THE UNIVERSITY OF MICHIGAN RESEARCH INSTITUTE
ANN ARBOR, MICHIGAN

Scientific Report FS-1

BI-POLAR PROBE INSTRUMENTATION NO. 1

Prepared on behalf of the Project by

N. W. Spencer

UMRI Projects 2521, 2816-1

GEOPHYSICS RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH CENTER
CONTRACT NO. AF 19(604)-1843, PROJECT NO. 7643
and
BALLISTICS RESEARCH LABORATORY
ABERDEEN PROVING GROUND
CONTRACT NO. DA-20-018-509-ORD-103
PROJECT NO. DA 5B03-06-011 ORD (TB 3-0538)

October 1958

ABSTRACT

The design and construction aspects of a bi-polar probe instrumentation for ionospheric investigations are discussed.

PERSONNEL DIRECTLY ENGAGED IN THE RESEARCH EFFORT

R. L. Boggess	Project Engineer
L. Brace	Physicist
D. Brown	Technician (Student)
G. Burdett	Engineer
J. Caldwell	Engineer
J. Check	Technician (Student)
R. L. Delosh	Engineer
W. G. Dow	Consultant
J. Findley	Technician (Student)
G. Hok	Consultant
W. Kartlick	Technician
J. Reines	Technician (Student)
L. Slider	Technician
N. Spencer	Project Supervisor

1. INTRODUCTION

This report describes instrumentation designed to measure several local properties of the ionosphere as a function of altitude. The experimental concept adopted here can be considered an application of the "Langmuir Probe" technique, well-known in gaseous conduction studies, and thus the primary function of the equipment is determination of a volt-ampere characteristic of the ionized region surrounding the equipment.

The shape of this characteristic depends on several properties of the ionosphere, such as (a) the temperature of the ions and electrons, (b) the electron density, (c) ion mass and relative number density, and (d) incident radiation. The volt-ampere curve also depends on the geometry and motion of the equipment which may, because of its presence, perturb the region undesirably.

A theoretical study is being carried out with the primary objective of properly interpreting "bi-polar" volt-ampere characteristics as obtained with particular geometries, in terms of the various ionospheric properties noted above, as well as, perhaps, other factors now unknown. The study is based upon various assumptions, many of which are questionable. A separate technical report detailing various aspects of the study, consideration of which led to design of the present equipment, is being prepared. This report is thus concerned only with the experimental aspects of the research program.

2. CONSIDERATIONS IN EQUIPMENT DESIGN

Although it would, of course, be desirable to conduct a measurement which would permit evaluation of several ionospheric properties simultaneously, the lack of sufficient basic information regarding fundamental aspects of the experimental technique and the ionosphere makes it impossible to attain this broad objective immediately. Thus an experiment has been designed which is intended to clarify certain questionable points, that is, to establish the validity (or invalidity) of some assumptions which are essential to the development of the desired experiment. It is possible, at the same time, to perform some elementary but desirable measurements.

An early decision in the design of this experiment was that it would be nearly hopeless to attempt measurements with equipment attached to, or in the vicinity of, the rocket employed to carry it aloft. Thus such unknowns as possible rocket-supplied gaseous contaminants, certain surface conditions, and the existence of undesirable or completely disrupting potentials, were eliminated. Although separation posed new problems (for example, effecting reliable ejection,

miniaturization, and telemetry), these were all insignificant, in comparison with those anticipated if ejection were not provided. Accordingly, the major objectives of the present instrumentation are to:

(a) establish without question that the presence of a relatively strong E-M field at the telemetering frequency does not perturb the medium appreciably,

(b) establish whether or not incident solar radiation (on the equipment) causes appreciable (detectable) surface emission,

(c) verify the magnitude of the predicted current,

(d) obtain measurements of electron temperature as a function of altitude,

and on the practical side:

(e) check the soundness of the design of the relatively complex mechanical arrangement made necessary by the requirement for separation of the experimental equipment from the launching rocket, and

(f) check the soundness of the measurement technique adopted.

The most elementary geometry for the ejected probe indicated by practical considerations and the present theoretical study and consistent with reasonably satisfactory assumptions is a configuration of two spheres connected by a small cylinder. The available rockets, as well as anticipated vehicles, the dimensions of necessary instrumentation components, etc., and factors dictated by the theoretical study, indicated that 6-in.-OD spheres separated by a 2-1/4-in.-OD cylinder 10 in. long would be suitable. For reasons discussed in the technical report, it was necessary (a) to split the two spheres into insulated hemispheres to provide the guard ring function, (b) to provide for vacuum tightness of the assembly to minimize contamination of the environment by internal gas, and (c) to provide an insulating center section which would enable application of the desired probe "guard ring" voltages as well as the telemeter RF output (antenna) voltage. The following sections describe equipment that has been constructed.

3. MECHANICAL ARRANGEMENT

Figure 1 shows an assembled double-sphere probe. The shiny material is stainless steel (19 gage), which was "spun" to the desired dimensions. The assembly is composed of four sections: two hemispheres and two "funnels." The funnels are assembled back to back on a Teflon insulating and supporting section, and the hemispheres are separated from the funnel sections by rubber gaskets which seal the joint against gas leakage. The hemispheres are secured to

