N69-28124
NASA CR-101430

THE PENNSYLVANIA
STATE UNIVERSITY

IONOSPHERIC RESEARCH

Scientific Report No. 335

ROCKET BORNE, SORPTION TYPE, ATMOSPHERIC SAMPLER AND PRELIMINARY QUARK ION AND HIGH ATMOSPHERIC ANALYSIS

by
R. G. Quinn
April 15, 1969

IONOSPHERE RESEARCH LABORATORY

University Park, Pennsylvania

NASA Grant NsG 134-61

Ionospheric Research

NASA Grant NsG 134-61

Scientific Report

on

"Rocket Borne, Sorption Type, Atmospheric Sampler and Preliminary Quark Ion and High Atmospheric Analysis"

by

R. G. Quinn

April 15, 1969

Scientific Report No. 335

Ionosphere Research Laboratory

Submitted by: John S. Nisbet

John S. Nisbet, Professor of Electrical Engineering
Project Supervisor

Approved by: A. H. Waynick

A. H. Waynick, Director
Ionosphere Research Laboratory

The Pennsylvania State University

College of Engineering

Department of Electrical Engineering

TABLE OF CONTENTS

ABSTRACT

The design characteristics, construction, and flight testing of a high altitude cryogenic sampler of the sorption type is described. The device is simple, light weight, bakeable to 500° C, will collect approximately one gram of air, is effective in the altitude range from 40 to 65 km., and capable of flight in rockets or balloons. The device has been used to obtain samples for quark ion analysis and a program for detailed atmospheric analysis is discussed.

INTRODUCTION

Gell-Mann (1962) developed a system of symmetry classification of known elementary particles in terms of entities called quarks. The quarks, whose existence has never been verified and is subject to considerable controversy, have charges of ± 1/3, 2/3, spin 1/2 and a mass at least the order of ten proton rest masses. McDowell and Hasted (1967) proposed a mechanism by which quarks externally incident upon the earth would become bound to atomic systems of relatively low molecular weight such as oxygen or water. These quark ion systems would then be swept to altitudes of approximately 50 km. by the earth's electric field. The order of magnitude calculations of the various lifetimes associated with this cyclic process suggested that one might expect to find an enhanced population of quark ions in the mesosphere. The authors suggested that samples of the upper atmosphere might be obtained by flying a cryogenic sorption pump utilizing charcoal as the sorbing material.

Because of the importance of such a discovery to physical science and the existing capabilities of the laboratory, it was decided to implement a program to obtain atmospheric samples in the altitude range from 45 to 65 km. for the purpose of determining the presence of quark ions. A suitable system was designed, constructed, tested, and flown on four separate occasions. Three samples for quark ion analysis were obtained. These samples are presently being analyzed at the Argonne National Laboratories and no results are available at this time. During the course of the investigations, it became apparent that the sampling system is useful for general atmospheric analysis provided that different procedures are used with respect to analysis of the sample. The purpose of this paper then is to explain the design, construction details and flight testing of the device outlining its various advantages and disadvantages with respect to other sampling devices.

ATMOSPHERIC SAMPLING DEVICES

There have been a number of various types of atmospheric samplers designed to be flown on balloons and rockets. (Dickinson and Tamarkin, 1965) Each type has various ranges of applicability with respect to altitude and type of species one wishes to observe. In the altitude ranges from approximately 40 to 65 km., the usual types to be considered most effective are condensation and sorption pumps.

One type of condensation pump, (Ballard et al. and Haire et al., 1968) utilizes a chamber whose walls are cooled by liquid neon. The chamber is opened to the atmosphere at a prescribed altitude range and the atmospheric constituents are condensed on the walls. This device is primarily intended to determine the amount of water present at a given altitude. It serves this function but is limited in the fact that certain non condensable vapors will not be detected. This device is capable of flight on a small rocket or balloon.

A much larger device, flown on an Aerobee rocket is designed to obtain much larger samples by condensing atmospheric constituents on liquid helium cooled surfaces. (Denton et al. 1967, and Martell, 1969) This system is extremely complex and relies mainly on the fact that a very large sample will be obtained. It suffers from the fact that it can sample only over very large altitude ranges and is subject to contaminants which may be present due to large surface areas and low bake out capabilities.

The device to be described herein utilizes the principle of cryogenic sorption of gases by charcoal or molecular sieves. It is simple, light weight and capable of high bake out. It can be designed to sample over altitude ranges of 5 km. The basic difficulty with this device is that the sorption rates for each species present are different for each sorber. Also it is possible that certain constituents may react chemically with the sorber.

It should be noted that these two difficulties are of no consequence if one is interested in determining the presence of quark ions because of their unique features. This paper then deals with all of the features of the sampler except those related to sample analysis. It then describes a series of laboratory measurements which will be performed in the future which will allow for an analysis of the pump properties and thus the sampled atmospheric constituents.

DESCRIPTION OF THE SAMPLER

The total package which is flown on an ARCAS rocket consists of the following components: a parachute, electronics package, pump and dewar assembly, sampling valve, protective shield, and nose cone. A photograph of the parachute, electronics package, pump-dewar assembly and sampling valve assembled for flight is shown in Figure 1. A photograph of the pump-dewar assembly, sampling valve, protective shield and nose cone is shown in Figure 2.

