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LIQUID HYDROGEN PUMPING FOR HYDROGEN TARGETS*

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INTRODUCTION

Forced circulation of liquid hydrogen through hydrogen targets is necessary when the geometry and heat load exceed the capacity of normal convection systems. Three small pumps, one centrifugal and two positive displacement, were built for that purpose. Hydrogen flows of 1/2 to 2 liters per minute were attained while the pressure head developed was 10 to 40 feet of liquid hydrogen.

THE TARGET

Physicists using the SLAC 2 Meter Streamer Chamber[1] last year needed a hydrogen target inside the chamber for studying Hyperon Production in K P interactions. The hydrogen supplied the protons to interact with the K particles that are produced by the SLAC linear accelerator. For the experiment to be productive, the distance from the liquid hydrogen to the neon-helium gas mixture in the streamer chamber had to be less than 2 mm, and the liquid hydrogen in the cell had to be free of bubbles. The first target consisted of a tape wound mylar straw, 8 mm in diameter, 460 mm long. It was supported inside a 10 mm I.D. mylar tube serving as a vacuum jacket.

The flask was constructed with an internal tube 2 mm in diameter to introduce the hydrogen at the tip of the target where it could flow back. (See Fig. 1.) No electrically conductive parts were within 700 mm of the end of the target.

The reason for the long nonconductive parts requirement is the high voltage field of the streamer chamber. The target operates between the electrodes

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of the chamber which are pulsed to plus and minus 600,000 volts over a gap of 60 centimeters.[1] The high voltage gradient of 20 kV/cm causes streamers and sparks within the chamber, so a conductor inside this field would be untenable even though it is located very near the ground plane. During operation, streamers and sparks resembling lightning bolts appeared very close to the target, but none punctured the mylar vacuum jacket. As added insurance against electrical breakdown in the target, pulsing of the electric field was prevented when the vacuum was worse than 1.5×10^{-6} Torr.

The mylar tubes[2] used for the feed lines, target cell, and vacuum jacket are purchased items, probably the same as used for electrical insulation. They were tape wound to our specification of size and wall thickness. Vacuum leak checking any mylar containers with a helium leak detector is not practical because helium diffuses right through mylar film fast enough to exceed the capacity of the leak detector. By careful bonding techniques, the system was put together well enough that vacuum leaks were not a problem.

Refrigeration was supplied by a reservoir of liquid hydrogen. Hydrogen gas was condensed into the heat exchanger and circulated by a pump. Inlet and outlet temperatures from the heat exchanger were measured by hydrogen vapor pressure bulbs. These bulbs could not be close to the cell, but with fluid circulating, and both vapor pressures lower than the fluid pressure there were no hydrogen bubbles in the cell.

THE CENTRIFUGAL PUMP

The first pump started out as a model 10-50-316 Micropump.[3] It was modified to the extent that only the 1-1/4" impeller and impeller thrust plate were in the final version. By driving the pump with an air motor[4] the speed could be controlled up to 10,000 r.p.m. The pump assembly is shown in Fig. 2.

A special ball bearing[5] with a filled polyimide retainer was used. The first whirl speed of the shaft is more than 12,000 r.p.m. An air drive motor was used because it was safe, inexpensive, and would function well in the magnetic field present.

We had no method of measuring the flow thru the pump, but the head vs. speed curve is shown (Fig. 3). The curve was not always reproducible. Since the flow was restricted by the 2 mm straw, only a small flow passed thru the system. Heat generated by the pump and bearing probably caused some cavitation that kept the output pressure below theoretical. The target filled and remained free of bubbles as long as the pump pressure was 30" of water or more. The high speed resulted in bearing life of a few hundred hours. Startup was also slow since the gas in the cell had to be forced thru the small feed straw. Another disadvantage to the high speed was the eddy current heating caused by the proximity of a large (5 megawatt) magnet. (Stray magnetic field was about 500 gauss.)

