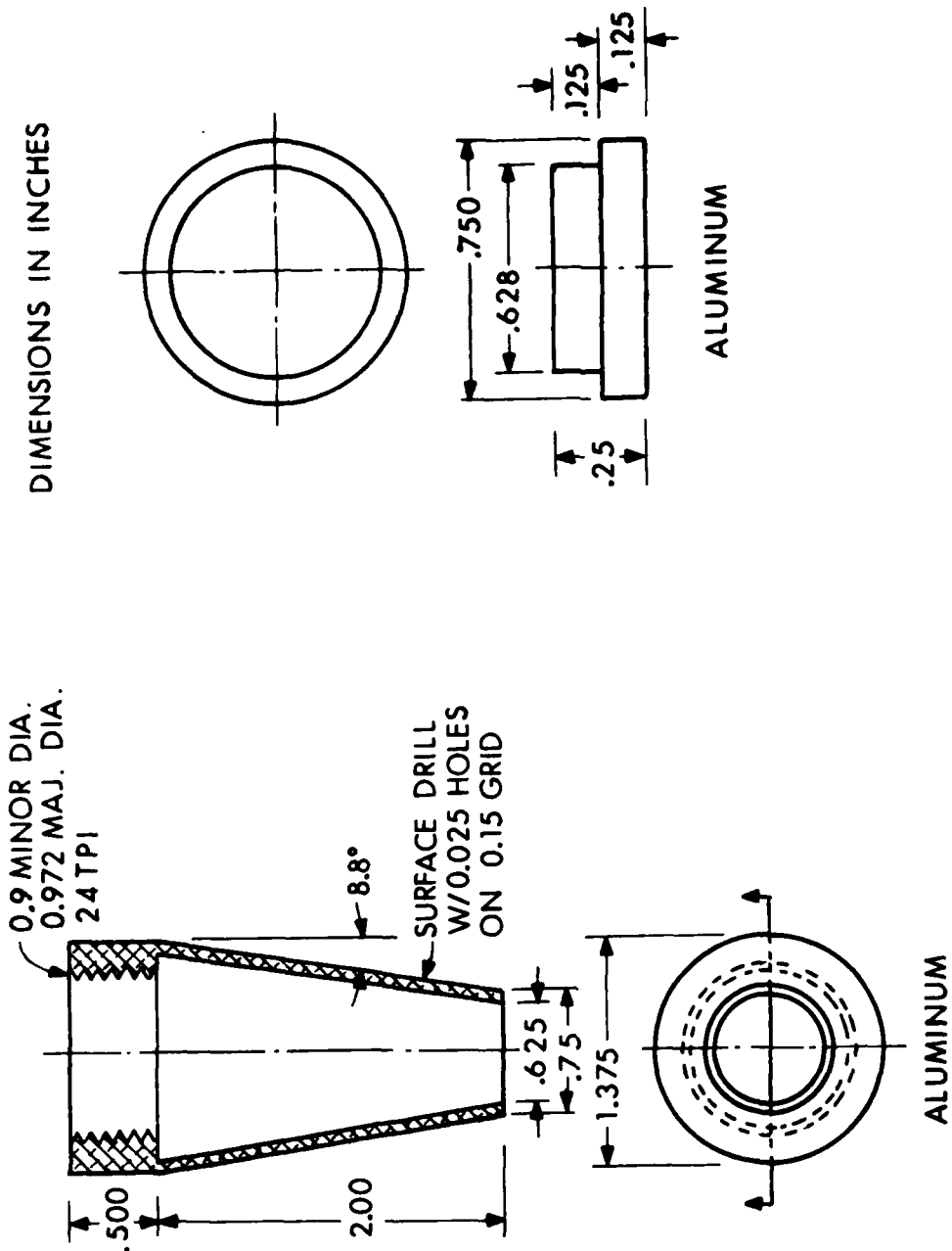


Figure 6. Tips and Related Parts

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