A general description of the procedures employed the details of which will be described later, is as follows. With the protective shield and nose cone over the electronics package, pump-dewar assembly and sampling valve, and mated to the parachute, the entire package is mated to the rocket body and placed horizontally on the launch pad. The dewar is charged with liquid nitrogen and the sorber inside the pump chamber is pre-chilled for approximately one hour. After launch and rocket burn out the package is expelled and the parachute deploys at an altitude of approximately 80 km. At this time the protective shield and nose cone are ejected and the timing portion of the electronics package activated. At a preplanned altitude, the sampling valve is opened and then closed after a given time interval. The package has a beacon and is also tracked by radar and is subsequently recovered by helicopter. The sorbed gas is then analyzed.

We will now proceed with the description of the device. The function of the parachute is to lower the descent rate thereby increasing sampling time and ensuring safe recovery. It is a standard device manufactured by the Gentex Corporation. The function of the nose cone and protective shield is simply to protect the pump during ascent. These two are mated together and ejected at the time of parachute deployment which occurs roughly at apogee. When the shield is removed, it activates a time circuit in the electronics package. The functions of the electronics package are to provide a beacon for tracking, a timing mechanism, and power to activate the explosive squibs in the sampling valve. A schematic diagram of the system is shown in Figure 3. (Ballard et al., 1968)

The sampling valve is a ball type designed by Petroff and Associates, Los Angeles, California. A close up of this assembly is shown in Figure 4. The ball is spring loaded and constrained in the closed position by a steel slug-cam arrangement. The first slug is removed by an explosive squib and the valve moves to the open position at the next slug. This second slug is also removed by a second squib after sampling. The valve then rotates to the closed position. The squibs are specially designed so that the explosive charge is completely contained so as not to contaminate the sample.

A cutaway view of the pump-dewar assembly is shown in Figure 5. A thin aluminum cylinder encases the dewar which is machined from a solid cylinder of high density polyurethane. This dewar is rugged, light-weight and has extremely good insulating properties. Fill and vent tubes pass thru the dewar and aliminum casing wall. The pump body which houses the sorbing material is made of stainless steel. The wall in the area near the valve assembly is made extremely thin. This provides minimum thermal conduction thus protecting the valve seat and gasket during bake out and cooling. A hollow central screened core is also provided in the pump chamber. This feature greatly enhances pumping speed as will be discussed later. Finally, the pump is provided with a valve for laboratory testing of sampled gases.

LABORATORY TESTING

The individual components of the entire assembly were spin and shock tested for reliability.

At cryogenic temperatures it is necessary to insure successful valve operation and elimination of contamination by gases which may condense on the external surfaces on the ground. The valve was repeatedly tested in the laboratory functioning perfectly in these tests as well as all flights. The condensation problems were eliminated in the following manner. First the thermal conduction from the pump body to the valve assembly is minimized by the thin wall stainless section. Second and more importantly, the nose cone and shield assembly completely encloses the system on the ground and at all altitudes up to apogee. Prior to charging with liquid nitrogen, the housing is purged for five minutes with helium and super dry nitrogen gas using the openings in the shield as entry and exit ports. The process removes all condensable gases from the housing. Further when the system is charged with liquid nitrogen, the boil off creates a situation in which the pressure inside the housing is slightly higher than ambient thus insuring that no condensable vapor can enter. Finally, when the shield is removed at apogee, the device is exposed to high vacuum for the period of the descent prior to sampling.

The ball valve and laboratory sampling valve were tested using a standard vacuum leak detector at pressures of 10^{-9} torr. There were no detectable leaks on all valves tested. The effects of long term leaks or out gassing were determined by the following method. The system was baked out at 200° C for a period of 24 hours followed by an hour bake at 400° C. A residual gas analysis was then made using a mass spectrometer at temperatures of 100°, 200°, 300°, and 400° C and also on the following three consecutive days. There was no detectable leak.

Sorption pumping is highly dependent upon the sorbing material, the gas being sorbed, surface area, pressure and temperature. Liquid nitrogen was chosen as the coolant in spite of the fact that other fluids, such as helium have lower boiling points. This was done because of the higher heat capacity of nitrogen and the much greater ease of handling, storage, availability and low cost. The effect of surface area on pumping speed is shown in Figure 6.

A cylindrical pump was chosen to maximize heat transfer to the liquid nitrogen. The tests were performed with the valve assembly exposed to the cavity of a cylindrical bell jar, 18" in diameter and 36" high. The bell jar was set at an initial pressure of 0.5 mm to correspond to typical sampling pressures at high altitudes. The ball valve was then opened and the cryogenic pump allowed to evacuate the bell jar further. The curves are bell jar pressure vs time. The slower pumping speed shown in the upper curve is that when the carbon is placed in the body with a conducting rod in the center. The higher speed curves show the improvement achieved by replacing the central rod with a wire screen core. Thus the wire screen core design was used in all flights.

It should be noted that the pumping rate is a function of ambient pressure and thus there will be an upper altitude limit above which the pump will not be effective. For example at a pressure of 1 mm, the pump tested sorbed at a rate of 0.007 grams/sec. A similar rate would be expected at altitudes up to approximately 65 kilometers. From published data on larger commercially available cryogenic roughing pumps, the theoretical upper limit would be 85 kilometers assuming the same sampling time and an increased weight.

Since the minimum detectable partial pressure of usual laboratory mass spectrometers is approximately 10^{-13} torr, the samples obtained will be sufficient to detect concentrations of the various atmospheric constituents of the order of one part in 10^{9}.