THE BELLOWS PUMP

In order to be able to develop higher pressures in the same space occupied by the centrifugal pump, a double acting bellows pump was hurriedly put together. Figure 4 shows the pump. The welded metal bellows were taken from SLAC stock and the valves are air compressor reed valves.[6] Initially, the pump stroke was 1/2". Since the net area was 2", one cubic inch of hydrogen was displaced each half stroke. Sixty to one hundred twenty strokes per minute provided ample flow.

The inverted design with pressure outside the bellows is more involved to build than with pressure inside, but the bellows will not squirm and can stand greater pressure that way. An air cylinder[7] with internal pilot valves provided the reciprocating motion necessary to make it pump. It pumped very well until a bellows failed after some 2 to 3 million cycles. The pump was rebuilt with the stroke shortened to 3/8", but we haven't needed it since then.

Before the bellows failed, the experimenter determined that he needed a slightly larger target, so one 10 mm diameter, 460 mm long was built with a 13 mm vacuum tube. This target had a 3 mm I.D. feed straw with .0005" walls to flow the LH_2 into the extreme end of the target (see Fig. 5). The new design had less impedance to flow which allowed the centrifugal pump to work well at the more reasonable speed of 6000 r.p.m. The lower impedance resulted from using a larger feed straw and a bypass in the target block.

A PISTON PUMP

Long, small diameter targets will probably be required regularly at SLAC, so another positive displacement pump has been built here. It has a 2 1/2" diameter double-acting piston (see Fig. 6). It uses the same type of valves as the bellows pump. The air cylinder providing the reciprocating motion is a one inch stroke version of the one used for the bellows pump. The piston rings are graphite filled teflon Tec Seals.[8] The piston rod and cylinder bore were hard chrome plated in the areas of sliding motion. Testing to date indicates that the pump works well with no obvious areas of high wear after 30 days of continuous operation. We anticipate continued use of this type of pump because it is reliable, relatively easy to build and maintain, and is readily accessible should it need maintenance. We experience less heat input from this pump than from the centrifugal pump, or the fans with a submerged electric motor.[8] Flow is easily controlled by adjusting the air pressure and flow rate.

SUMMARY

Several small pumps have been built which provide sufficient throughput to operate poorly insulated targets or those with unfavorable aspect ratios. A vacuum space of only 1.0 to 1.5 mm was sufficient to allow our pencil target to work. Heat transfer to the vacuum tube was sufficient to cause condensation on humid days, but no ice formed.

Tape-wound mylar straws can serve as carriers of liquid hydrogen or as vacuum vessels.

A liquid hydrogen target can operate in a streamer chamber without electrical problems if the vacuum is good.

