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COLLEGE OF ENGINEERING
Department of Electrical Engineering

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MEASUREMENTS OF ATMOSPHERIC PRESSURE, TEMPERATURE, DENSITY, AND COMPOSITION AT VERY HIGH ALTITUDES

Prepared for the project by

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I. INTRODUCTION

This report is the first of a series on a research effort whose objective is the determination of the ambient pressure, temperature, density, and composition of the earth's atmosphere at altitudes above the level where the mean free path of the various particles is appreciably greater than the dimensions of the measuring object.

It is intended that devices to be developed and employed will be, in general, of the ionization-gage type. That is, they will depend for their operation upon the relative electrical charge of gas particles encountered in reference to the device elements.

The research effort is organized initially in terms of several tasks, as follows:

(a) theoretical study of the general measurement problem;
(b) development of supporting rocket-borne instrumentation;
(c) development of ultra-high vacuum system to enable study and calibration of sensors; and
(d) study and development of sensors.

In general outline, it is expected that the experimental approach will be to eject at high altitude a sphere (not necessarily exclusively) which will contain the appropriate sensors and, in addition, suitable equipment for telemetry and tracking. Associated, but not ejected equipment will probably consist of a vacuum chamber, timing and other devices associated with ejection, and perhaps tracking and other related items.

II. DISCUSSION

A. THEORETICAL STUDY

The measurement technique that has been adopted is based upon the concept of measuring the partial pressures of various gases as experienced by a sensor mounted appropriately in a sphere that is moving at an appreciable velocity at high altitude. Rotation of the sphere produces a velocity scanning effect that can enable one to determine ambient conditions of pressure, temperature, and density. If the response of the sensor employed is dependent upon the mass of the individual particles in some manner, then composition can also be determined. A brief discussion of these factors has been reported.[1]

Continued study and analysis of the measurement technique is being carried out as indicated above under task (a), as part of the present effort. A detailed mathematical treatment of the problem is being initiated. The intent at present is to concentrate on that aspect of the problem most appropriate to a satellite application of this experiment, as this appears to be the easiest theoretical problem, and will, moveover, serve as an introduction to several aspects of the general problem. Very soon, however, likely during the next reporting period, the approach will be broadened to include applications of the technique to vertical trajectories. It is, of course, expected that first experiments will be of this type.

B. SUPPORTING INSTRUMENTATION

One of the more difficult aspects of direct measurements at high altitude for most experiments is contamination of the environment with gas from the intruding, measuring object. The outgassing rate of most materials is such that, even under the most favorable conditions, there is insufficient time during a reasonable vertical sounding flight to effect adequate outgassing. Information presented by Russian experimenters indicates that Sputnik III outgassed so slowly that the minimum pressure detected on the surface was 10^{-7}mm Hg the first day, 10^{-8} the second day and 10^{-9} the third day. This, if true, which seems likely, indicates that for a vertical sounding, the instruments must be ejected from the launching rocket, which is always a potent gas source. Furthermore, the instruments must be outgassed in some manner prior to ejection. Since adequate power and time are available only before launching for reasonably available sounding rockets, the measuring instruments must be carried aloft in a vacuum chamber and in an outgassed condition. Ideally, also, ejection should occur at zenith, hopefully at a pressure not less than the chamber pressure.

Consideration of materials and techniques by which the above might readily be accomplished has been initiated during the period. Other work in the laboratory,[2] involving ejection of an ionosphere experiment, is demonstrating a solution of the ejection problem and will thus contribute to this phase of the general problem.

It appears at this time that a sphere or other instrument enclosure fabricated from "Pyrocerain"* or similar glass crystalline materials, might prove very desirable from the outgassing standpoint. A non-conductor might also be welcome from the standpoint of antenna design. A metallic container has not, however, been rejected.

It is not expected that much effort will be devoted to this phase of the problem for the next few months.

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*Trademark of Corning Glass Works.

C. ULTRA-HIGH VACUUM SYSTEM

The design of an ultra-high vacuum system has been completed and construction of the station has been initiated. An angle-iron table with a top fabricated from "tranrite" has been built with provisions for control panel, pumps, and an oven for baking the high-vacuum portion of the system.

The system, at least initially, will be assembled following the published information by Alpert.[3] The high-vacuum portion of the system will be enclosable with an oven arrangement that will permit a bake-space approximately 8 x 8 x 27 inches. Bakeout at any temperature up to 1000°F while under vacuum will be possible.

It is expected that the system will be completed and in operation by the end of the next reporting period.

D. SENSORS

Reference 1 suggested the Omegatron as a strong possibility for use in this experiment. Accordingly, the literature and available models of the device have been studied in expectation of constructing and experimenting with appropriate designs. To this end, an experimental model has been designed and arrangements have been made to construct test units in the tube shop of the Department of Electrical Engineering where extensive experience in construction techniques may be employed to advantage. The approach will be to build and operate a unit similar to previous designs to enable gaining intimate familiarity with the characteristics of the device. At the same time, alternate designs, apparently more suitable to the intended use, will be fabricated.

One of the limitations of using an omegatron-type device at high altitudes is the relatively small output signal that must be accommodated. Techniques employed extensively in connection with other ionization-gage applications in this laboratory[4] have made direct measurements of the ionization current. This approach will, in general, be adequate only for applications at altitudes up to 200-300 miles. At least two alternative schemes are possible, however. These appear quite promising and will be investigated during the next reporting period.

It is anticipated that a first device model will be completed and put in operation in the laboratory during the next reporting period.

III. BIBLIOGRAPHY

An effort will be made to record in these quarterly reports a list of publications appropriate to the subject material.

1. Spencer, N. W., and Boggess, R. L., On the Use of Ionization Gage Devices at Very High Altitudes, UMRI Report 2534-1-F, Ann Arbor, January, 1958.

2. Spencer, N. W., Bi-polar Probe Instrumentation No. 1, UMRI Report 2521, 2816, 1-1-S, Ann Arbor, October, 1958.

3. Alpert, D., and Buritz, R. S., "Ultra-High Vacuum II. Limiting Factors on the Attainment of Very Low Pressures," J. Appl. Phys., 25, 202 (February, 1954).

4. Spencer, N. W., Boggess, R. L., Brace, L. R., and El-Moslimany, M. A., Radioactive Ionization Gage Pressure Measurement System, UMRI Report 2597-3-S, Ann Arbor, May, 1958.

5. Sommer, H., Thomas, H. A., and Hipple, J. A., "Measurement of e/m by Cyclotron Resonance," Phys. Rev., 82, 697-702 (June, 1951).

6. Edwards, A. G., "Some Properties of a Simple Omegatron Type Mass Spectrometer," Brit. J. Appl. Phys., 6, 44-48 (February, 1955).

7. Bell, R. L., "Omegatron as a Leak Detector," J. Sci. Instr., 33, 269 (July, 1956).

8. Wagener, J. S., and Marth, P. T., "Analysis of Gases at Very Low Pressures by Using the Omegatron Spectrometer," J. Appl. Phys., 28, 1027-1030 (September, 1957).

9. Alpert, D., "New Developments in the Production and Measurement of Ultra-High Vacuum," J. Appl. Phys., 24, 860 (July, 1953).

10. Sommer, H., and Thomas, H. A., "Detection of Magnetic Resonance by Ion Resonance Absorption," Phys. Rev., 78, 806 (June, 1950).