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THE UNIVERSITY OF MICHIGAN
ANN ARBOR

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

Quarterly Report

for the period

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by

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Department of Aeronautical Engineering

Project 2387

DEPARTMENT OF THE ARMY PROJECT NO. 3-17-02-001
METEOROLOGICAL BRANCH, SIGNAL CORPS PROJECT NO. 1052A
CONTRACT NO. DA-36-039 SC-64659

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ABSTRACT

The grenade and grenade-section developments for Aerobees SM 1.01 and 1.02 were continued. A rubber-nylon combination lanyard was developed and tested. The instrumentation section for these Aerobees was designed and construction started. This work included design of the flash detector circuit and choice of photocell. Programming of the DOVAP spin-correction process for MIDAC was completed.

Sample bottles and instrumentation sections for Aerobees SC-34 and 35 were constructed.

A research note "On the Motion of a Projectile in the Atmosphere" was prepared.

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1. INTRODUCTION

This is the fifth in a series of quarterly reports on Contract No. DA-36-039 SC-64659. The purposes of the contract are:

a. to adapt the rocket-grenade experiment for use in the Arctic during the International Geophysical Year,

b. to collect and analyze upper-air samples, and

c. to engage in the general investigation of problems relating to upper-air research.

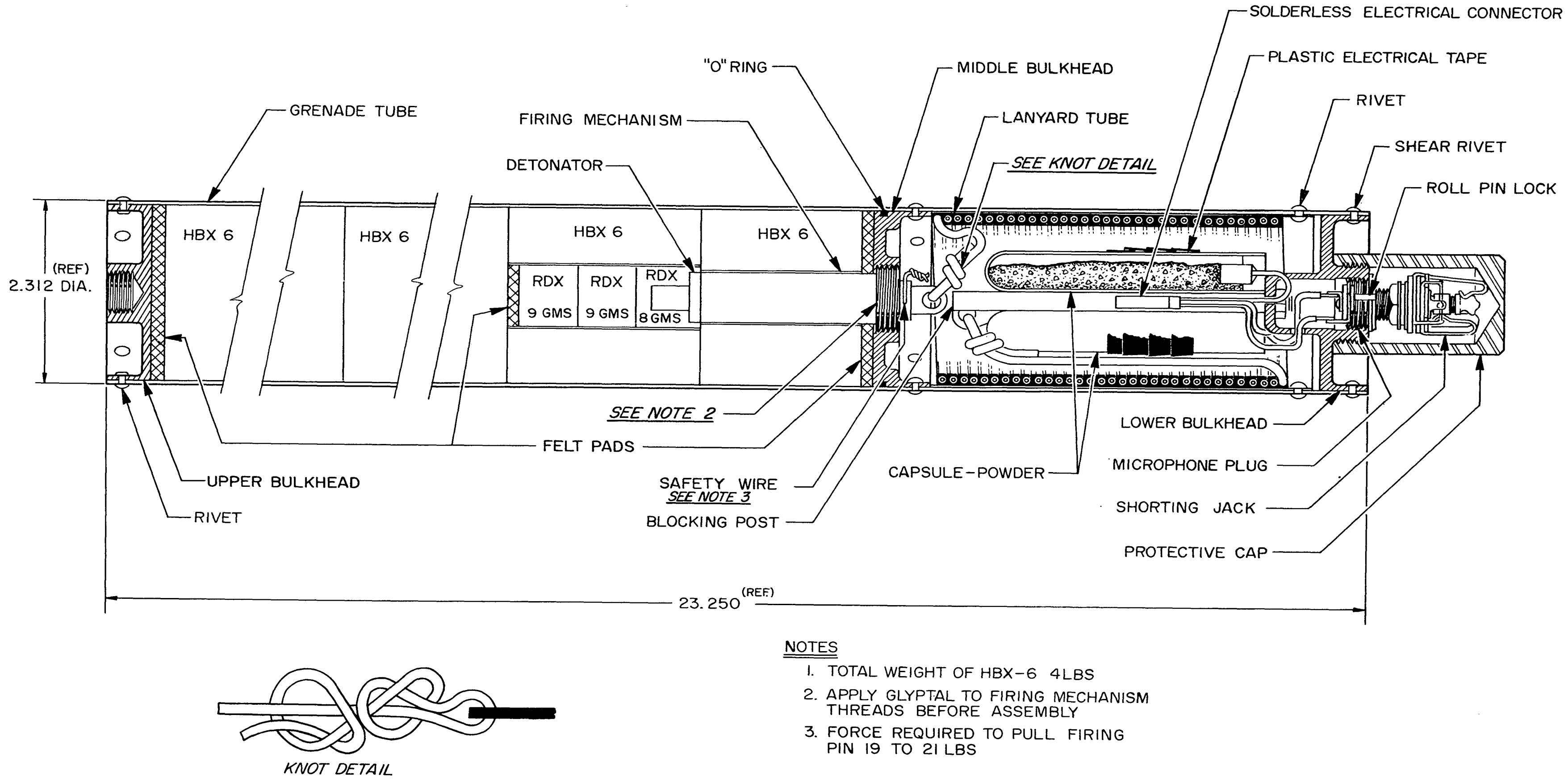
2. GRENADE EXPERIMENT

The greatest part of the effort on the grenade experiment went into preparations for two pre-IGY grenade Aerobees (SM 1.01 and SM 1.02) to be fired at Ft. Churchill in November. The main items of development are the grenade, the grenade section (mortars), and the instrumentation section.

2.1 THE GRENADE

Development of the lanyard-operated grenade was continued. A new approach to the design was made. The main features of the prototype are seen in Fig. 1. Inasmuch as the design is still underway it will not be described completely until the next report. The lanyard itself, which is one of the principal components of the grenade, underwent further development.

2.1.1 Lanyard Development.—Investigation of lanyard materials was continued with the hope of finding one which would satisfactorily withstand the heat of the propelling fire without critical tailoring of the charge. Fiberglas sleeving over rubber tubing was tried with no success. The rubber tubing was intended to provide shock absorption to the otherwise inelastic fiberglas. Using a 6-gram, black-powder propelling charge the fiberglas became brittle and fractured like corn flakes. Another approach using a nylon-



NOTES

1. TOTAL WEIGHT OF HBX-6 4LBS
2. APPLY GLYPTAL TO FIRING MECHANISM THREADS BEFORE ASSEMBLY
3. FORCE REQUIRED TO PULL FIRING PIN 19 TO 21 LBS

Fig. 1. Prototype of lanyard-operated grenade.