ACKNOWLEDGMENTS

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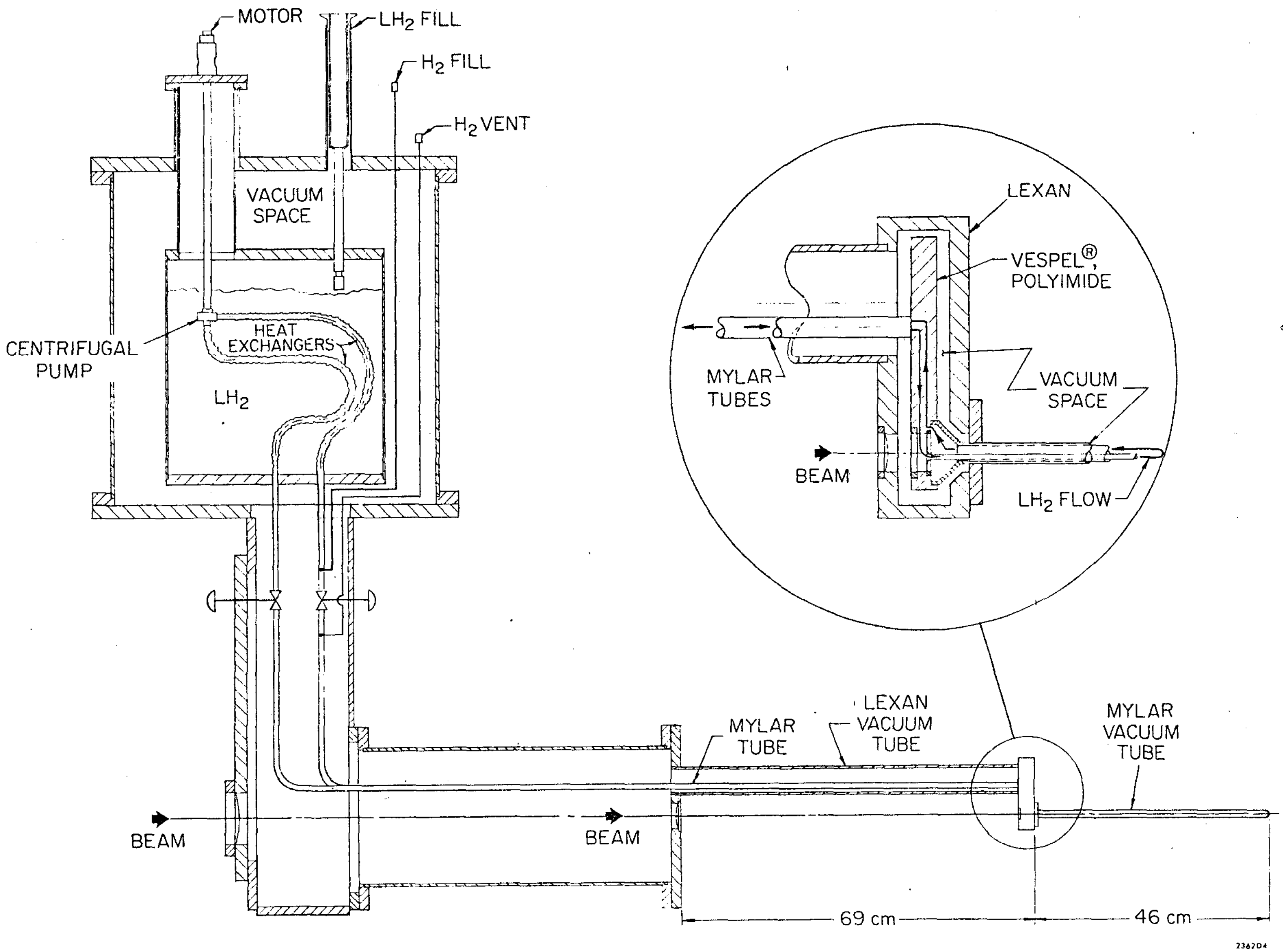

Figure 1. Hydrogen Target Assembly for Streamer Chamber.