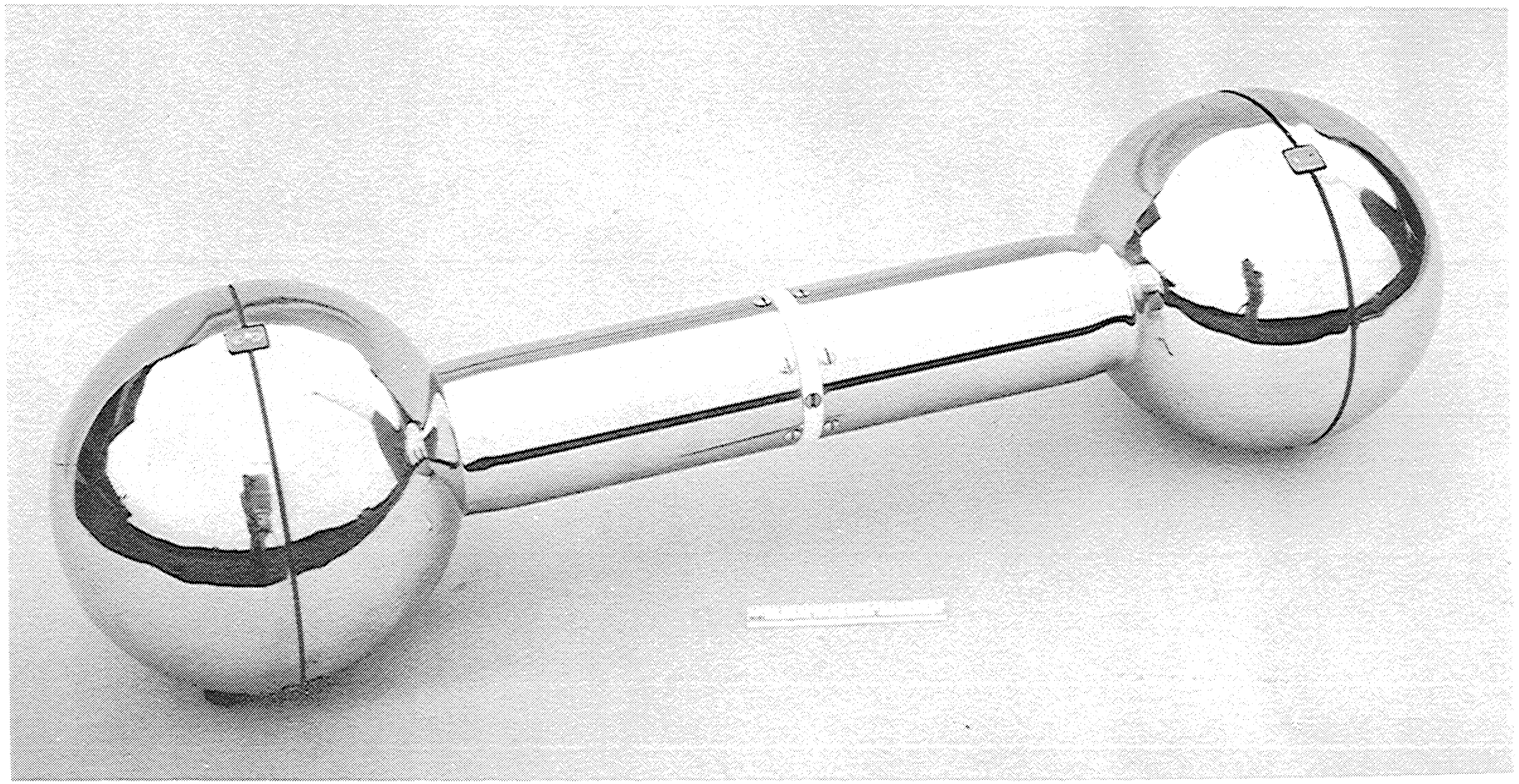

Fig. 1. Assembled double-sphere probe instrumentation.

the funnel sections by three Fiberglas-like clips which are slipped over steel pins when the rubber gasket is properly compressed. The assembly has been pressure-tested to approximately twice atmospheric pressure differential. Figure 2 illustrates a disassembled probe showing hemispheres, gaskets, funnels, and Teflon center section with o-rings in place. Figure 3 shows the pin and clip detail which provides adequate tensile strength for securing the hemisphere to the funnel against the force of internal atmosphere pressure and the compressed rubber seal. The clip with the rubber seal provide the necessary insulation between the hemisphere and the funnel.

Figure 4 is a view of the nose assembly constructed to house and eject the probe. Figure 5 shows the same assembly in the opened condition. The probe is supported by four "fingers" which also provide angular constraint during nose opening. Figure 6 shows the fingers and the end of the spring-loaded (80 lb) plunger which, when actuated, first releases the fingers and then thrusts the probe forward out of the nose cone. The cylinder halves are hinged at the base with close-tolerance 1/2-in. dowel pins. The forward cone, split along its axis, and the cylinder halves which support it are held together by a frangible ring which, when in place in the undercut section of the cone just aft of the tip, completes the cone surface. Shear strength along the split is provided by 6-1/4-in. dowel pins (see Fig. 7) which are secured to one half-section, and which engage holes in the mating section. The frangible ring is broken when ejection is desired by four electrically initiated primers. Spring force, as well as centrifugal force due to rocket roll, opens the sections, which, when opened to approximately a 50-60° gap, release the plunger. The primers are fired by a timer which is set to function at an altitude of approximately 100 km.

The plunger impulse and "dumbbell" mass are such that an additional velocity of approximately 10 fps is imparted to the probe. The probe weight is about 14 lb.

4. CIRCUIT ARRANGEMENT

Figure 8 is a block diagram of the double-sphere system. The two probe-voltage generators (precision potentiometers, common shaft, 4 rps), which apply the desired potentials between the outer hemispheres in one case and the funnels in the other, are shown. The potentiometers and associated battery supplies are arranged so that the back-to-back saw-toothed voltages produced are equal; thus the voltage difference between hemisphere and associated funnel is zero (in practice a few millivolts are easily attained). As shown, however, the current is measured only between outer hemispheres. Thus a double half-sphere geometry is closely realized (in spite of the structurally necessary connecting cylinder).