Finally the interaction of the sorber and various atmospheric constituents affects the process. These effects are especially important and different for every species. These properties of the device have not been examined to date. A systematic investigation is in progress and will be described in a later section.

FLIGHT EXPERIMENTS

Flight I WSMR 22 January 1968

The primary purpose of the first flight was of course to determine the existence of quarks. Bake out and testing for residual gases was not as comprehensive as in later flights although a residual gas analysis was to be made by a private vendor. Because of the prevailing winds and the surrounding terrain it was decided that a special parachute having a higher descent rate should be used. This parachute was of an experimental type and failed to properly deploy. The package suffered a free fall from 80 km. but nevertheless operated and remained intact. Thus the quark sample was obtained but the atmospheric sample ruined. This is true because, if they existed, such ions would be extremely stable or virtually incapable of interacting with other constituents. This same package was flown on Flight II after some minor repairs.

Flight II WSMR 6 March 1968

In flight signals indicated that the parachute failed to deploy and the entire package was lost. From the various bits of information available it was surmised that the failure was due to excessive weight. These conclusions were verified in Flight III.

Flight III WSMR 22 May 1968

A modified lighter package was launched, successfully sampled the air in the preplanned altitude range and recovered. The device was recovered in an essentially pre-flight condition, and an excellent sample from the standpoint of both searching for quarks and measuring atmospheric constituents was obtained. This is mentioned because subsequent analysis by a private vendor indicated that the mass spectrometer system leaked.

The sample was therefore ruined during the analysis; however, it was still highly satisfactory for determining the possible presence of quarks in the sampling region.

All of the charcoal from Flights I and III have been sent to Argonne National Laboratories to undergo the highly specialized analysis necessary for the detection of quark ions. As of the date of this writing no positive results have been obtained.

Flight IV (Balloon) WSMR 11 September 1968

With the reliability of the device proven on the preceding flights, and adequate samples taken for detecting the presence of quarks, emphasis was placed more on determining atmospheric constituents. The double sampling device shown in the photograph of Figure 7 was constructed for flight on a balloon designed to reach an altitude of 50 kilometers. The samplers were programmed to measure at different altitudes for extended periods of time. In addition extensive preflight leak detection and mass spectrometer analysis were conducted in laboratories at The Pennsylvania State University. The package was one of an integrated set of experiments all of which functioned perfectly. Unfortunately, the balloon and experiment package were lost due to some failure in the tracking network. The device was subsequently recovered in March 1969, again providing a sample for quark ion analysis only.

SUMMARY

The principles of operation, design details, and flight testing of a cryogenic sorption device have been discussed. The device is light weight, bakeable to 500° C, will collect approximately one gram of air and is effective in the range 40 to 65 km. and capable of flight in rockets or balloons.

FUTURE INVESTIGATIONS

A gas handling and mass spectrometer system has been established to test the sorption properties of the sampler by allowing the device to sample known quantities and mixtures of various gases of interest. The gases will then be desorbed and analyzed to determine what interactions, if any occur. With the data obtained, it will be possible to make comprehensive atmospheric analysis in the altitude ranges discussed.

REFERENCES

Ballard, H.N., Izquierdo, M., Haire, A., A Cryogenic Sampler for Determination of Atmospheric Composition. Presented at the American Meteorological Society Conference on Composition and Dynamics of Upper Atmosphere, November 6-8, 1968.

Denton, E.A., Hoard, J., Jacob, R.B., Martell, E. A., Preliminary of NCAR-1 Rocket-Borne Cryogenic Air Samplers, NCAR Technical Note, NASA Contract NASr-224 (1967).

Dickinson, H., and Tamarkin, P., Systems for the Detection and Identification of Nuclear Explosion in the Atmosphere and in Space Proceedings IEEE, Vol. 53, 1921 - 1934 (1965).

Gell-Mann, Murray, Symmetries of Baryons and Mesons, Phys. Rev., 125, 1067 - 1084, (1962).

Haire, A., Pope, K., Internal Cryogenic Probe Sampler, National Engineer Science Company, Pasadena, California, (1968).

Martell, E.A., To be presented at Spring Session of AGU, 1969.

McDowell, M.R.C., and Hasted, J.B., A Quark Albedo?, Nature, 214, 235-237, (1967).

