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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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1.0 INTRODUCTION

This report is the fourth in a series which outlines a research effort oriented toward development of a system employing a small mass-spectrometer-type device in the measurement of pressure, temperature, and density of the atmosphere at altitudes where the mean free path of the neutral particles is long in comparison with the dimensions of the measuring object.

As noted in previous reports, the effort is devoted to several tasks:

(a) a theoretical study of the general measurement problem, and several associated problems;

(b) development of suitable sensors;

(c) development of associated instrumentation to permit fruitful employment of the sensors; and

(d) the development of an ultra-high vacuum system capable of achieving pressures as low as the state of the art permits, with the final objective of sensor calibration and testing.

The following sections of the report will summarize the work during the quarter in these regards.

2.0 THEORETICAL STUDY

Present efforts in this area are concerned with the orifice problem. That is, what is the optimum chamber size, orifice shape and size with reference to the main spherical body, and its motion. Work on this problem is being carried out on a part-time basis and will be completed in the near future. A detailed analysis will appear as an appendix to a future status report.

3.0 SENSOR DEVELOPMENT

The construction of two new tubes, serial nos. 5 and 6, has been completed. Serial no. 5 was constructed similar to serial no. 4 described in report GQ-3, except that the envelope and one end-plate element of the electrode structure were arranged to permit the addition of an electron multiplier. This tube is ready for test, prior to addition of the multiplier.

Serial no. 6 was constructed to improve the uniformity of the r-f field, so that an investigation of this general problem could be made. Thus the tube was constructed of machined elements which were stacked somewhat in the fashion of the tube illustrated in Sommer's paper (Ref. 1). This tube was likewise ready to be tested at the end of this reporting period.

4.0 ASSOCIATED INSTRUMENTATION

Instrumentation required for implementation of the planned experiment is logically divided into two classes: that of the sphere which will be ejected from the rocket; and that of the rocket and ejection nose cone. Consideration has been given to the general outline of these two areas.

The general form of the nose cone and its equipment will be such that a sphere of about 12 in. in diameter will be carried in a vacuum chamber which will constitute a major portion of the nose cone. The vacuum chamber is necessary to provide as nearly an optimum vacuum cleanliness condition of the sphere as reasonably possible, to avoid contamination of the region around the sphere after ejection. In general, the system will be arranged for opening of the nose cone and ejection of the sphere at an altitude where the mean free path is large with respect to the sphere dimensions.

The design of the nose-cone system has been initiated. It is planned that the ejection system will be patterned after similar systems employed for other experiments underway in the laboratory. In this regard, nose-cone opening is effected by spring force after a retaining ring is broken by primers, which are timer-actuated. Once the container has opened a prescribed amount, a trigger is activated and a spring-loaded plunger propels the desired object axially away from the rocket at a velocity, with respect to the rocket, of 5-10 fps. This system has been proven satisfactory in other experiments (on four occasions out of four attempts), and thus no difficulty is anticipated.

Because a particular motion of the sphere is desired (see Appendix GQ-2 or Ref. 12), the proper motion must be imparted to the sphere upon ejection. This motion must be rotation about the axis of maximum moment and location of that axis in a plane normal to the plane of the trajectory.

The first of these conditions is relatively easily attained by spinning the sphere at ejection. The second however requires either ejection when the appropriate axis is in the correct position or some correcting effect that can operate after ejection. The difficulty of achieving the latter restriction of the motion appears to be primarily determined by the required precision which, initially at least, is not great; $\pm$ 20° may be adequate for an exploratory experiment.

The balance of the equipment associated with the nose cone and rocket will include: timer and ejection circuits, vacuum-chamber pressure-measurement device, DOVAP for trajectory and operations telemetry, and devices necessary for rocket safety, such as radar beacon and cut-off equipment.

The sphere portion of the system will contain, in addition to telemetry and its associated power supply, the pressure-measurement devices. In broad outline, it is desired to incorporate an adequate arrangement of sensors to assure sufficient implementation of the experiment to yield data concerning the upper atmosphere and substantiation of the experimental approach. To this end, it is planned to include as a minimum complement: (a) a single omegatron arranged for purposes of simplicity to measure only one or two gases; (b) a single thermionic ionization gage for total pressure measurement; and (c) a "Diatron," also arranged to cover one or two gases, preferably the same gases as the omegatron. If the sphere will adequately accommodate additional equipment, it would be helpful and desirable to add additional omegatrons, with their orifices at different points of the sphere. The three devices (a, b, c) will be oriented such that their openings all lie on a great circle of the sphere, the plane of which will be normal to the axis of maximum moment of inertia of the sphere.