The current detector includes a semi-conductor ring-modulator followed by a transistor amplifier. The ring-modulator is driven from a transistor-oscillator source (4 kc) and thus the amplifier band-pass is centered on this frequency. The

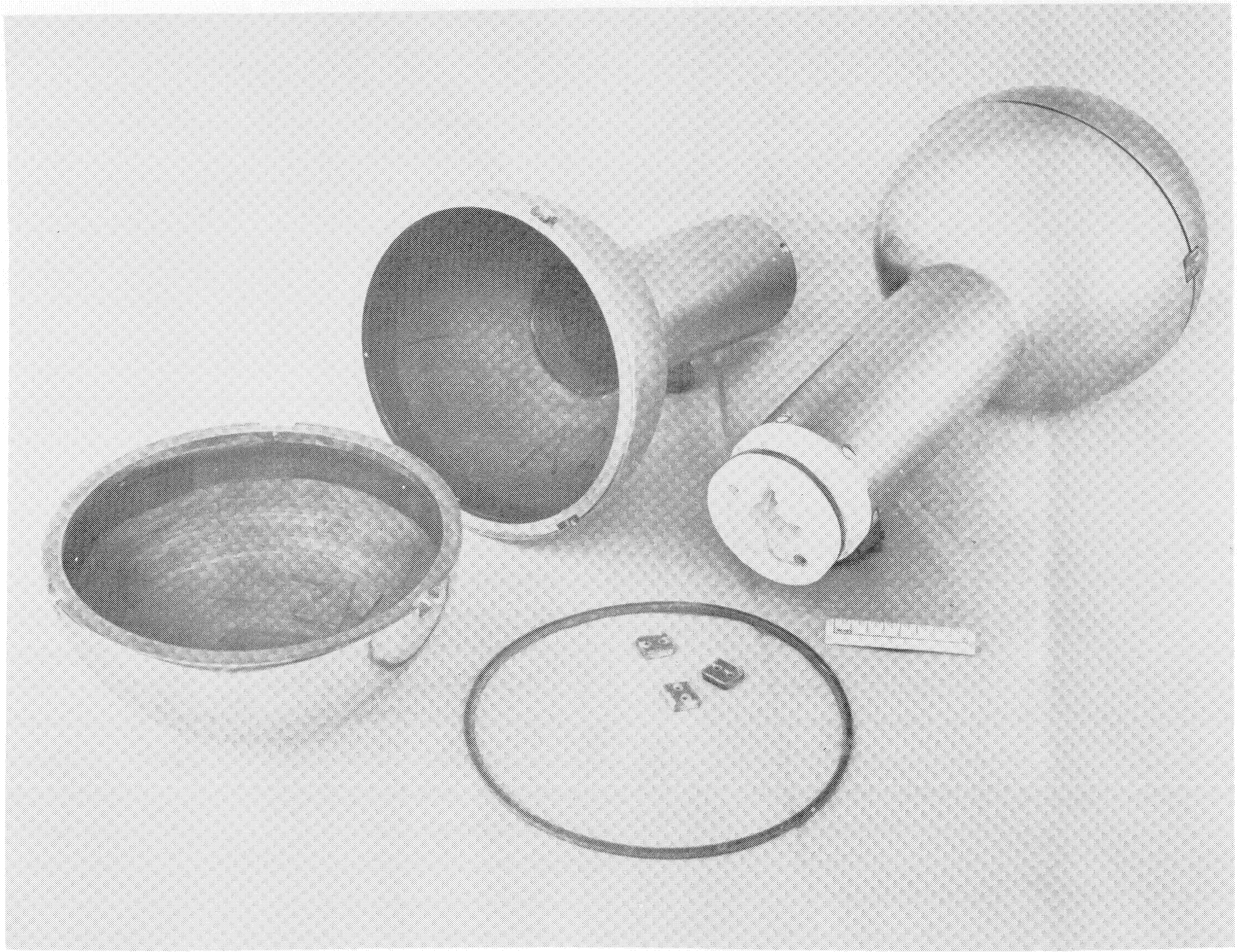

Fig. 2. Disassembled double-sphere probe shell.

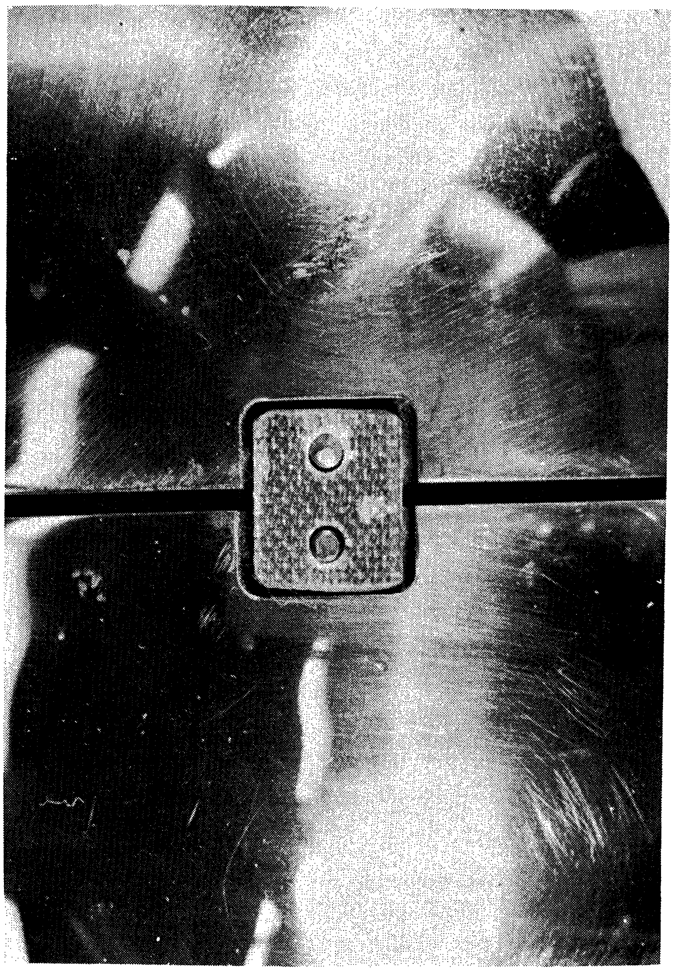

Fig. 3. Detail of pin-clip fastening system.

