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PROGRESS REPORT

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UPPER-ATMOSPHERE WIND, TEMPERATURE, AND PRESSURE MEASUREMENT

REPORT NO. C7-C8

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Project Supervisor

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.

Project 2096

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ABSTRACT

This report presents a discussion of the upper atmosphere instrumentation developed for an Aerobee rocket firing which took place July 14, 1954, and in addition, a statement of the preliminary results of the experiments.

Plans for the immediate future are likewise presented.

PERSONNEL EMPLOYED DURING THE PERIOD OF REPORT

R. L. Boggess[1]	Engineer	Half-time, student
H. V. Dada[2]	Data Analyst	Part-time, student
J. A. Foster[3]	Engineer	Full-time, student
W. G. Kartlick	Technician	Full-time
A. A. Kirsons	Data Analyst	Full-time, student
D. L. McCormick	Machinist	Full-time
T. R. Pattinson[2]	Technician	Part-time, student
H. F. Schulte	Project Engineer	Full-time, student
S. Shah	Data Analyst	Part-time, student
H. S. Sicinski	Project Physicist	Full-time
N. W. Spencer	Supervisor	0.9 Time
J. Zoerner	Data Analyst	Full-time, student

[1] Employed as of 1 September 1954.

[2] No longer associated with the project.

[3] Decrease to less than half time following July field trip.

UPPER-ATMOSPHERE WIND, TEMPERATURE, AND PRESSURE MEASUREMENT

INTRODUCTION

Progress reports under contract AF 19(604)-545 are generally submitted covering a quarterly period. However, this report covers the six month period as indicated on the cover to provide more continuity in reporting. Since an Aerobee rocket firing took place very nearly in the middle of this double period, this report includes a discussion of instrumentation preparation, use during firing, and assessment of the preliminary results of the firing. In order to avoid possible confusion in regard to report numbers this report carries the dual number C7-C8.

INVESTIGATIONS BEING UNDERTAKEN

General

Previous progress reports under this contract have described in some detail instrumentation considered for the Aerobee rocket firing held July 14, 1954. In order to provide continuity for the reader, much of the material presented earlier will be included here as well. Thus, this section will present a discussion of the instrumentation actually used, as well as comments relative to performance of the equipment.

The period from 1 April to 1 July was devoted almost entirely to the construction, installation, and testing of the various equipments of which the ultimate instrumentation was composed as described below. Personnel from the AFCRC arrived with their portion of the instrumentation (see below) about the middle of June and in the next several days that equipment was installed and tested with most of the University of Michigan equipment, the purpose of these preliminary tests being to insure that interference between the various equipments would not be encountered after the field parties arrived at the launching area. The tests were successful, and AFCRC personnel returned to their laboratories. The University of Michigan field group subsequently left, June 28, for the field test.

One of the objectives of this firing was to enable a comparison between the University of Michigan gyro-aspect system used in previous instrumentations in connection with alphatron-temperature experiments and the Air Force Cambridge Research Center sun-horizon-aspect system previously utilized in other Aerobee instrumentations. The gyro system has been used successfully for a number of rocket flights, as has the sun-horizon-camera system. Each system has, of course, its merits and drawbacks. The gyro system produces aspect data with relatively little data-reduction effort, whereas the sun-horizon system requires a relatively considerable data reduction effort. It, however, has the merit of being much simpler from the instrumentation standpoint, requiring only the proper installation of a special camera in a given instrumentation. The gyro is much more complicated in this respect, requiring careful preparation prior to flight, as well as a rather complicated installation by comparison.

Operationally, the gyro system has the merit of being useful at anytime of the day or night independent of weather or visibility conditions, whereas the sun-horizon system is useful only in the daytime and then only during sun-up periods. The sun-horizon system has the additional merit however, of being an absolute system, that is, each data point it yields is independent of every other point.

The accuracy of the two systems is believed to be comparable and it was the purpose of this firing to establish the validity of this belief.

The gyroscope used in this system is a specially modified Bendix type J-8 instrument. Modifications include the installation of a motor-driven, remotely controlled erection system, the substitution of specially engraved scales, the use of bearings selected particularly for low friction, and procedures which permit as near perfect balance of the gyrostat as may be achieved. This work is in general accomplished under controlled laboratory conditions utilizing a dust free box in order to maintain conditions of cleanliness. It is believed that modification and preparation in this manner permits the attainment of data of accuracy better than 1° in an Aerobee rocket.

