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UNIVERSITY OF MICHIGAN
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PROGRESS REPORT

for

1 July 1953 to 1 October 1953

UPPER ATMOSPHERE TEMPERATURE AND PRESSURE MEASUREMENT

REPORT NO. C-4

by

H. F. SCHULTE

PROJECT DIRECTOR: W. G. DOW

Submitted to the Geophysics Research Division, Air Force Cambridge Research Center, Cambridge, Massachusetts. The work reported herein is of a preliminary nature and the results are not necessarily in final form.

Approved by:

N. W. Spencer, Project Engineer

Project 2096

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PERSONNEL EMPLOYED DURING PERIOD OF REPORT

W. G. Dow	Project Director	
D. G. Dow	Assistant in Research	
J. A. Foster	Research Assistant	Part-Time (student)
G. Hok	Faculty Advisor	Part-Time
W. G. Kartlick	Research Technician	
A. A. Kirsons	Technician	Part-Time
D. L. McCormick	Machinist	Part-Time
H. F. Schulte	Research Engineer	
H. S. Sicinski	Research Physicist	
N. W. Spencer	Project Engineer	

ABSTRACT

The status of the Bendix J-8 gyroscope, telemetering limiters, new photographic system, and 400-cycle inverter power supplies is discussed. Experiments conducted in the University of Michigan Supersonic Wind Tunnel to investigate conical flow patterns and wind-vane performance are described.

Abstracts of two papers accepted for publication are included in this report. The first, titled "Dynamic Probe Measurements in the Ionosphere" by Gunnar Hok, N. W. Spencer, and W. G. Dow, was published in the Journal of Geophysical Research, Vol. 58, No. 2, June, 1953. The second paper is titled "Rocket Measurements of Upper-Atmosphere Ambient Temperature and Pressure in the 30 to 75-Kilometer Region" by H. S. Sicinski, N. W. Spencer, and W. G. Dow, and is tentatively scheduled for publication in the December, 1953, issue of the Journal of Applied Physics.

The presentation of two papers at the Oxford, England, meeting of the Upper-Atmosphere Rocket Research Panel is also reported. The titles are as follows: "Density-Gauge Methods for Measuring Upper-Air Temperature, Pressure, and Winds" and "Exploration of the Ionosphere by Means of a Langmiur-Probe Technique".

TABLE OF CONTENTS

PROGRESS REPORT
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INVESTIGATIONS BEING UNDERTAKEN

1. Missile-Attitude Determination System

The Bendix J-8 attitude gyroscope is designed for aircraft service, and is not suitable for rocket use without alteration. To remedy this situation the following components are removed: the "flag alarm indicator", the "vernier horizon bar", and the "automatic erection system" which corrects for precession when the instrument is used in an aircraft. In addition, the manual caging device is removed and replaced by a project-designed motor-driven caging mechanism which facilitates remote control of the gyroscope. To provide the desired data resolution, the gyro sphere is engraved at 1-degree intervals to provide pitch (climb or dive) readings and a second scale, also divided into 1-degree intervals, is externally mounted on the instrument case to provide roll (bank) readings.

The above-mentioned modifications have been accomplished during the period and arrangements have been made to take the modified gyroscope back to the manufacturer for final cleaning, rebalancing, and installation of new bearings if necessary.

The trip, scheduled for October, 1953, will also afford an opportunity to consult the gyroscope engineers concerning a proposal to mount the missile-borne gyro in a new position. Up to the present time, all gyros have been mounted with both the pitch and roll axes perpendicular to the longitudinal axis of the missile. The angular data so obtained has been satisfactory, but the amount of computation required to determine missile attitude could be reduced considerably if the gyro were mounted with its roll axis parallel with and its pitch axis perpendicular to, the longitudinal axis of the missile. This position, however, would impose a substantial thrust load on the "roll" bearings during the powered portion of the flight, with a consequent possibility of increased bearing friction. Preliminary laboratory experiments indicate that gyrostat precession caused by increased bearing friction might preclude the use of this mounting position for the gyroscope. These tests do not simulate flight conditions too closely, however, and therefore will not be used as the only basis for evaluation of the mounting. It is hoped that the manufacturer can provide additional information.

