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UNIVERSITY OF MICHIGAN
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UPPER-ATMOSPHERE WIND, TEMPERATURE, AND PRESSURE MEASUREMENT

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This report, not necessarily in final scientific form, is intended for internal management uses of the contractor and Air Force.

Approved by
N. W. Spencer
Project Supervisor

Project 2096

GEOPHYSICS RESEARCH DIRECTORATE, AIR FORCE CAMBRIDGE RESEARCH CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
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ABSTRACT

Results of the recently completed series of wind-vane, supersonic wind-tunnel tests and a brief description of the next missile wind-vane experiment are presented. The progress of data analysis for the July, 1954, Aerobee (USAF 48) and laboratory work presently in progress is also discussed.

PERSONNEL EMPLOYED DURING THE PERIOD OF THE REPORT

R. L. Boggess	Engineer	Half time, student
H. V. Dada	Data Analyst	Part time, student
W. G. Dow	Consultant	
P. D. Engelder	Technician	Part time, student
J. A. Foster	Engineer	Part time, student
W. G. Kartlick	Technician	Full time
A. A. Kirsons	Data Analyst	Part time, student
D. L. McCormick	Machinist	Full time
H. F. Schulte	Project Engineer	Full time, student
S. Shaw	Data Analyst	Part time, student
H. S. Sicinski	Project Physicist	Full time
N. W. Spencer	Supervisor	Half time

UPPER-ATMOSPHERE WIND, TEMPERATURE, AND PRESSURE MEASUREMENT

I. INVESTIGATIONS BEING UNDERTAKEN AND PLANNED

A. Wind-Vane Flight Data

Additional study of the telemetering record from the July Aerobee firing (USAF 48) has not modified the preliminary wind-vane results presented in the previous status report. Unless some new information not presently known to this project appears in the future, the behavior of the wind-vane system can be described as follows:

(a) Normal signals occur up to the time of cover ejection which occurs at about 30 seconds.

(b) Zero flag angle (aligned with the nose cone axis) is steadily indicated from cover ejection to 54 seconds, where the telemetering record ceases.

(c) At 90 seconds, the signals appear momentarily and the indicated angle remains zero degrees.

(d) At 118 seconds, the record returns for a few seconds, at which time recalibration occurs as planned.

(e) The record returns periodically until 182 seconds, when it again fades.

Since missile yaw can be computed from the gyro data only when trajectory data are also available, it is not now possible to check the present opinion that the vanes behaved as expected. Apparently, the missile had little yaw up to zenith, and thus the wind vanes produced no usable data during the periods when telemetering was functioning.

B. Gyro Data

Analysis of the gyro data obtained from the July 14 Aerobee firing (USAF 48) continued during the period. The process of cross-checking the data produced by the two gyros has been complicated by an obstruction which affected one of the gyros for the first 30 seconds of flight. The situation has been resolved, however, and it is expected that the data will be issued in report form during the next reporting period.

C. Wind-Vane Wind-Tunnel Tests

A major portion of the project activity during the first two months of this period was devoted to the completion of a series of supersonic wind-tunnel tests on the wind-vane system. The experimental data obtained were used to verify the aerodynamic theory of the wind vanes as Mach meters and yaw angle meters. The theory and experimental results were presented in a paper entitled "Mach Number and Yaw Angle Determination for Conical Flow Regimes Using Two Surface-flow Angle Indicators" by H. S. Sicinski and H. F. Schulte, before a meeting of the Division of Fluid Dynamics of the American Physical Society at Fort Monroe, Virginia, on November 22, 1954.

In order to collect the maximum amount of data from each wind-tunnel run, a dynamic experimental model was constructed. It consisted of a hollow brass right circular cone of a 7.5-degree half angle. The base of the cone was attached to a supporting sting by means of ball bearings arranged to allow rotation of the conical model about its axis. A small motor, gear train, and electrical reversing switch system also mounted at the base of the model provided a means to rotate the cone through two 180-degree cycles during the supersonic portion of the wind-tunnel run.

Instrumentation for the experiment consisted of a wind-vane bearing assembly and electronic capacitance translator, both mounted inside the cone model and connected by cables to the various power supplies; amplifiers were placed outside the tunnel. Data recording was accomplished with a multiple-channel Miller oscillograph, which required the construction of an oscillograph driver amplifier and calibrator to achieve the proper operation of the system. With the exception of the oscillograph amplifier, all portions of the instrumentation were those recovered from the last Aerobee firing (USAF 48) by the University of Michigan.* In some cases, slight modifications in the units were necessary to facilitate long-term laboratory use.

As a result of the starting and stopping shock waves created in

* See the previous Progress Report C7-C8, dated September, 1954.

the intermittent-flow wind tunnel, it was necessary to devise a method of protection for the wind vane during these periods. The "cover" system for the wind vane consisted of a cylindrical rod, one end of which was slotted and then ground to a wedge-shaped point for aerodynamic smoothness. The rod was mounted on a nonrotating portion of the model support, and arranged to slide forward so that the slot would engage, but not contact, the wind vane when the vane was aligned with the axis of the cone. The cover rod was manually activated during the run by a flexible control cable from the outside of the tunnel.

The wind-tunnel tests consisted of a series of runs at various Mach numbers with the model adjusted through a known angle-of-attack range. During each run, the rotational position of the model was recorded on the oscillograph simultaneously with wind-vane positional data to form the dynamic record as the model rotated.

Very satisfactory agreement between the theory and experimental data was achieved from this series of wind-tunnel tests.