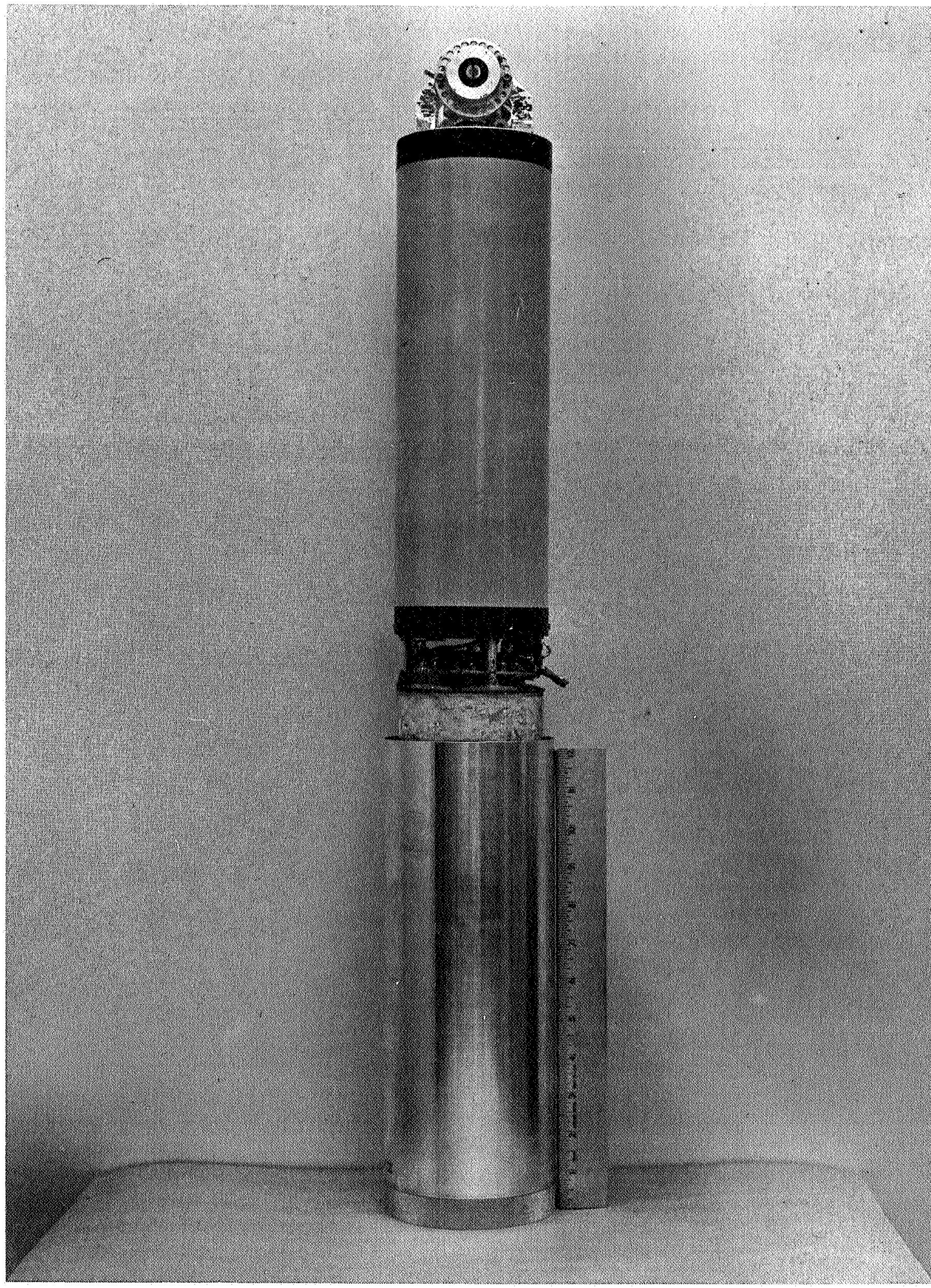

Figure 1 Partially Assembled Sampler. Bottom-Parachute. Center - Electronics Package. Top - Pump-Dewar Assembly.