2. Improved Telemetering Limiter

The ever-present need for improved data transmission prompted a re-evaluation of the telemetering limiters used by this project. Since initial experiments indicated that an improved limiter could be designed, the investigation was continued during this quarter. The performance characteristics of the new limiter are appreciably better than those of earlier models. Simplicity of design has been maintained and reliability of the circuit has been increased by substituting semi-conductor diodes for vacuum-tube diodes in the circuit. Limiting action on both positive and

negative overvoltages has been improved and the circuit is less sensitive to ambient temperature variations.

The improved limiter performance has been attained by employing new and improved components in the circuit. Mercury cells (P.R. Mallory) are utilized as bias sources because of their superior temperature characteristics and low internal impedance, and the recently developed type 1N100 germanium diode (Hughes Aircraft Company) is used as the active limiting element.

Development work and the rough draft of a report on the new limiter were completed at the end of this quarter. The report will be issued as the first of a series of Technical Notes on various subjects investigated during the course of research by this project.

3. New Photographic System

The last four Aerobee firings in which this group has participated have utilized type B-2 16-mm motion-picture cameras suitably modified for rock-borne data recording. This camera is now obsolete, however, and therefore cannot be procured for future firings. After a rather thorough search for a suitable commercially available camera proved fruitless, it was decided to develop a new photographic system here.

The photographic system will use a 35-mm camera in which the film will move continuously. Although the camera will contain no shutter, a sequential series of exposures will be produced by employing a flashing-light system which will flash in synchronism with the film movement. The resulting photographs will be identical with those obtained by using a conventional shutter-type intermittant-film-transport motion-picture camera.

The new system appears to provide several advantages when compared with a system utilizing a conventional camera. First, the film-transport

mechanism is simple but positive, thereby reducing the possibility of film jamming. Second, the electronic flash tube used as a light source has a flash duration of about 0.001 second, which precludes any reasonable possibility of blurred images caused by camera vibration. Third, the color temperature and light output from electronic flash tubes allows greater latitude in selection of the type of film emulsion. When high resolution and grain size are important in a particular application, the ability to use a slow fine-grain film can be a decided advantage.

A small power supply has been developed for the electronic flash tubes, and mechanical design for the 35-mm camera is now complete. The system has produced very satisfactory photographs in the laboratory, and it is expected that final models of both the power supply and camera will be completed during the next quarter.

A more detailed description of the system will be presented in a future Technical Note.

4. Inverter Power Supply

It is anticipated that the next firing in which this group will participate will employ two gyroscopes and two flashing lights for photographic illumination. Consequently, the 15-watt 400-cycle inverter (Airpax Products, Inc.) used in previous instrumentations must be supplemented by an additional inverter. A 30-watt inverter will be added to supply power for the second gyroscope and the two flashing lights. New line filters have been developed for both the 15- and 30-watt units. The filters are designed to minimize the spurious signals often present on the d-c supply leads of the inverters.

Although no difficulty has been experienced with Airpax inverters during flight, the presence of two inverters affords an opportunity to provide an additional margin of 400-cycle power supply reliability. An

"inverter changeover system" has been developed which will automatically transfer the gyro load from the 15-watt inverter to the 30-watt inverter if the 15-watt unit should fail for any reason. The changeover system is composed of a small relay, two selenium rectifiers, and a 1/2-watt resistor. The relay will be operated normally-closed, and any relay contact chatter caused by missile vibration will not affect the system adversely. Barring failure of a changeover-system component (of which the probability in this case is small), it is felt that this device will enhance the overall dependability of the 400-cycle power supply system.

5. Supersonic Wind Tunnel Tests

The University of Michigan Supersonic Wind Tunnel located at the Willow Run Airport was employed for a series of tests to investigate the flow regime along the surface of a truncated right-circular cone. The results obtained served to substantiate experimentally the assumptions made in the method of ambient temperature determination developed by this project.