D. Wind-Vane Photography

The wind-vane system as flown in the last Aerobee was designed to provide quantitative data regarding rotation of the vane shaft but no direct information concerning the actual position of the vane itself. Since wind-tunnel testing does not accurately simulate the missile-flow conditions, it seems desirable to devise an experiment to directly determine the vane position, flexure (if any), and other possible abnormal behavior during rocket flight.

It is felt that this procedure will lend further credence to the opinion that the wind vanes offer a practical means to measure flow angle on a cone and thus enable computation of upper-atmospheric winds, temperature, etc.

The most direct and accurate approach to the problem of determining the vane behavior in flight appears to be one which employs some means of photographic recording. Although this statement is simple in theory, its practical application is complicated by the physical and aerodynamical requirements of such a test. The vane must be photographed from a position in which its angular position, curvature, and tilt (if any) will be discernible. Furthermore, it is necessary that there be no exterior surface discontinuities ahead of or near the region of the flag which would cause aerodynamic difficulties.

To determine whether it is possible to photograph a vane which is

only 0.003 inches thick and comply with the other conditions of the experiment, a series of laboratory tests have been planned and are now in progress to investigate the feasibility of the method. It is expected that the results of these tests will provide the basis for a rocket-borne experiment of this type to be flown sometime in the summer of 1955.

E. Preparation of the Vacuum System

The vacuum system used in the past by this project to test and calibrate Alphatron and other vacuum gages has been disassembled and is in the process of being cleaned and reinstalled in the laboratory. This activity is in preparation for the Alphatron gage study which will be undertaken in the near future.

F. Technical Reports and Papers

A Technical Note detailing the steps involved in modifying a Bendix J-8 altitude gyroscope for Aerobee rocket aspect use is now in rough draft form. It is expected that the completed report will be issued during the next period.

A Technical Note describing various power supplies incorporated in Aerobee rocket instrumentations in the past is now in preparation and will be issued during the next period.

Reprints of the paper 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, which was published in the Journal of Applied Physics, Vol. 25, No. 2, 161-168, February, 1954, will be issued by this project as Scientific Report No. CS-2. This action was prompted by exhaustion of the supply of reprints furnished by the publisher.

The material presented in the wind-vane paper mentioned earlier in this report will be formalized and submitted for publication to the Journal of the Aeronautical Sciences.

Following below is the abstract of the wind-vane paper presented at the meeting of the Division of Fluid Dynamics of the American Physical Society at Fort Monroe, Virginia, on November 22, 1954. It is understood that this abstract will be published in a forthcoming issue of the Physical Review.

"Mach Number and Yaw Angle Determination for Conical Flow Regimes

Using Two Surface-flow Angle Indicators* H. S. Sicinski and H. F. Schulte, University of Michigan. - In the search for principles applicable to measuring upper air environments (i.e., temperature, density, wind vectors, etc.) from supersonic missiles in the regions above 30 kilometers altitude, it became evident that knowledge of the angle of surface flow on a right circular cone coupled with body-coordinate rotational parameters would permit calculation of the free stream Mach number and the yaw angle. An instrumentation was developed for measuring the surface flow angle utilizing a rectangular metal plate 3/4 x 1/8 x .003 inches driving a capacitive transducer. The electronic version of the instrument requires a minimum force of 60 dynes at the plate's center of pressure for accurate alignment with the stream. Correlation of the theory with experiment was provided in a series of wind tunnel experiments with the subsequent realization that the vane angle as measured by an external optical system would provide a reliable 'Mach meter' for wind tunnel instrumentations, particularly low density tunnels where conventional Pitot tubes become complicated by having to measure very low pressures. Such an optical transducer for the vane angle would require a lower actuating force than the electronic version of the instrument. (However the electronic version is better suited to recording dynamic conditions such as encountered in free flights) The discussion will concern the governing relations, the solution of the resulting transcendental equations, experimental results, and the possible applications."

*The research reported in this paper has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

G. Future Plans

It is planned to continue work on the vacuum system, preparation of additional Technical Notes, wind-vane photography, and the gyro aspect data report on the July, 1954, Aerobee firing. In addition, it is expected that tentative long-range plans outlining project activities for the next three years will be formulated by the end of the next period. Emphasis will also be placed on the design and construction of equipment for rocket-borne photographic recording of wind-vane performance as discussed earlier in this report.

II. PERSONNEL, ADMINISTRATIVE, AND FISCAL INFORMATION

A. Personnel

(1) Mr. James Zoerner, student, who was employed as a data analyst, terminated employment in October.

(2) Mr. Paul Engelder, student, joined the project as a part-time technician in November.

B. Administrative

A contract continuation proposal for the coming year was prepared and submitted to the Contracting Officer during the period.

C. Technical Meetings and Visits

Mr. N. W. Spencer visited the Air Force Cambridge Research Center in November to discuss contract renewal, future plans, and probable participation in the International Geophysical Year activities by this project.

Mr. H. S. Sicinski also attended the Cambridge meeting, and in addition travelled to Fort Monroe, Virginia, to present the wind-vane paper discussed elsewhere in this report.

D. Fiscal

As of 31 December 1954, approximately 50 percent of the funds budgeted for a quarter remain unexpended. These funds will be carried over and applied to project activities during the coming year.

E. Property Acquired during the Period

(1) File cabinet

(2) Small parts cabinet

(3) 7-1/2 ampere powerstat (used)

(4) 30-volt-ampere Sola constant voltage transformer

(5) Sprague TO-3 condenser-resistor analyzer (used)

(6) Metal storage cabinet