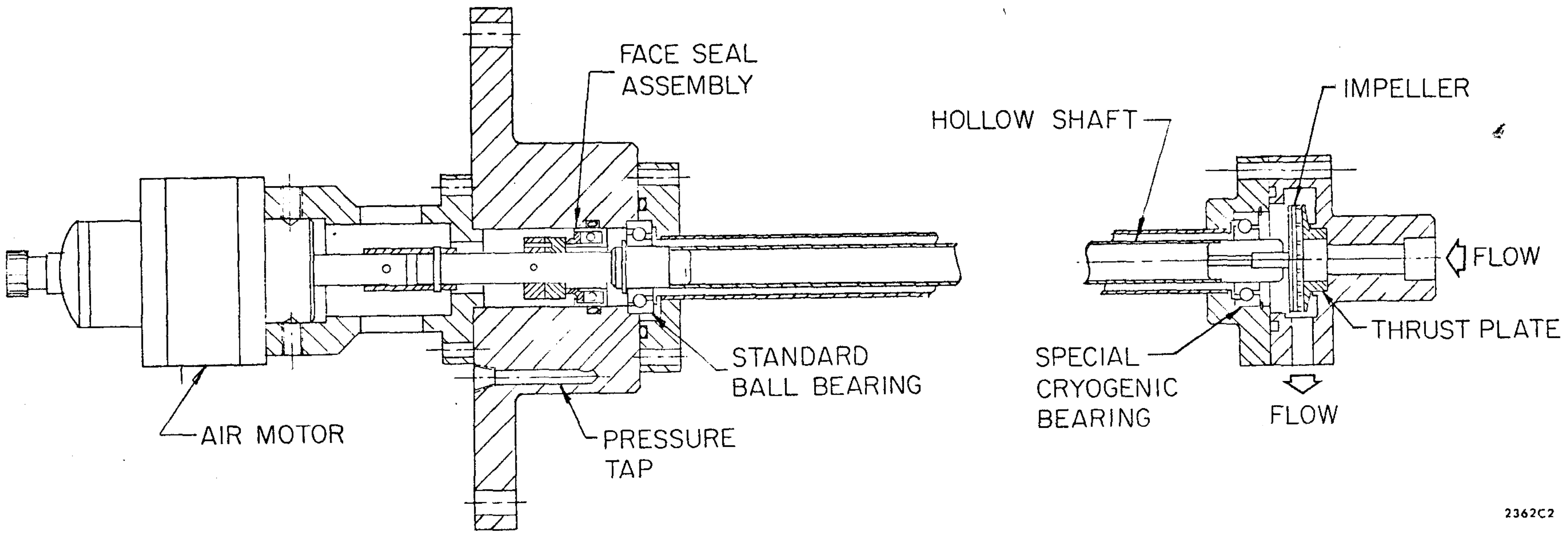

Figure 2. Cryogenic Centrifugal Pump.