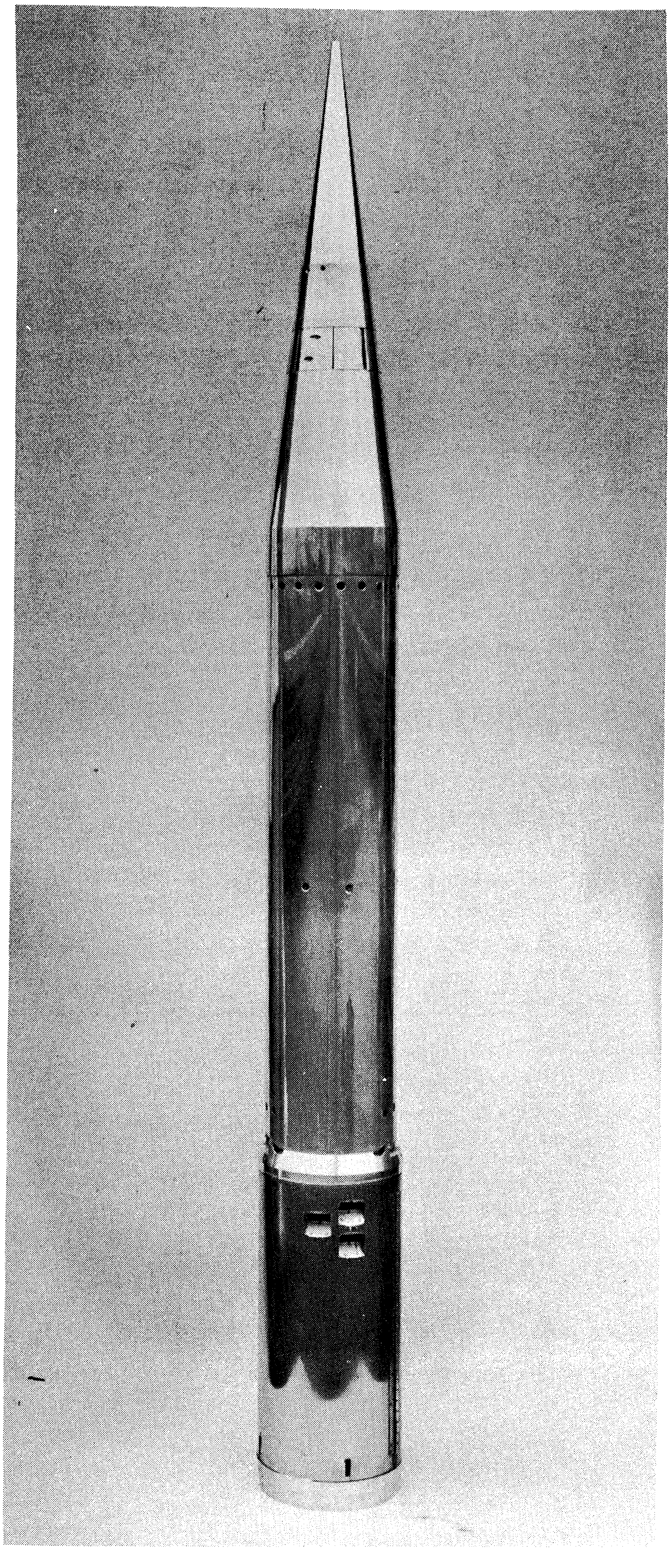

Fig. 4. Nose assembly in closed position.