The data from the gyroscope is recorded in flight by a 16 mm motion picture camera carrying the designation B-2. Like the sun-horizon system the film must be recovered subsequent to flight.

The sun-horizon-aspect system likewise utilizes a B-2 camera with a modified lens structure to permit wide-angle viewing. For the July firing the installation of the aspect camera was the responsibility of the AFCRC, and thus, will not be described here.

Both systems are believed to have operated essentially as anticipated during this firing. The film was recovered from the missile intact and has been processed. At the present time reduction of the gyro data which appears to be satisfactory, is under way. A study of the film has revealed that an obstruction may have affected gyro operation for the first 30 seconds of flight. Subsequent to this time, however, the obstruction was not present and operation was normal. It is estimated that final flight data will be available in approximately one month.

Second Gyro

A second gyro with associated camera and lighting system was likewise utilized in the July Aerobee firing. The second gyro was prepared in a manner similar to the first, however the installation was different in that an alternative mounting position was chosen. The new position if proven successful will permit a further reduction in the time required for data reduction, due to the elimination of certain steps in the computational procedure.

The camera utilized for recording the data from the second gyro was designed and built specially for this purpose. Whereas the B-2 camera used currently for recording data is of the conventional shutter type, the new camera transports the film, 35 mm in this case, past the aperture at a constant velocity and does not use a shutter. In order to provide the effect of a shutter a flashing-light system was developed and used with the camera. An electronic flash tube is employed and is flashed at the appropriate interval, in this case ten (10) times per second; appropriate synchronism thus permits a frame rate of ten (10) frames per second. The use of the flashing light enables, for instance, photography completely free from possible vibration. It likewise permits, due to the readily attained high light intensity, the use of film with finer grain, and consequently, an improvement in image detail.

For the July firing, the camera, lighting system, and second gyro apparently operated satisfactorily. The data from this system are likewise being reduced at this time and will be available in a few weeks time. The flashing-light photography system is now considered proven and will probably replace the earlier B-2 camera and regular lighting in subsequent firings.

Wind Vanes

Previous progress reports have described a system of temperature measurement, under preliminary development by this project, employing small wind vanes on a missile-nose cone surface. Through use of such vanes, measurement of the angle of the airstream over the cone surface may be accomplished permitting computation of atmospheric ambient temperature.

The July firing provided the first opportunity for a rocket-borne experiment utilizing these devices. Two vanes were installed at a point approximately 20 inches from the nose cone tip, spaced 120 degrees. The vanes consisted of rectangular pieces of steel feeler gage stock 1/4" x 3/4" x 0.003" and were soldered with special high temperature (600°) solder to the shafts of project built transducers. Each transducer was essentially a three plate condenser, carefully developed utilizing jeweled bearings and saphire ball plate spacers. The objective in the design was to produce a device with minimum friction, as well as reasonably low mass, in order to permit precise alignment of the wind vanes with the airstream at relatively low densities. It was determined in this regard that operation would be satisfactory to attitudes as great as fifty miles. In order to promote reproducibility of capacity as a function of angle, the tolerances to which the transducers were constructed were held as small as was feasible, considering reasonable machine shop facilities. Thus the vane shafts were centerless ground, the diameter being chosen so that the clearance between the shafts and jewel bearings was about 0.0003 inch. Shaft end play was minimized by holding the pointed end of the shaft against a cap jewel through use of a small slug of alnico. These provisions resulted in a device wherein the "play" was discernible only microscopically.

The transducer (capacitor) was connected in a parallel resonant circuit tuned slightly off resonance. Power at approximately 10 megacycles was inductively coupled into the tuned circuit, across which was connected a crystal detector. Thus changes in capacitance of the transducer could produce changes in the output voltage of the detector, and hence, a measurement of angle change of the transducer. The power source of the tuned circuit employed a crystal oscillator and amplitude stabilized Class-C RF amplifier. In addition to this precaution for constant excitation of the resonant circuit, B^+ power was obtained from a regulated power supply. Also the tuned circuit-detector system was temperature controlled.