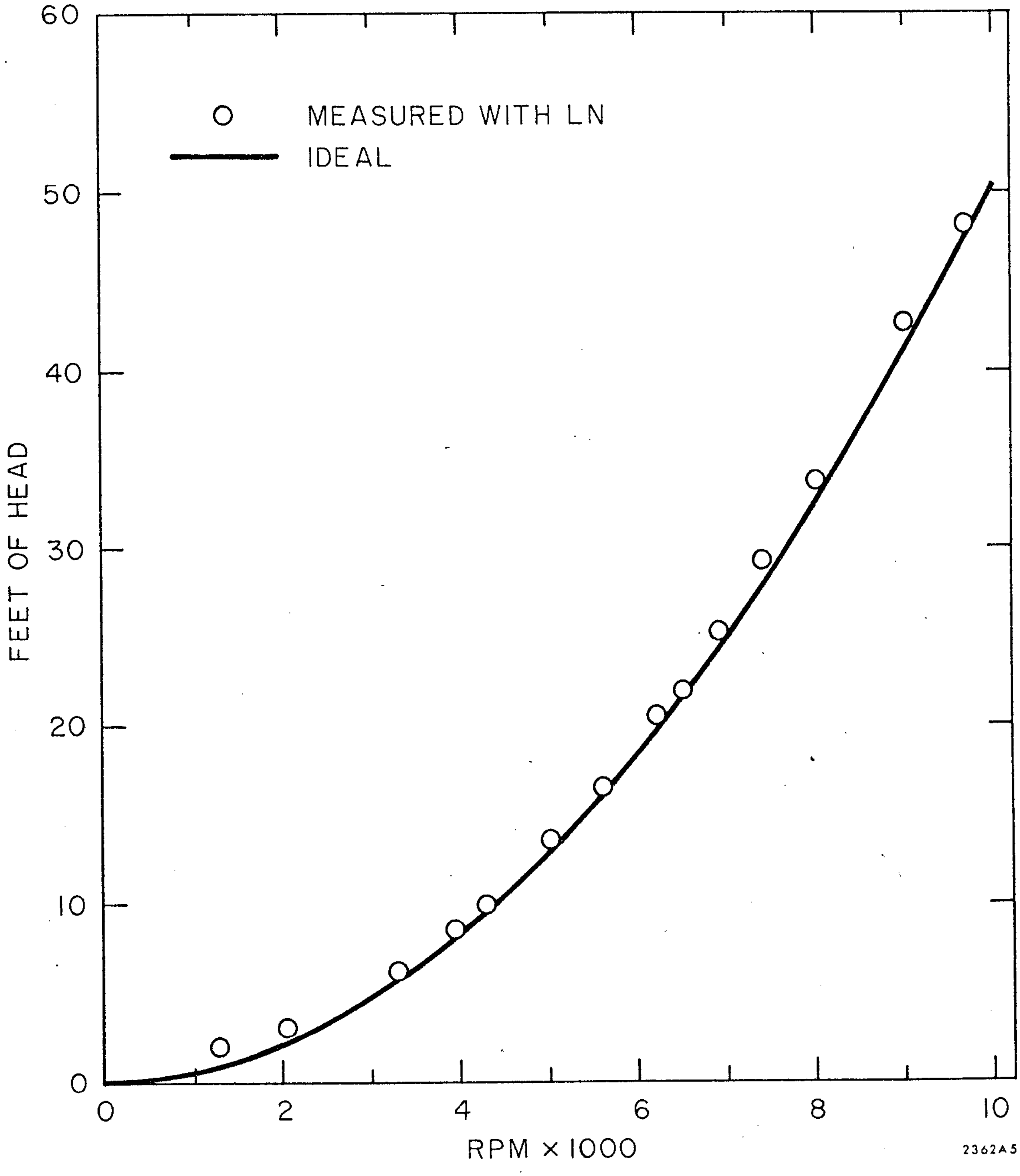

Figure 3. Cryogenic Pump Performance with Liquid Nitrogen, Total Head at Low Flow Rate.

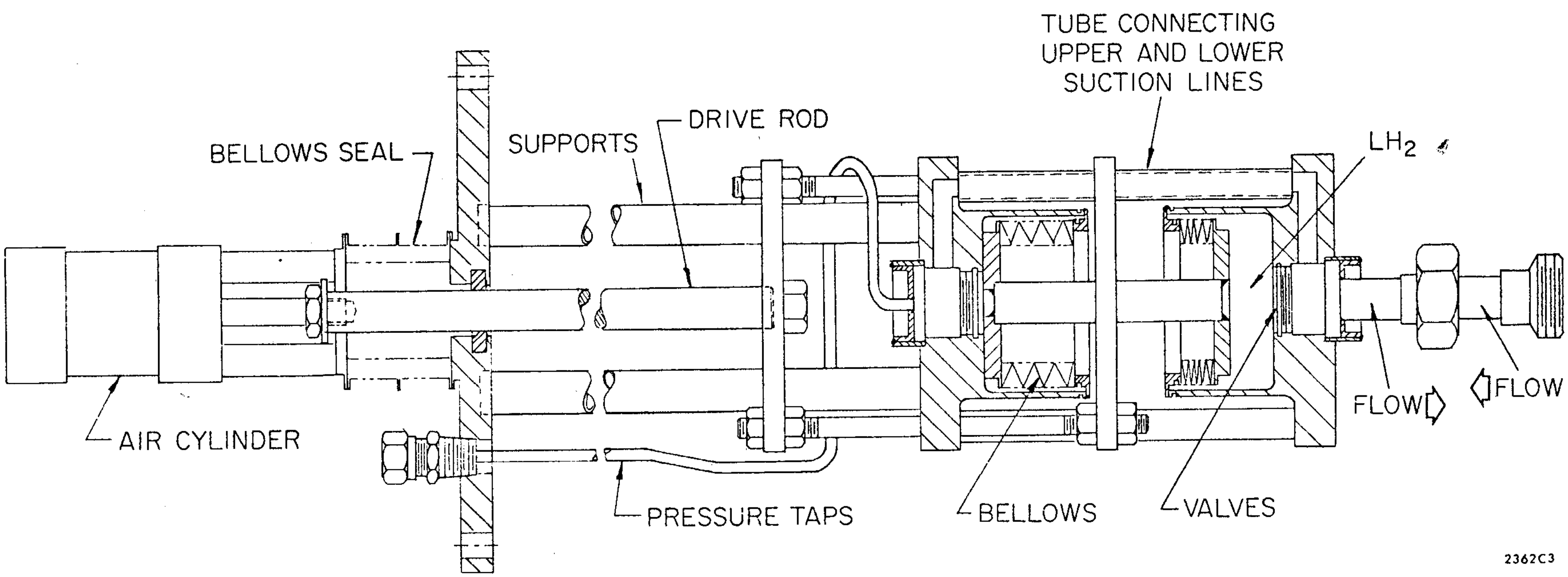

Figure 4. Double Acting Cryogenic Bellows Pump.