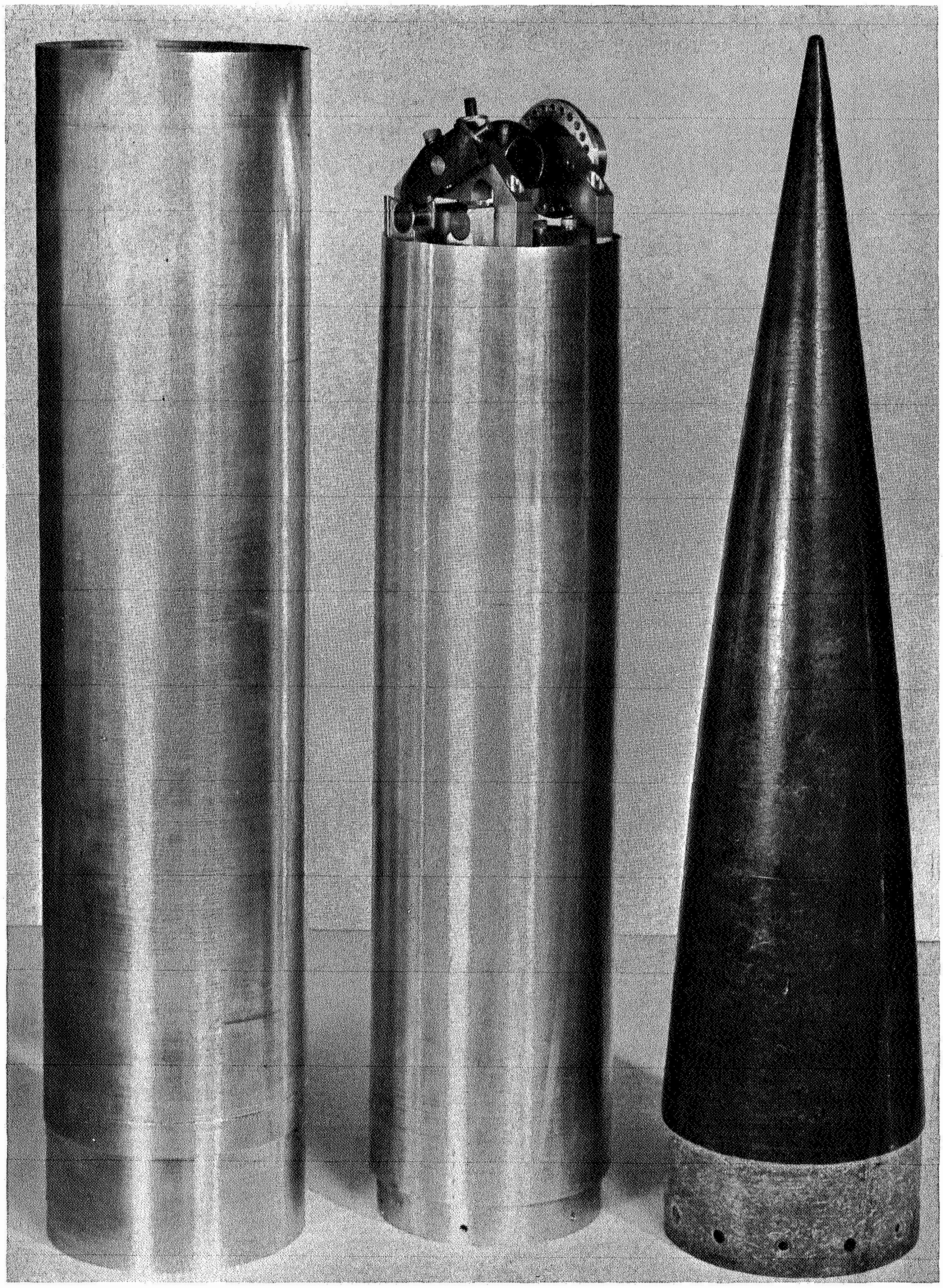

Figure 2 Unassembled Sampler. Left - Protective Shield. Center - Pump-Dewar Assembly. Right - Nose-Cone.