The output of the detector was applied to a cathode follower and thence to telemetering. In order to stabilize operation of the cathode follower, the heater supply was regulated by both Amperite current regulators and Thyrite regulators. B^+ was obtained as above from the regulated power supply.

As a result of these precautions, the complete wind-vane system exhibited excellent stability in permitting the measurement of vane angles to an accuracy believed to be better than 0.1 degree. The goal in the development was reproducibility to 0.03°; however, how nearly this was achieved has not been finally determined.

Instrumentation of this type, mounted on the outer surface of a missile nose cone is of course subjected to rather high temperatures. This was considered in the design and accounts, e.g., for the use of high-temperature solder in the vane mounting, and to some extent for the clearance of shaft bearings. Additionally, it was deemed necessary to keep the vanes covered during the portion of the flight prior to missile burnout for protection from excessive heating during this critical heating period. Accordingly, small aluminum wedge-shaped covers were designed. They were secured to the cone surface by piano wire which was spring loaded. When removal was desired it was then necessary only to apply power to the wire, melt, and thus part it; allowing the covers to be ejected by the springs. Cover alignment was maintained through use of integral keels which engaged appropriate slots in the cone surface.

As mentioned above, two vanes were employed in the July firing. The systems were completely independent except for the common regulated supply. In regard to results of this experifment, it has not yet been firmly established how the vanes operated. A preliminary study of the telemetering record apparently indicates the following:

(a) normal signals up to the point of cover ejection which occurs at about 30 seconds,

(b) steady signals (apparently nearly constant) from cover ejection to 54 seconds where telemetering record ceases,

(c) record blank until 90 seconds when apparently nearly constant signals again appear momentarily,

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

(e) record returns periodiocally until 182 seconds when it again fades and flag outputs are nearly constant whenever seen, and

(f) record returns at 272 seconds where vane outputs show marked differences.

The above brief description of the early portion of the record will give some indication of the evidence available to determine operation of the system. The record up to 54 seconds appears to indicate satisfactory operation. Although, less constancy might be presumed during the period of flight following burnout, the Aerobee as studied in earlier University of Michigan flights generally does not experience much yaw, usually less than 1 to 2 degrees. This magnitude would produce vane voltage changes of the order of 0.1 volt.

The constancy of the outputs at about 90 seconds and later is, however, quite questionable, as greater angles than indicated are expected during that period. If information from other equipment indicates that the missile did experience the expected angles, this constancy of vane output will perhaps suggest that the vanes became separated from the shafts of the transducers some time between 54 and 90 seconds. However, this is difficult to reconcile with angle change evidence later in the flight and our opinion is that the stream at this time lacks sufficient energy to cause vane failure.

Likewise, the appearance of the transducer shafts after impact suggests that the vanes were wiped off at impact, rather than being lost due to excessive heating during the flight.

Thus it seems more likely than not at this time, that the vanes were intact throughout the flight, but that they failed to respond as expected sometime after 54 seconds. An additional fact that perhaps supports this belief is that the circuitry associated with the vanes has since been operated successfully; seeming to preclude failure during the flight.

This study is of course being continued. The next step in the analysis will be to perform a detailed reduction of the telemetering record to numbers to permit further interpretation and evaluation of the results. It should be stated that even in the event that valid data are determined during the 30 to 54 second period, it will not be possible to compute temperatures due to the lack of missile velocity information.

Air Speedometer (AFCRC)

Equipment utilizing ion generators and receivers was designed, installed, and operated by personnel of the AFCRC as their responsibility for this firing. The purpose of the experiment was to provide measurements of stream velocity on the nose cone. Since this experiment was not the responsibility of the University of Michigan it will not be covered by this report. It is believed to have operated successfully.

Accessory Equipment

In addition to the major portions of the instrumentation provided by the University of Michigan group for this firing there are also accessory items necessary for operation. The power supply systems to power the gyroscopes and the flashing-light system fall in this category.