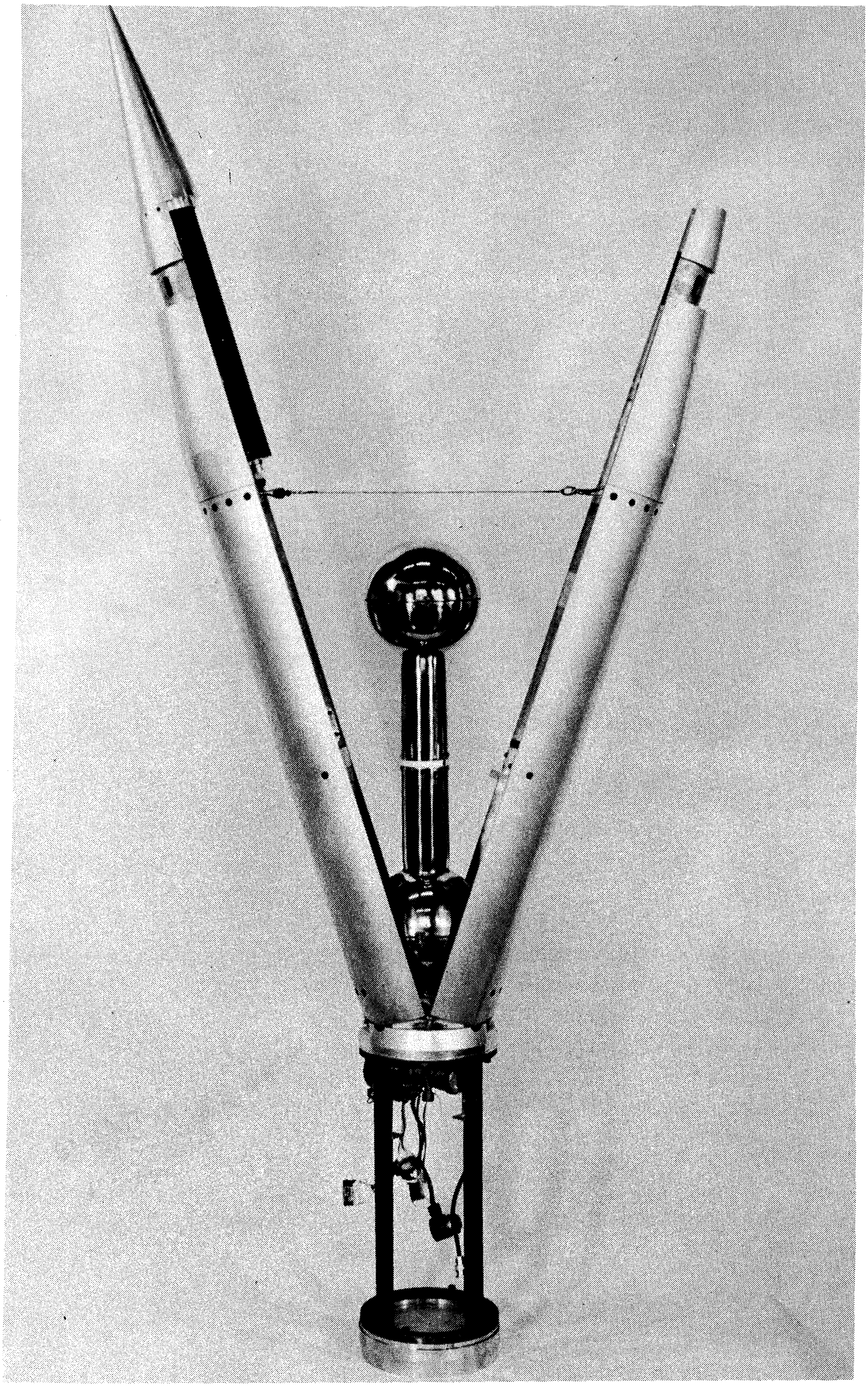

Fig. 5. Nose assembly in open position.

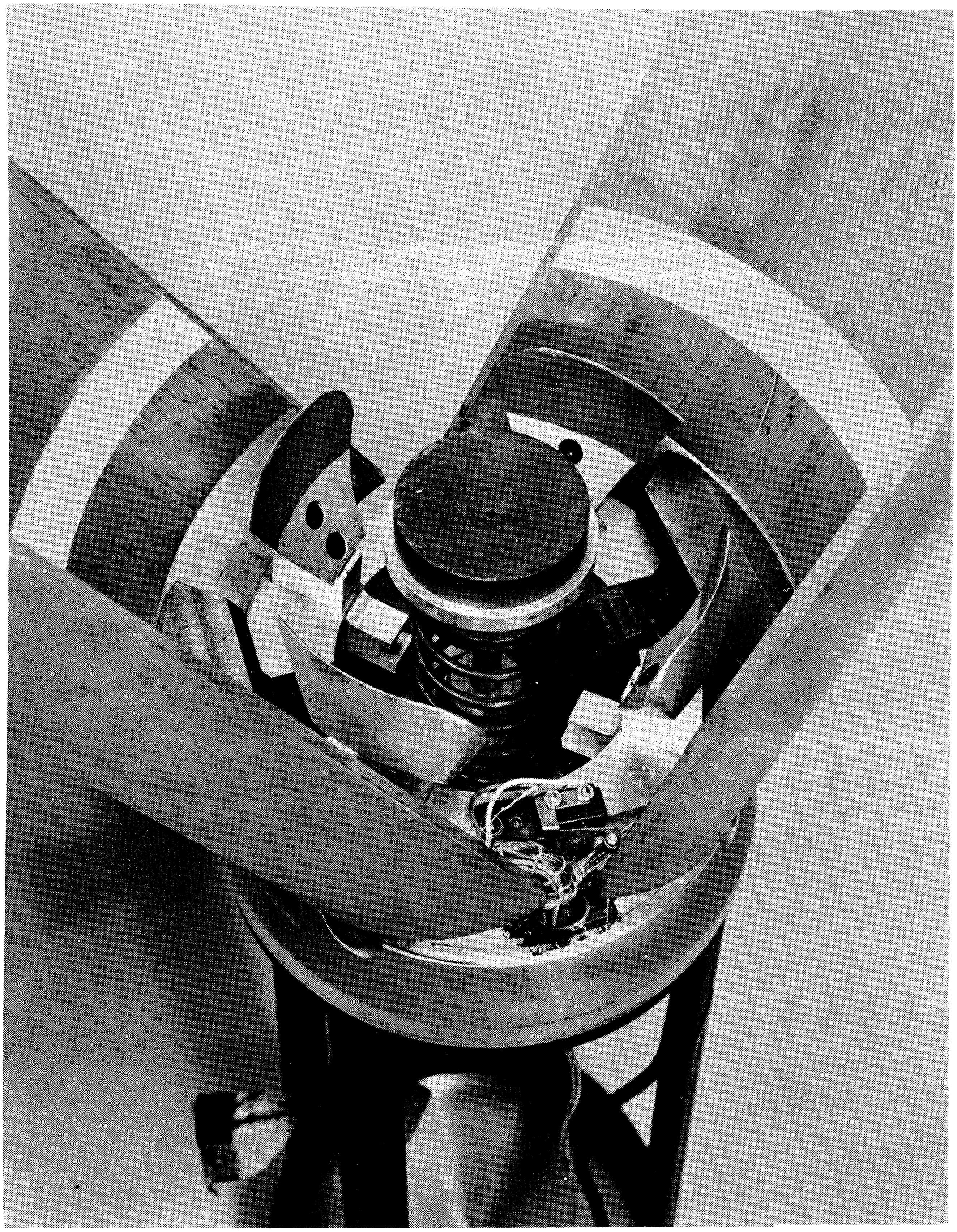

Fig. 6. Detail of probe support and ejection arrangement.