A series of preliminary experiments was also performed to test the feasibility of using a small wind vane to indicate the direction of the flow vector near the surface of the cone. High-speed Schlieren photographs taken with a Fastex camera showed that with proper mechanical design, a vane only 0.001 inch thick can withstand the forces encountered at velocities greater than Mach 1.0.

Theoretically, the wind vane shows considerable promise as a means of obtaining not only upper-atmosphere wind velocity and direction, but ambient temperature as well. The system of equations that define the wind-vane behavior has been developed but not evaluated as yet. This work will be continued with emphasis on the determination of temperature.

Of particular importance from an experimental standpoint is the accuracy required of the vane rotational-position instrumentation.

Preliminary estimates require that for a temperature accuracy of about 5°K, the absolute position of the vane must be measured to about 0.03 degree of arc. At the same time, the transducer must contribute negligible inertial and frictional load to the rotating system. Computation of forces on a flat plate in a low-density supersonic flow indicates that the vane should function throughout the major portion of the upward flight. The upper limit will be determined by the bearing "break-away" torque and the moment of inertia of the total rotational system. Additional computational and experimental work will be done to obtain more precise information on these problems.

Various mechanical features of wind-vane design are also being studied at present. The actual vane material and methods of fabrication must be considered carefully because of the heating and mechanical forces imposed on the vane during rocket flight. It is hoped that it will be possible to produce a vane with a thickness of the order of 0.001 inch. It is planned to provide protective caps which will cover the vanes completely for the early portion of the flight. At an altitude of about 20 miles, the caps will be cast off the cone surface, thus exposing the vanes for the measuring portion of the flight.

Two complete vanes will be flown on the forthcoming Aerobee. The vanes will be located approximately 16 inches aft of the nose-cone tip, and spaced 120 degrees apart.

RESEARCH REPORTS, PUBLICATIONS AND OTHER SCIENTIFIC ACTIVITIES

1. Publications

a. A paper relating to work sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and

Development Command, under our previous contracts (Nos. W-33-038 ac-14050 and AF 19(122)-55) was published in the Journal of Geophysical Research, Vol. 58, No. 2, June, 1953. The paper is titled "Dynamic Probe Measurements in the Ionosphere" by Gunnar Hok, N. W. Spencer, and W. G. Dow.

Abstract. Preliminary rather successful attempts to determine the ionization in the E-layer by means of a probe technique are described. The probe current showed an extremely rapid rise between altitudes of 90 and 105 kilometers. The result indicates a positive-ion density about ten times larger than the electron density. Further measurements with improved equipment are recommended.

b. A paper outlining the method of ambient temperature measurement developed by this project has been accepted for publication in the Journal of Applied Physics. Final corrections in the manuscript were completed and it was returned to the Journal during this quarter. It is tentatively scheduled to appear in the December, 1953, issue under the title "Rocket Measurements of Upper-Atmosphere Ambient Temperature and Pressure in the 30- to 75-Kilometer Region" by H. S. Sicinski, N. W. Spencer, and W. G. Dow.

Abstract. A method for determining ambient temperature and ambient pressure in the upper atmosphere is described, using the properties of a supersonic flow field surrounding a right circular cone. The underlying fundamentals stem from basic aerodynamic principles in combination with the developments of the aerodynamics of supersonic cones by G. I. Taylor, J. W. Maccoll, and A. H. Stone. The experiment provides the necessary cone

pressures, velocities and Eulerian angles, so that a Mach number characterizing the ambient space conditions may be computed. A description is given of the requisite experimental equipment and related techniques. Experimental data from two rocket-borne systems are presented with the resulting calculated pressures and temperatures experienced over New Mexico to approximately 70 kilometers.