twine core inside a rubber insulating sleeve showed good promise and was chosen as the one to develop.

Initial tests of the nylon-rubber combination consisted of common laboratory rubber tubing through which a nylon cord had been threaded. Samples tested consisted of 2 cords of 175-pound-test nylon in natural-rubber tubing, single cord 175-pound-test nylon in red reclaimed-rubber tubing, single cord 225-pound-test nylon in red reclaimed rubber, single cord 175-pound-test nylon in silicone tubing, and 225-pound-test nylon in silicone tubing. All samples tested worked satisfactorily with 12-gram propelling charges. Later tests indicated, however, that the silicone-rubber-covered lanyards were prone to fail by rupturing the silicone tube if the potting material which temporarily holds the lanyard in place was applied too generously. Once the tube ruptured the nylon would melt. This shortcoming was due to the poor mechanical properties of silcone rubber and did not appear when other rubber compositions were used. Despite its superior temperature characteristics, which do not appear necessary for this application, silicone rubber was rejected as an insulating material for lanyards.

The lanyard material chosen for the production grenade consists of 225-pound nylon with a coating of neoprene extended over the nylon.

Coiling the lanyard appeared to be the most satisfactory method of storing the lanyard for very rapid unwinding. Single-, double-, and triple-layer coils were tried with and without rigid separators between coils. Also, coils attached to the grenade proper and free-floating coils (unattached except at terminals) were tried. The single coil attached to the grenade with 2 tear-away potting material worked quite satisfactorily and was chosen as the method to be used.

Stainless-steel spring connecting clips were designed and tested with good initial success. The clips were intended to facilitate manufacture of the grenade. Although the clips were amply strong, as shown by static tests and firing tests, occasions did arise when the clips would become disconnected during firing. These clips were not failed and would work satisfactorily on subsequent firings. Time did not permit an exhaustive investigation, so the clips were eliminated from the grenade design until time does permit development of higher reliability.

Lanyard materials were tested in a laboratory tensile-test machine both alone and in conjunction with terminal attachments.

Firing tests using a grenade propulsion section, identical to the proposed design, attached to a dummy cylinder to simulate the weight of explosive charge were made from single-barrelled mortars. From the standpoint of the lanyards, these tests were performed to indicate suitability of the lanyards under actual conditions. The dynamic loads, the stress concentration at the terminal connections, and the heat of the launching charge were identical to those anticipated in the actual grenades.