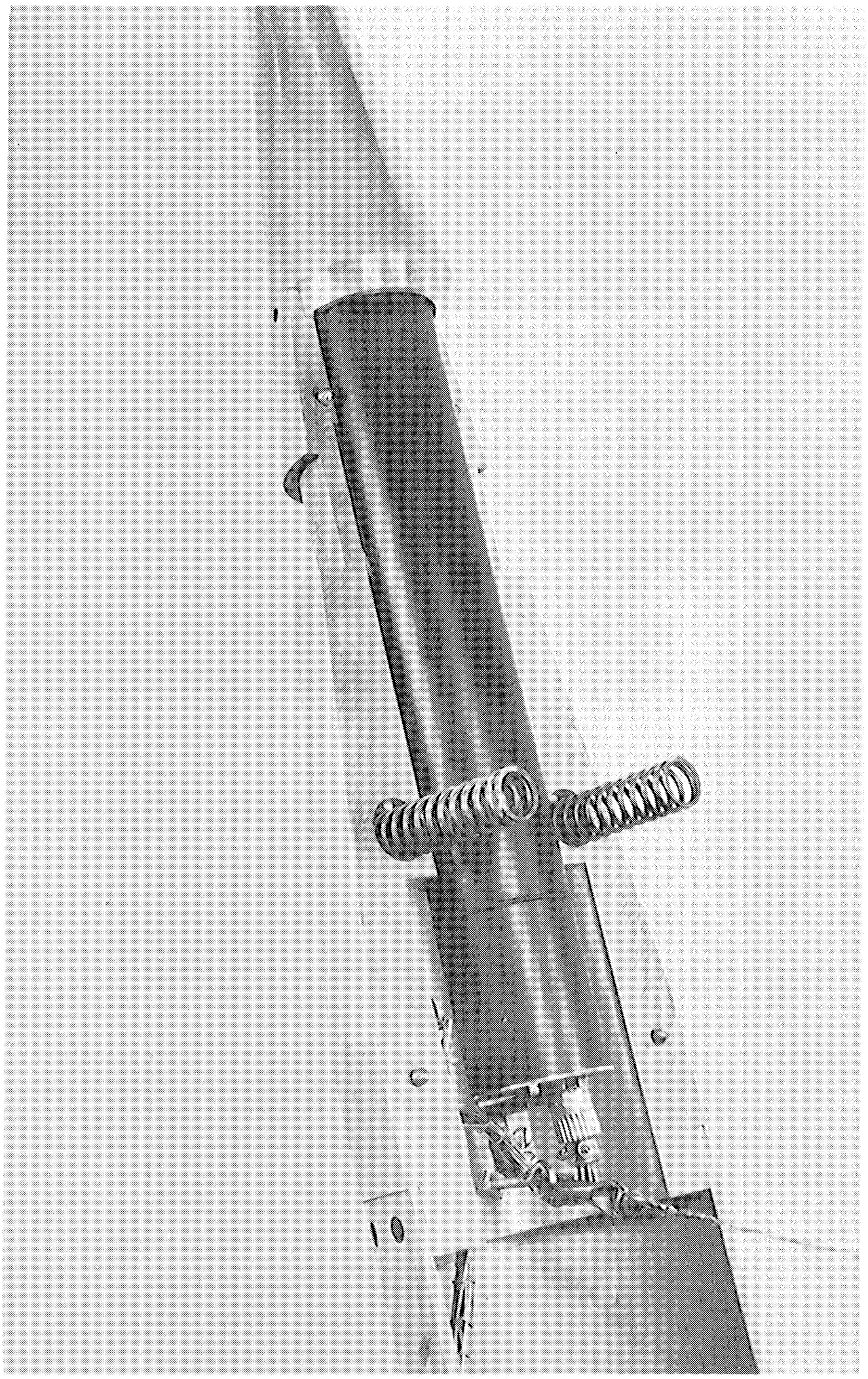

Fig. 7. Detail of nose section showing shear pins and opening springs.