Data transmission from the sphere will be provided by a Bendix FM-PM system, the TXV-13. There has been recent experience with such a system on another experiment in the laboratory that employed a 7-in. sphere. Satisfactory signals were recorded throughout a flight; thus it is anticipated that telemetry will not pose serious problems.

The circuitry to be associated with each of the three sensors will in general consist of (a) a filament power and emission control circuit; (b) an output current detector, employing electrometers for each of the spectrometers; and (c) particular voltage sources such as an r-f generator for the omegatron and appropriate sawtooth direct current for the Diatron. Each sensor's system will "feed" one sub-carrier oscillator, and an additional separate channel will be provided for commutated, selected pieces of information regarding particular operating voltages, temperatures, etc. Orientation of the sphere will be telemetered, the sensors in this case being magnetometers. DOVAP telemetry from the main body will provide information relative to the ejection.

5.0 ULTRA-HIGH VACUUM SYSTEM

The ultra-high vacuum system discussed in earlier reports is in operation continuously. Minor changes have been made in the location of a copper-foil trap as one step in studying the reasons for the present lower pressure limit attainable, which is approximately 3×10^{-10} mm Hg indicated by an Alpert ion gage, which also acts as the pump.

This pressure is the present operating level and is readily reached a few hours after an overnight bake-out. The nature of the remaining gas has not been determined. It may be water vapor, oil vapor from the diffusion pump used for roughing, helium from the atmosphere, or other gases. It is planned to employ the Diatron in due course to determine the composition of the remaining gas.

As a further step in attempting to lower the present limit, a double-walled chamber will be investigated.

6.0 FUTURE WORK

The original contract time limit would normally have occurred July 1. However, since the task has not been completed and the work is in progress, a request for a no-cost extension has been processed.

Thus work will continue in sensor development, and in circuit and nose-cone design, as suggested by the discussion in this report.

7.0 REPORTS AND TRAVEL

In connection with circuit development for the experiment which is the subject of this report and other experiments, a report is being prepared which will detail various applicable circuits such as current detectors, sub-carrier oscillators, timers, etc. It is expected that the report will be completed during the next quarter.

Two meetings pertinent to the research were attended by N. W. Spencer during the quarter. One, held at RAND Corporation in Santa Monica, was a symposium on the subject of high-altitude aerodynamics. The other was a technical meeting in Los Angeles on the subject of mass spectrometers.

BIBLIOGRAPHY

The following listing includes papers and reports relevant to the subject of the research effort, and which may have been mentioned in this or the previous quarterly report.

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

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

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

4. 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).

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

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

7. 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).

8. Berry, C. E., "Ion Trajectories in the Omegatron," J. Appl. Phys., 25, 28 (January, 1954).

9. Brubaker, W. M., "Influence of Space Charge on the Potential Distribution in Mass Spectrometer Ion Sources," J. Appl. Phys., 26, 1007 (August, 1955).

10. Brubaker, W. M., and Perkins, G. D., "Influence of Magnetic and Electric Field Distribution on the Operation of the Omegatron," Rev. Scien. Inst., 27, 720 (September, 1956).

11. Hopkins, N. J., "A Magnetic Field Strength Meter Using the Proton Magnetic Moment," Rev. Scien. Inst., 20, 401 (June, 1949).

12. Spencer, N. W., Boggess, R. L., Lagow, H. E., and Horwitz, R., "On the Use of Ionization Gage Devices at Very High Altitudes," Jour. Amer. Rocket Soc., to be published.

13. Spencer, N. W., and Boggess, R. L., "Radioactive Ionization Gage Pressure Measurement System," Jour. Amer. Rocket Soc., 29, 68 (January, 1959).

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

15. McNarry, L. R., Development of a Miniature Mass Spectrometer of the Omegatron Type, N. R. Council of Canada Report No. 4259 (ERA-31), December, 1956.

16. Paul, W., and Raether, M., "Electric Mass Filter," Zeitschrift für Physik, 140, 262-273 (1955).

17. Todd, J. B., "Outgassing of Glass," J. Appl. Phys., 26, 1238-1243 (October, 1955).

18. Robinson, C. F., "Compound Ion-Resonance Mass Spectrometer," Rev. Scien. Inst., 27, 88-89 (February, 1956).