Another test program was initiated to measure the dynamic load in the lanyard during a launch. A suitable strain-gage beam was built and calibrated for these tests. A few tests were run but time again did not permit extensive testing. Early tests indicate that firing pins which can be pulled statically at approximately 20 pounds require in excess of 100 pounds when pulled dynamically under the conditions of launching.

2.2 GRENADE SECTION (Mortars)

The general layout and design features of the grenade or mortar section were developed. This section holds 18 grenade mortars arranged for forward ejection. The proposed design is seen in Fig. 2.

2.3 GRENADE INSTRUMENTATION SECTION

The mechanical design of the rocket instrumentation section has been started. A standard 15-inch Aerobee extension will contain the following equipment:

a. DOVAP transponder,
b. DPN 19 radar beacon,
c. AN/DRW-3 cutoff receiver,
d. Arm-Disarm Ledex relay,
e. Timer and program Ledex relay,
f. Photocell flash detector, and
g. Batteries for all equipment.

The cutoff receiver will use a notch antenna mounted in one tail fin. The turnstile antenna, mounted on a second fin, will be used with the DPN-19 radar beacon. The antennas for DOVAP will consist of four of the so-called "handle-bar" type mounted at the top end of the rocket tank section.

The timer will allow emergency fuel cutoff by AN/DRW-3 command during the period of time 2.5-36 seconds after take-off. Fuel cutoff will be accomplished by prima-cord severance of the fuel line.

Ejection of the grenades will be controlled by the timer. The ejection will be monitored by means of a microswitch which will operate when the grenade has traveled a distance equal to its own length.

The DOVAP single-channel telemeter will be used to transmit both the grenade-ejection and grenade-burst signals provided by the photoelectric flash detector.