2. Presentation of Papers

The Oxford, England, meeting of the Upper-Atmosphere Rocket Research Panel, held September 24-28 of this year, was attended by W. G. Dow, Project Director, and Professor Gunnar Hok of this project. Professor Dow presented a paper titled "Density-Gauge Methods for Measuring Upper-Air Temperature, Pressure, and Winds" by N. W. Spencer and W. G. Dow. Professor Hok presented a second paper titled "Exploration of the Ionosphere by Means of a Langmiur-Probe Technique" by Gunnar Hok and W. G. Dow.

It is understood that plans have been completed to publish all material presented at the symposium in book form.

3. Reports

Final compilation of the preliminary data obtained from the October 1952 "T"-day Aerobee firing (USAF 31) was completed. A report on this subject was prepared and forwarded to the Air Force Cambridge Research Center. The data presented are subject to modification when the uncertainties observed in certain portions of the missile velocity data supplied by the Holloman Air Development Center are resolved.

4. Other Scientific Activities

a. Preparation of a table "Pressure Ratios $P_o'/\overline{P_s}$ and $P_1/\overline{P_s}$ versus Mach Number for a 15° Right Circular Supersonic Cone" was initiated at the beginning of this quarter. The computations have been completed and the material is being prepared for presentation as a scientific report.

b. A computation of air density (just off the nose cone surface) vs. altitude for the September 1951 Aerobee has been completed. These data are to be included in a scientific report and a publication describing the air-density measurement experiment (utilizing the Paschen Law relationships) which was flown on the September missile.*

c. A theoretical study was made to determine the feasibility of building a system to calibrate the alphatron pressure gages dynamically. The method would simulate the rate of change of pressure that a gage experiences during the measuring period of a typical rocket flight. The results of the study indicate that it should be possible to construct a satisfactory system of this type. Because of the demands of other matters, however, this program will be temporarily discontinued.

d. Construction of the instrumentation rack for the February 1954 Aerobee is now in progress.

e. In addition to the trip to Oxford, England, by Professors W. G. Dow and Gunnar Hok, Mr. N. W. Spencer visited the Air Force Cambridge Research Laboratories on July 27 and 28. Discussion topics included contract renewal, the proposed February 1954 Aerobee firing, and the October 1952 "T"-day results. During the same period Mr. Spencer met with representatives

*Progress Report No. A-8, dated October 1951, Contract No. AF 19(122)-55

of the National Research Corporation to discuss problems associated with the alphatron gages used by this project.

Mr. H. S. Sicinski visited the data-reduction section at Holloman Air Development Center, Alamogordo, New Mexico, on September 21 through 24. Inconsistencies in the "T"-day missile-velocity data were discussed and the possibility of computing a vacuum trajectory to supplement the present data was considered. It was mutually agreed that the following steps would be taken by the Holloman group in an attempt to resolve the present uncertainties in the "T"-day velocity data.

(1) Fit a second-order polynomial to eleven selected points in the velocity data between missile burnout and zenith.

(2) Obtain the telemetering records from six previous Aerobee flights (former missiles used by the University of Michigan are excluded) and compute velocity versus time for each firing.

FUTURE PLANS

Except where otherwise noted in this report, the present activities will continue. Additional emphasis will be placed on construction of the nose cone, rack, and all portions of the instrumentation to be flown in the February 1954 Aerobee.

PERSONNEL AND ADMINISTRATION

A proposal to extend the present contract to December 31, 1954, was submitted to Air Force Cambridge Research Center in September, 1953.

Mr. D. G. Dow has been added to the staff as an Assistant in

Research. He received his M.S.E. degree in Electrical Engineering from the University of Michigan in June, 1953.

Mr. H. V. Green resigned his position as technician in July.

FISCAL INFORMATION

The financial status of the project is satisfactory. Approximately 75 per cent of the initial budget has been expended as of October 1, 1953. The present rate of expenditure is slightly lower than anticipated in the initial budget.

Following is an unofficial list of property acquired that contributes directly to the research endeavor:

(a) Kiethly Model 200 vacuum-tube electrometer,

(b) Royal typewriter,

(c) Monroe Model CAA10-3 desk calculator (statistical model), and

(d) Miscellaneous routine supplies.