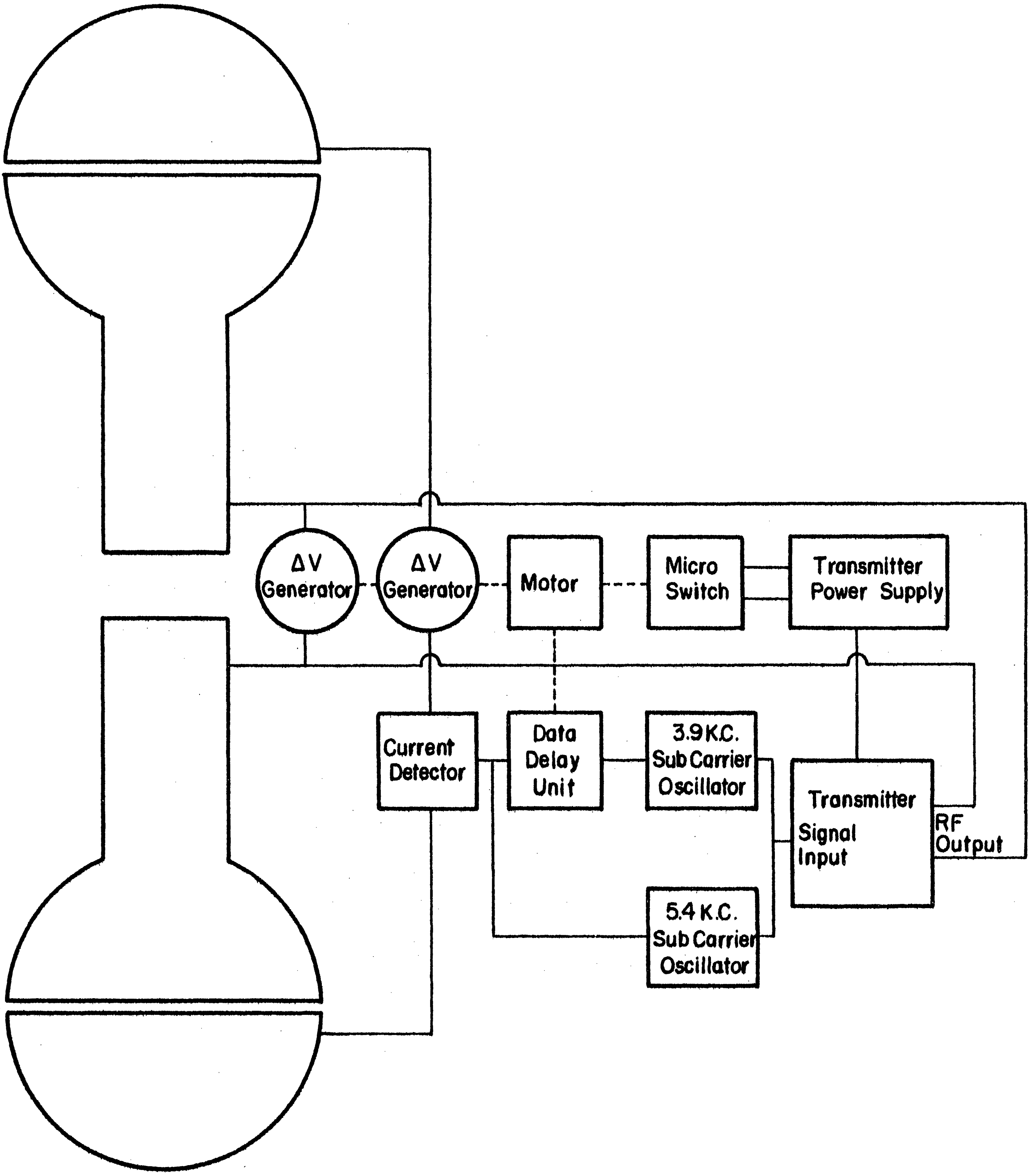

Fig. 8. Block diagram probe signal system.

output is rectified and applied directly to the 5.4-kc subcarrier oscillator and to the 3.9-kc subcarrier oscillator through the data storage unit. As indicated, the subcarrier oscillators modulate the transmitter which employs the "dumbbell" as a dipole antenna.

The transmitter is powered from a transistor-oscillator power supply which operates from a 24-v battery pack. A separate 6-v source supplies filament power.

A regulated motor drives the two potentiometers at a 4-rps rate and operates a switch once per second, on for a half-second and off for a half-second. The switch controls the transmitter (B+), thus permitting radiation in half-second duration pulses. The data-delay unit is also driven by the motor. It functions to record data during the off-period and make them available during the transmitting period. The recorded data are transmitted via the 3.9-kc subcarrier oscillator and directly taken data are transmitted via the 5.4-kc subcarrier oscillator. This system permits comparison of the volt-ampere curve both in the presence and absence of the rf field of the telemeter within an interval of approximately 1/2 second. This interval should be adequately short, particularly near the peak of the trajectory.

The first version of the data storage unit employed a continuous loop of magnetic tape for recording and playback of the 3.9-kc subcarrier frequency. Considerable difficulty was, however, encountered in stabilizing tape speed and signal magnitude adequately in the limited space available, and it was concluded that the mechanism (without extensive modification) was not capable of sufficiently satisfactory tape operation. The use of tape was accordingly abandoned in favor of a capacitance storage system which records several points of the volt-ampere curve, rather than the whole curve, for later playback.

The voltages applied to the potentiometers are altered periodically by a solenoid switching system to enable a survey of maximum voltages required to display adequately a volt-ampere characteristic. Correspondingly, for purposes of current detector calibration, a resistance is periodically switched into the system in substitution for the probe current signal.

5. ACCESSORY INSTRUMENTATION

A section immediately aft of the probe housing provides space for a DOVAP transponder, and miscellaneous items associated with both the ejection timer and a single radioactive ionization gage (see Fig. 9) which is located in the forward nose tip. This latter equipment is not associated with the probe experiment. It is carried as a completely independent experiment which enables measurement of the ambient density of the atmosphere to a maximum altitude of 80-90 km.