The gyros, light system, and regulated power supply require 110 volt, single phase, 400 cycle power. Vibrator type invertors operating from 24 volt lead acid cells provided the requisite power, three units being employed. One 30 watt unit supplied both gyroscopes, another 30 watt unit supplied the flashing-light system and a third, 15 watt unit powered the regulated power supply. In order to prevent "noise" generated by the invertors possibly interfering with information signals fed to the telemeter, all invertors were heavily filtered on the primary side. In addition, phase angle correction was applied to the invertor output.

Many vibrator type invertors have been utilized in Aerobee rocket instrumentation by this project and failure of the units in flight has not been experienced nor was it during the July firing. However, for this flight, in view of the special importance of obtaining proper gyro operation, it was decided, to insure power for the gyros, to provide a switch-over system for the invertors that would operate in case of invertor failure. Thus a circuit was devised that would switch the gyros from the invertor which normally powered them to the other 30 watt invertor in the event that the output of the first invertor failed.

Although operation of the change-over circuit and vibrators has not specifically been checked subsequent to flight, the proper operation of gyros and other equipment powered from the invertors implies normal operation and that the change-over system was not used.

Another item of accessory equipment consisted of an in-flight telemeter calibrator. This unit employed a motor driven multiple point (20) switch which inserted carefully measured voltages in the range 0 to 5 volts periodically during the flight. Constancy of voltage was achieved reasonably well through the use of mercury cells. The purpose of the calibrator was of course to provide a detailed in-flight calibration of the telemeter and at the same time provide an opportunity to evaluate the telemeter in terms of reproducibility and stability.

Two timers were employed in the July firing. The units were identical and were operated in parallel so that failure of either at any point in its program would not affect the operation of the other. This policy of duplication where feasible of course lends assurance of successful operation and is believed worthwhile.

The timers in this flight provided several functions, including chiefly:

(a) insertion of calibration to 26 seconds;
(b) cover ejection, one at 28 seconds, the other at 29 seconds; and
(c) reinsertion of calibration at 118 seconds.

On recovery both timers were determined to be in "time-out" position thus indicating correct operation of both units.

Additional items of accessory equipment included a commutator for use with the telemeter, limiters for telemeter protection (as described in Tech. Note No. 1.), acceleration switch to determine instant of launch, and a cam switching device for cross timing references for the various cameras. These units operated satisfactorily.

RESEARCH REPORTS, PUBLICATIONS, AND OTHER SCIENTIFIC ACTIVITIES

T-Day (October 22, 1952, Aerobee)

The results of the T-Day firing, October 22, 1952, were originally submitted in an informal report entitled "Preliminary T-Day Report". The report was prepared in the interest of indicating firing results as early as possible, but was necessarily considered tentative due to the lack of reliable trajectory data involved in the computational procedures. Thus a so-called vacuum trajectory was assumed in lieu of actual trajectory information. Subsequent to the issuance of the preliminary report, a request was made to the data reduction group at the Holloman Air Development Center to reevaluate the desired trajectory information which was inconsistant in itself. Revised trajectory data were later received and studied in comparison with the assumed vacuum trajectory data; revealing the necessity for revision in certain of the temperature data resulting from the earlier computations. Accordingly, temperatures were recomputed and submitted in a new informal report entitled, "Revised T-Day Report".

Differences in temperature as compared with the early tentative results were rather minor, but of sufficient magnitude to indicate the inadequacy of the assumed vacuum trajectory. The conclusion reached as a result of this work is that the vacuum trajectory assumption was not entirely adequate for measurements of temperature by the University of Michigan method.

It should perhaps be pointed out that the term vacuum trajectory as used here refers to the changes or rates-of-change in the body orbit as produced by gravitational forces varying with an inverse square variation with altitude, centrifugal forces, and those produced by the Coriolis acceleration forces each acting on a body beginning at an altitude where the propulsion forces cease.

It is not expected that further work is necessary in connection with the T-Day data, except that it is planned tentatively to resubmit the revised report as a "Scientific Report" under the contract and as the subject of a "Letter to the Editor" in the Journal of Applied Physics.

Technical Papers

A technical paper entitled "Rocket Instrumentation for Reliable Upper-Atmosphere Temperature Determination" by N. W. Spencer, H. F. Schulte, and H. S. Sicinski was published in the July, 1954, issue of Proceedings of the I.R.E.