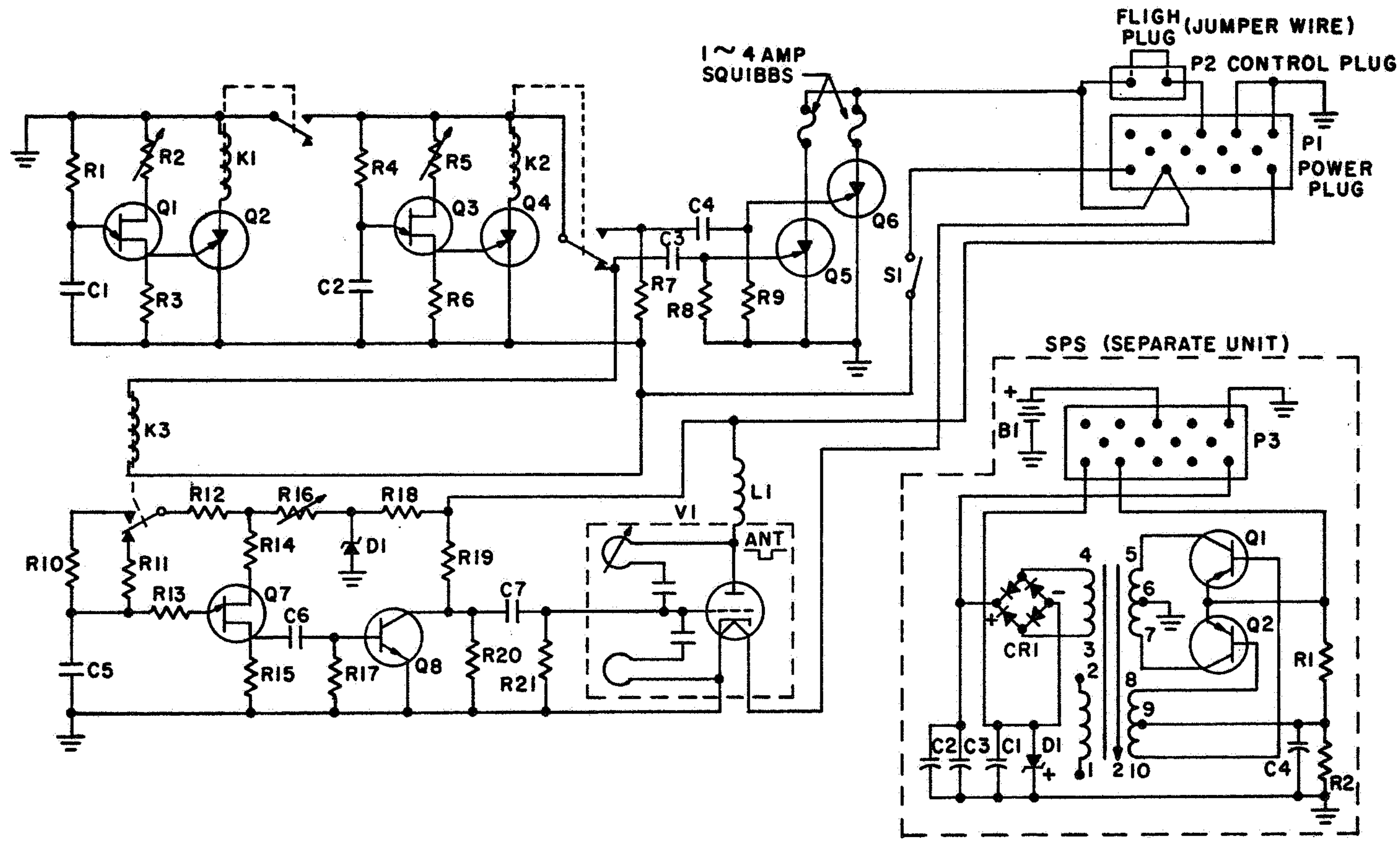

Figure 3   Schematic Diagram of Electronics Package

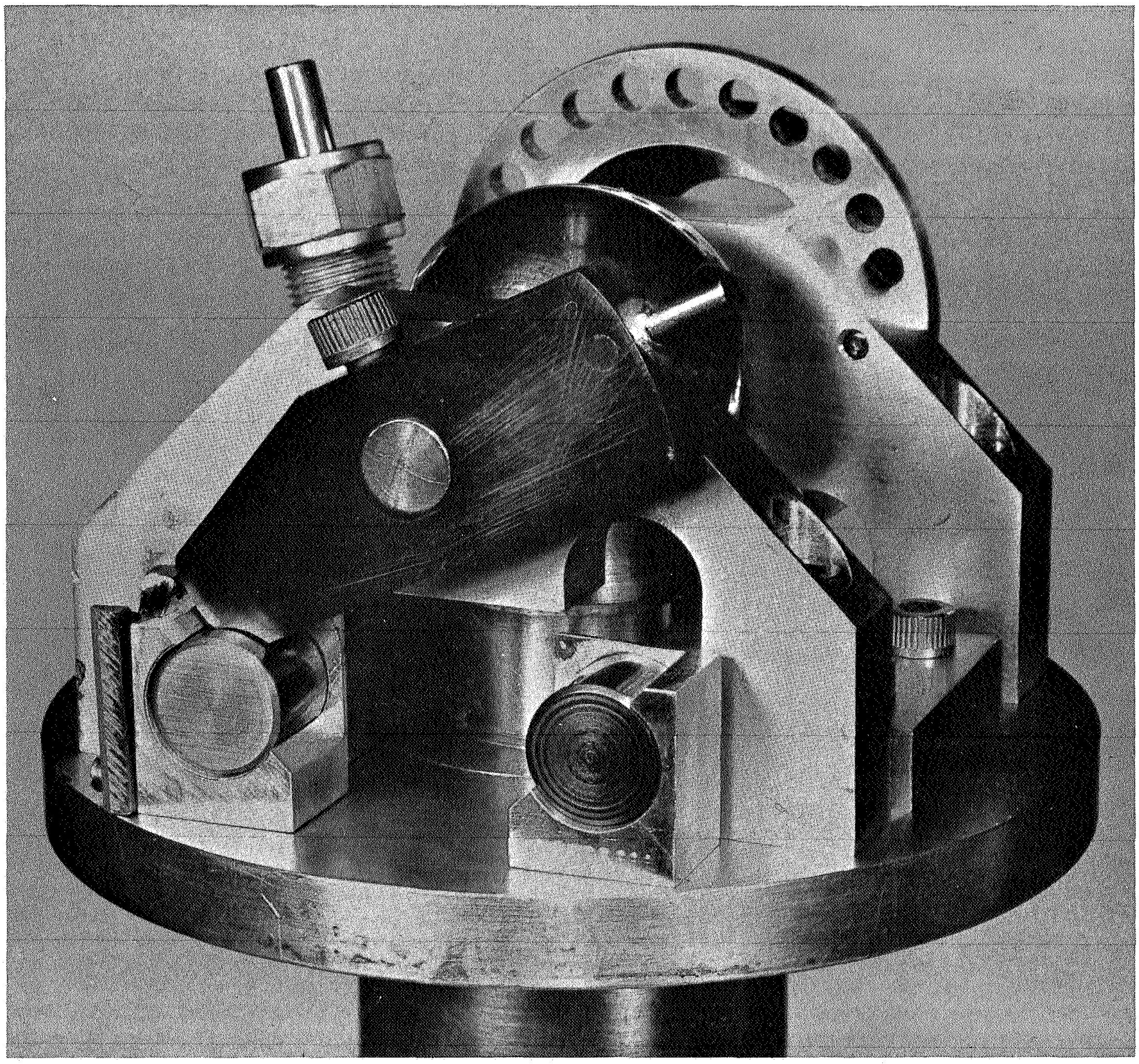

Figure 4 Sampling Valve Assembly

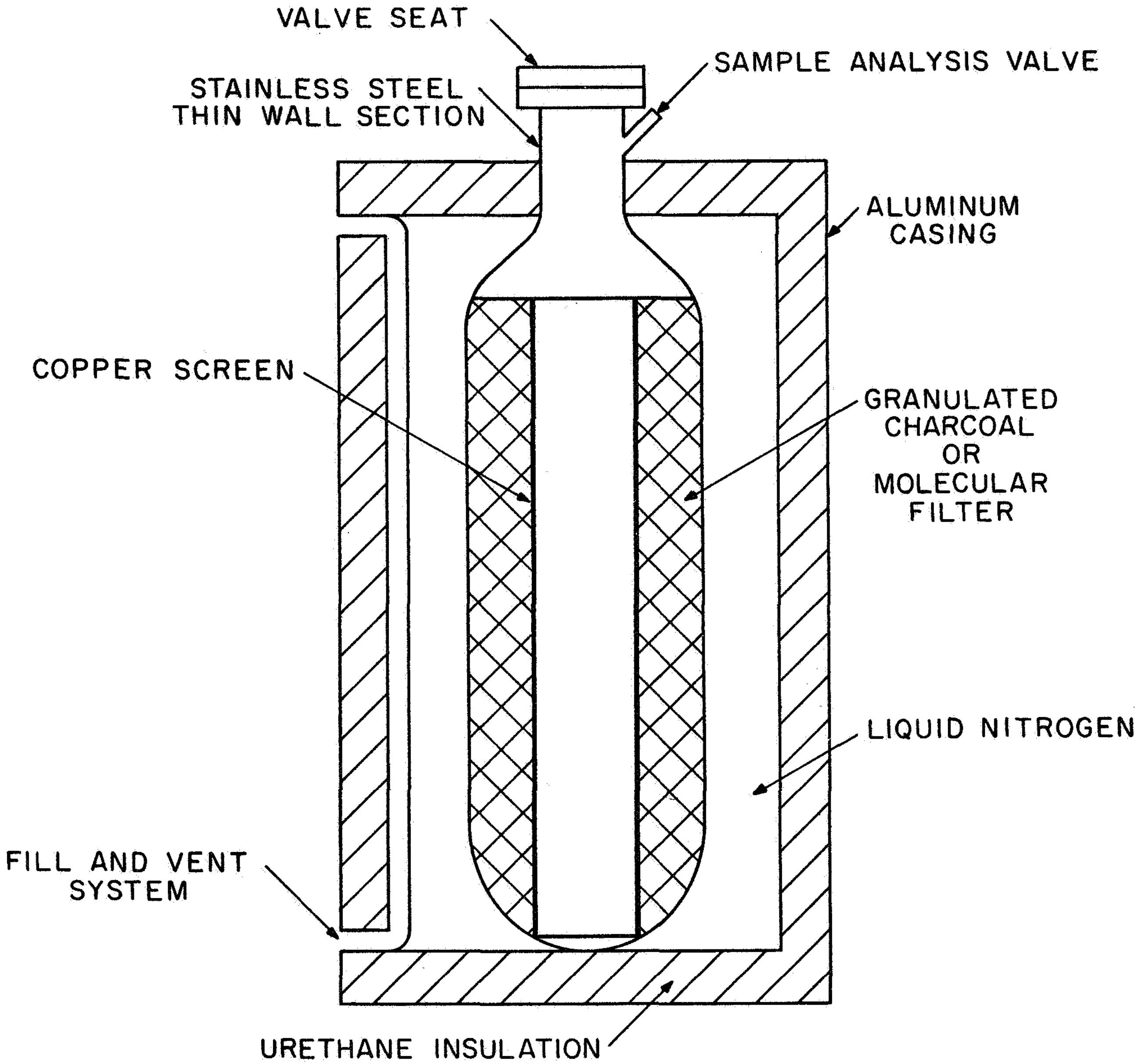