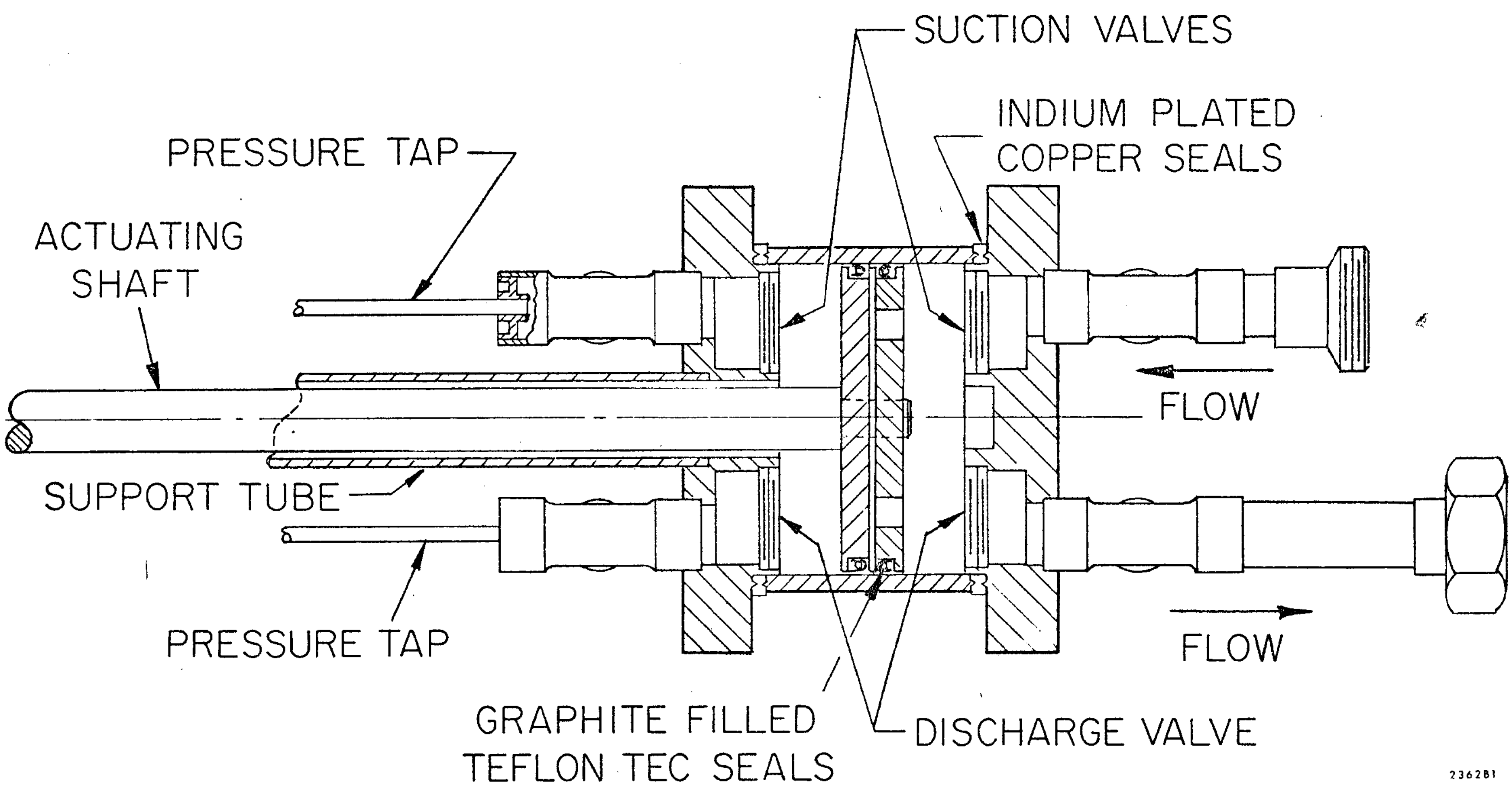

Figure 6. Double Acting Cryogenic Piston Pump.