Two papers as follows: "Exploration of the Ionosphere by Means of a Langmuir-Probe Technique" by Gunnar Hok and W. G. Dow and "Density Gauge Methods for Measuring Upper-Air Temperature, Pressure, and Winds" by N. W. Spencer and W. G. Dow were published in book form with several other papers presented at the Oxford England Meeting of the Upper Atmosphere Rocket Research Panel in August, 1953. The title of the book is not known to the writer.

A technical paper entitled "Mach Number and Yaw Angle Determination for Conical Flow Regimes using Two Surface-Flow Angle Indicators" by H. S. Sicinski is to be presented before a meeting of the Division of Fluid Dynamics of the American Physical Society of Fort Monroe, Virginia, November 22, 1954. This paper details the theoretical aspects of the wind vane system as developed by Mr. Sicinski.

<u>Technical Meetings and Visits</u>

(a) N. W. Spencer and W. G. Dow attended two meetings of the Upper Atmosphere Rocket Research Panel held in Washington, D. C. in April and September, 1954.

(b) Mr. H. S. Sicinski visited the Langley Laboratory of the NACA in April to discuss matters relating to the use of wind vanes.

(c) H. F. Schulte, W. G. Kartlick, J. A. Foster, and R. L. Boggess conducted the field trip in July during which the Aerobee firing discussed in this report took place. Mr. Schulte was field director for the University of Michigan for this firing. Mr. Spencer was also present.

FUTURE PLANS

Emphasis is being placed at the present time and for the next few weeks as follows:

(a) Reduction of gyroscope data from July Aerobee firing.

(b) Preparation of vane equipment recovered from July Aerobee for use in wind tunnel vane tests. The data resulting from these tests are expected to verify theories developed earlier and will be a portion of the subject of the paper to be presented by Mr. Sicinski in November, as discussed above.

(c) Further study of other results of the July firing, with particular emphasis on the wind vane experiment. It is hoped that this experiment will develop into a form suitable for incorporation into instrumentation contemplated for the International Geophysical Year studies. Furthermore, the success of this type of equipment will facilitate future upper-air-wind measurements.

(d) Preparation of technical notes on the subjects of gyro preparation, 35 mm continuous run camera, and flashing-light system.

PERSONNEL AND ADMINISTRATION

(a) Mr. T. R. Pattinson, who was employed on a part-time basis as a technician, terminated employment in July.

(b) Mr. R. L. Boggess has been employed as a Research Associate as of 1 September. Mr. Boggess previously was employed as an Assistant Professor of Electrical Engineering at the University of Kentucky where he earlier received the degree M.S.E.E. He will work approximately half-time while continuing studies leading to the Ph.D.

(c) Mr. Dada left the data reduction group of the project in June.

(d) Mr. James Zoerner, a student, joined the data reduction group in August.

(e) Mr. S. Shah, student, joined the data reduction group in June.

(f) Mr. J. A. Foster left the project as of July 20, 1954. However, it is anticipated that he will return for a short period in the fall on a limited part-time basis. Mr. Foster was responsible for the preparation of the gyro, as well as certain other portions of the instrumentation, for the July firing. It is contemplated that he will write a Technical Note concerning gyro preparation on his return.

FISCAL INFORMATION

It is anticipated that 20 percent of the funds on hand as of 31 August 1953 will remain at the end of this reporting period, September 31, 1954. This amount is very nearly in accord with the established budget.

PROPERTY ACQUIRED DURING THE PERIOD

The following capital equipment items were acquired during the reporting period:

(a) Hewlett Packard model 410B VTVM

(b) Millivac model MV-17C

(c) 4" Ames Indicator model 4824

(d) Bausch and Lomb Filar Eyepiece

(e) 3 Height Gages

(f) Portable Newcomb Film Reader

(g) Used MA-7 Monroe Calculator

(h) File Cabinet

ACKNOWLEDGEMENT

The University of Michigan field party wish to express their appreciation for the excellent cooperation received from the Holloman Air Force Base Aerobee project group under the direction of Capt. J. Hurst during the July field trip. We wish also to express our appreciation to Capt. J. J. Quintis for his special assistance with a helicopter in effecting ultimate recovery of the instrumentation, a vital consideration in regard to gyro and aspect system success.