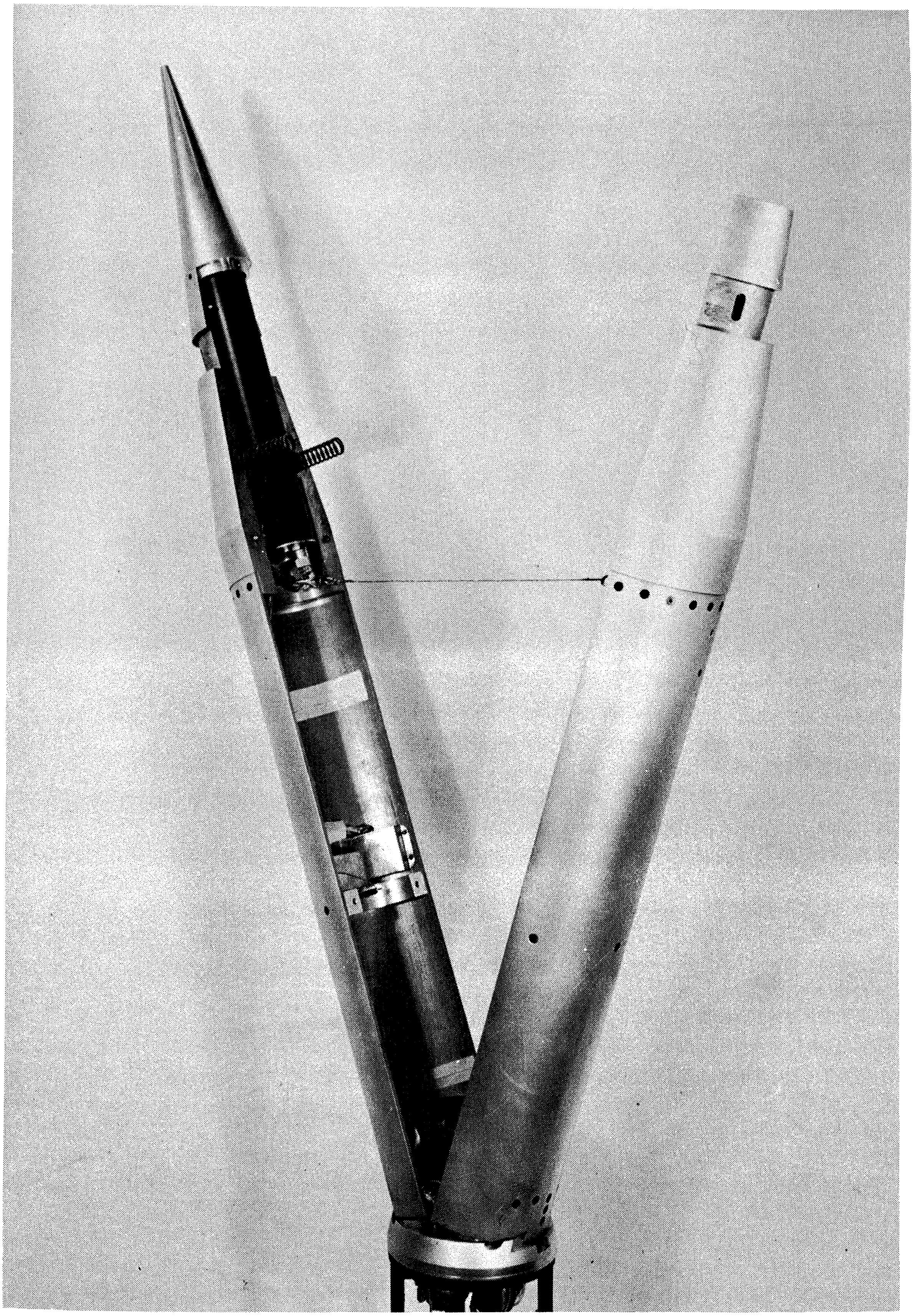

Fig. 9. View of nose section showing radioactive ionization gage in position.

6. CONCLUSION

This report summarizes the present hardware aspects of a new experiment designed to permit useful measurements of several properties of the ionosphere. A second objective of this first instrumentation is to provide answers to some fundamental questions that have arisen in a theoretical study of the problem. Satisfactory performance is expected to permit both determination of electron temperatures and the design of probe systems which emphasize the measurement of additional parameters at higher altitudes.

7. ADDENDUM

Shortly following the preparation of this report, launching of the equipment described took place. Ejection occurred as intended and the expected currents were measured. A peak altitude of approximately 82 miles was attained. Figure 10 is a photograph of the final installation of the probe package.

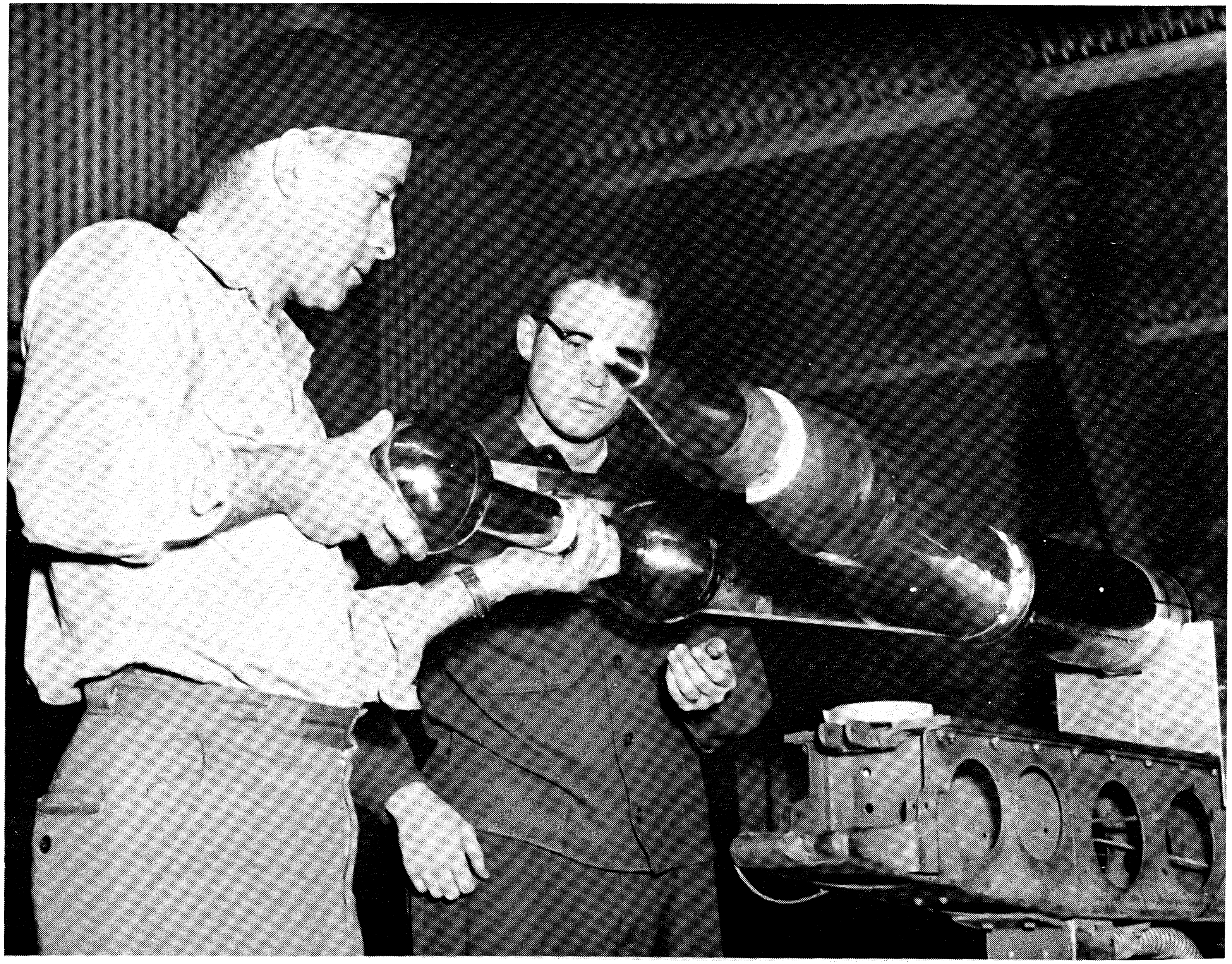

Fig. 10. Final installation of probe package in Nike-Cajun ABM6.207 prior to launching 20 October 1958.