Figure 5 Vertical Section of Pump and Dewar

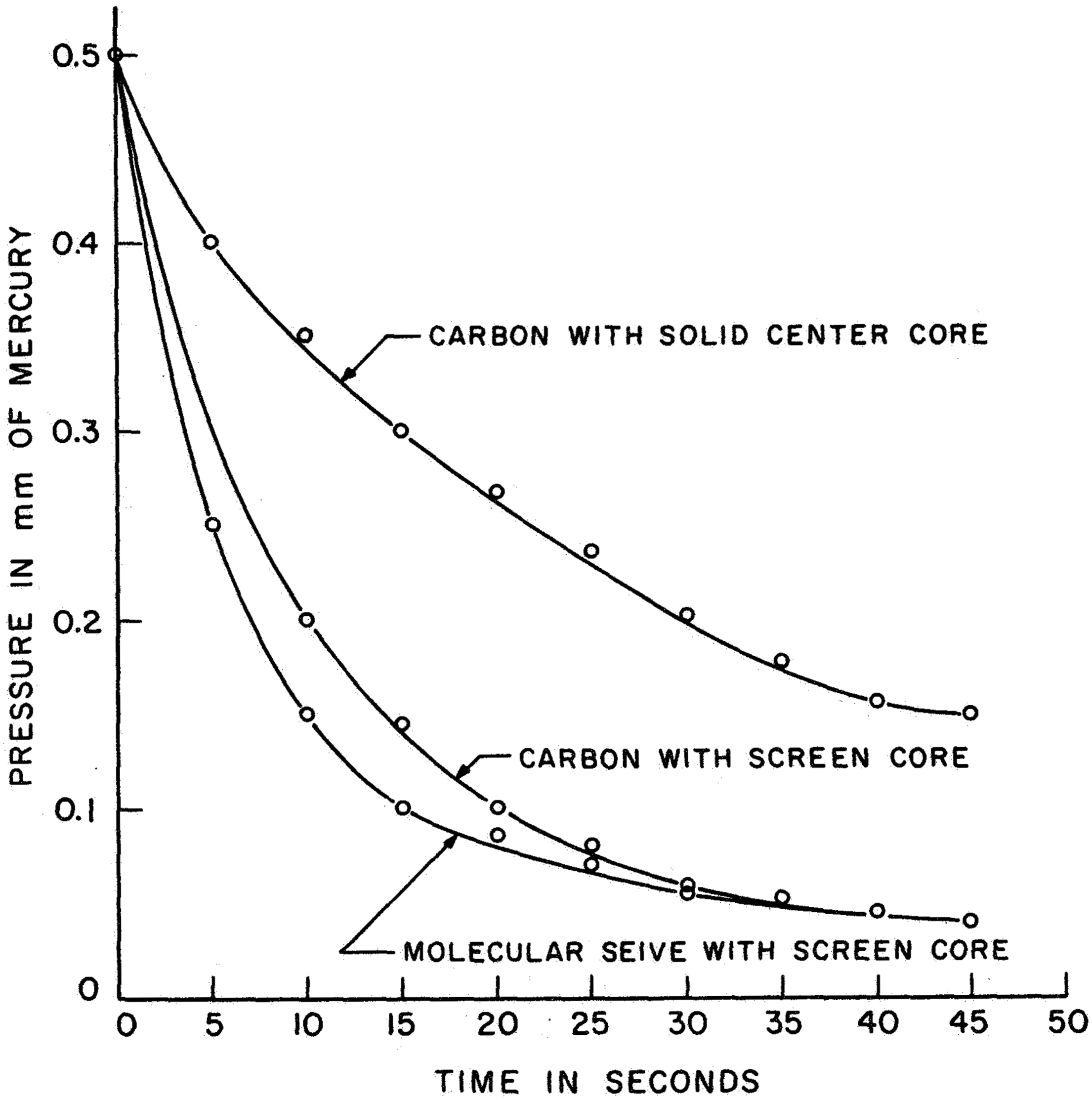

Figure 6 Pump Characteristics

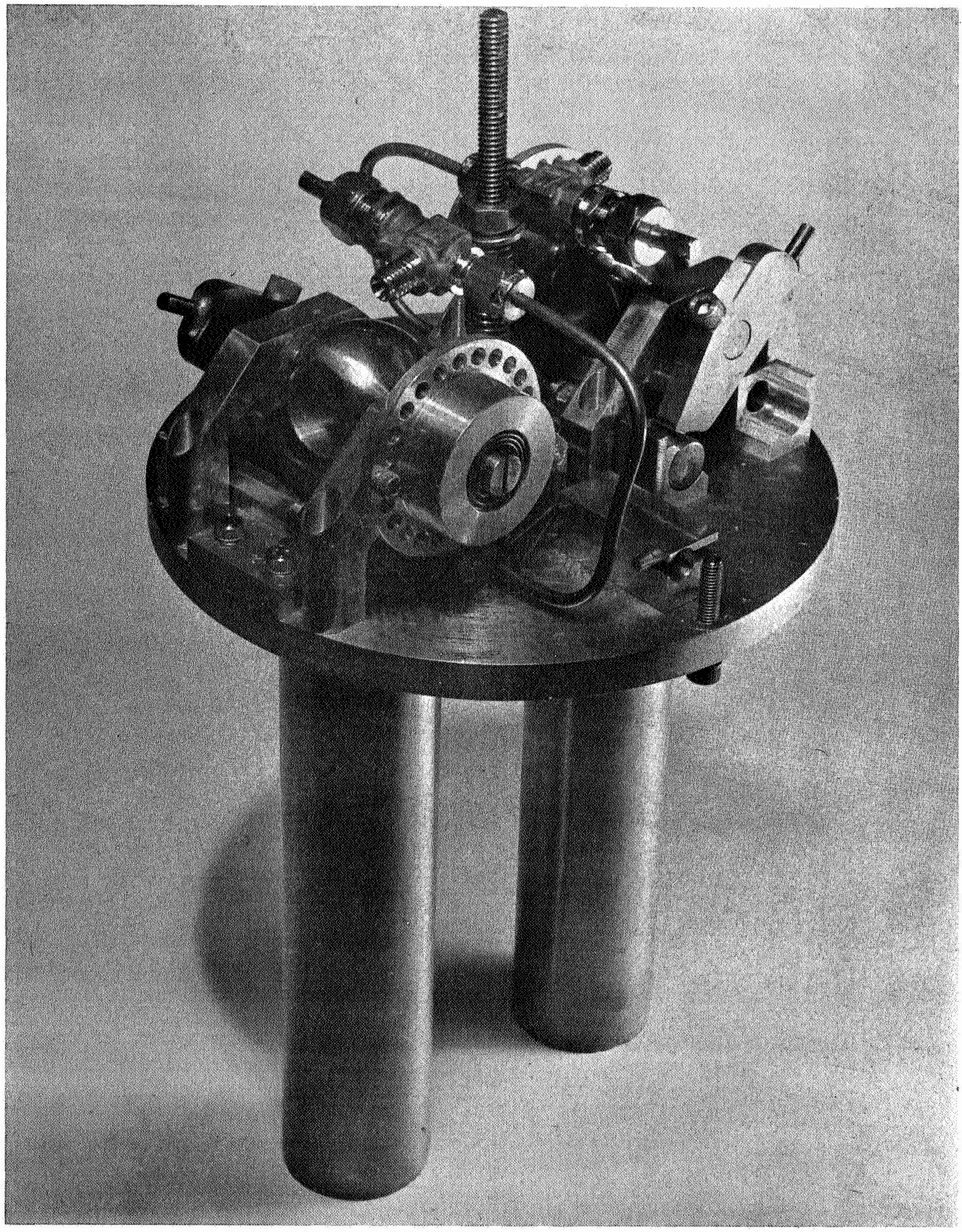

Figure 7 Double Sampler for Balloon Experiment

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Harold N. Ballard of the Atmospheric Sciences Office, U.S. Army Electronics Command, and Miquel Izquierdo of the Shellinger Research Laboratories, University of Texas af El Paso for their many contributions to this effort.