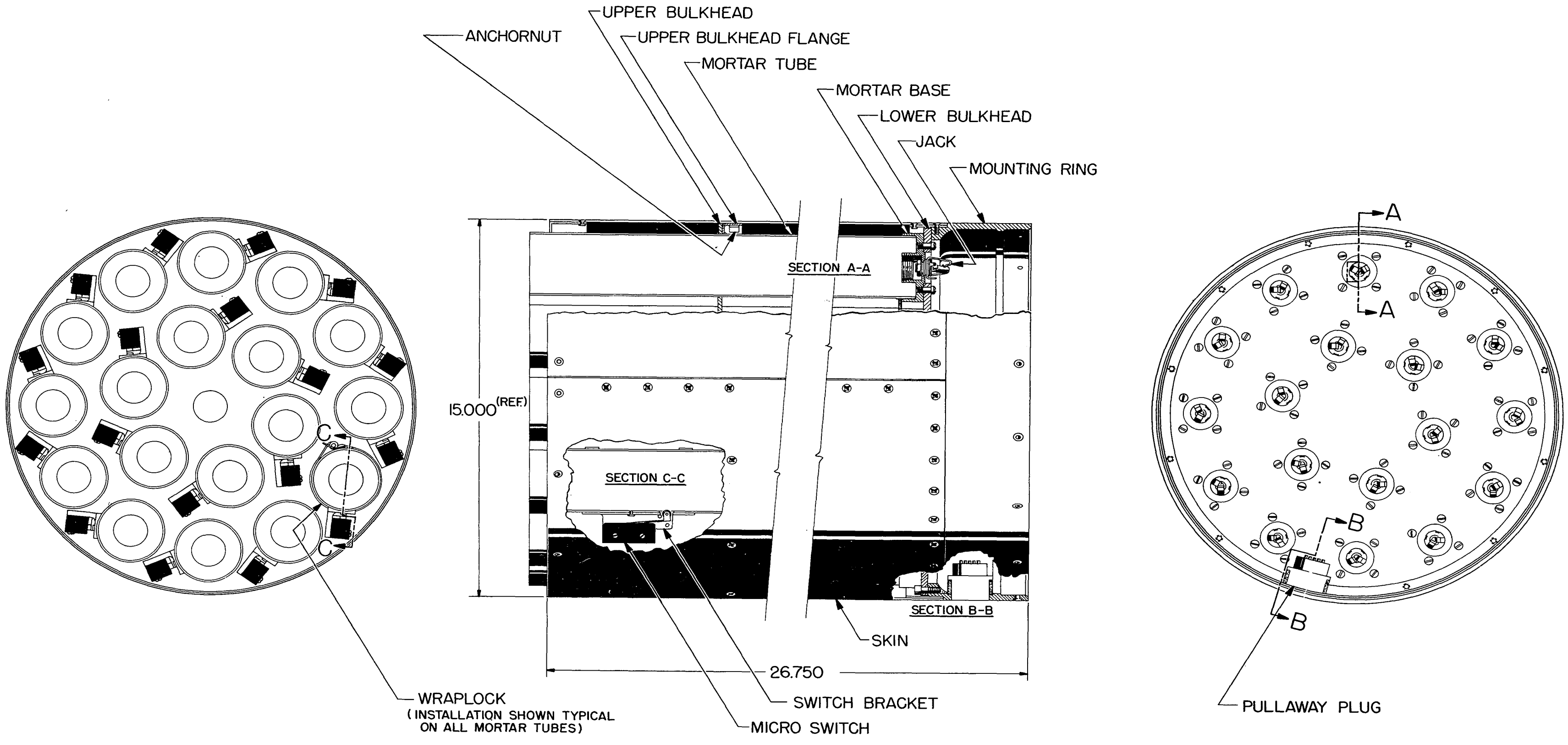


Fig. 2. General layout of grenade section.

2.4 ROCKET-BORNE PHOTOELECTRIC FLASH DETECTOR

Following are the considerations which have led to the proposed design of the rocket-borne photoelectric flash detector.

The high explosive to be used on the flash-and-sound units (grenades) will be 45/35/20/5-RDX/TNT/Al/wax. The spectral distribution of the flash of such a grenade is not known accurately. Indeed, the spectral distribution of the flash of such a grenade will be a function of time, for the initial explosion of the RDX and TNT will be followed after about 30 milliseconds by the burning of the aluminum. Since we are interested in determining the time of the start of the explosion, we are interested in the spectral distribution of that part of the flash which accompanies the initial explosion of the RDX/TNT.

If we assume that the explosion radiates as a black body, then it is sufficient to know the temperature of the explosion, for the temperature will determine the spectral distribution of the flash. By Wien's Displacement Law the wavelength λ_{max} at which the radiation intensity is a maximum is given by

$$\lambda_{max} = \frac{.28971 \times 10^8}{T} \text{ Angstroms} , \qquad (1)$$

where T is in degrees Kelvin.

Following is some of the information available about the temperature of explosions:

a. J. Taylor in his book, Detonation in Condensed Explosives, Oxford University Press, 1952, p. 118, gives the temperature of the explosion of high-density TNT as 3900°K.

b. Maurice Distel in his master's degree thesis, "Rocket-Borne Flash-Detector System," Department of Electrical Engineering, Brooklyn Polytechnical Institute, 1952, gives the figure of 1800°K for the explosion of RDX.

By Wien's Displacement Law the λ_{max} values corresponding to these temperatures are:

$$\text{a.} \quad \lambda_{max} = \frac{.28971 \times 10^8}{2900} = 7428 \text{ Angstroms.}$$

$$\text{b.} \quad \lambda_{max} = \frac{.28971 \times 10^8}{1800} = 16095 \text{ Angstroms.}$$

It is felt that the initial explosion temperature of the RDX/TNT will lie in the range 2000°-3500°K. Thus, it appears that the spectral distribution of the radiation during the first few milliseconds after the start of the explosive will have a peak intensity at a wavelength in the near infrared.

The possibility of a spurious signal from the sun for daytime flights must also be considered. The spectral energy distribution of the solar radiation closely approximates the spectral energy distribution of a black body at about 6100°K.* The wavelength λ_{max} of the peak of the spectral distribution is about 4700 Angstroms, i.e., at the lower end of the visible region.

It appears that a photosensitive device, sensitive only to light in the infrared, would have a better signal-to-noise (sun) ratio than a photocell with sensitivity only in the visible region. A comparison of the magnitudes of the signals expected from the explosion and from the sun by photocells of these two types is given below.

For the infrared-sensitive cell, a Kodak "Ektron" lead-sulfide cell could be used with a filter to give a response in the range of 8,000-25,000 Angstroms. A photocell of the 1P42 type would have roughly a uniform response over the range 3,400-6,000 Angstroms, covering the visible region.

The total energy received from the sun is very nearly 2 cal/cm^2 minimum or 0.14 watt/cm^2. Approximately 38% of the total lies in the 8,000-25,000 Angstrom range; about 45% of the total lies in the range 3,400-6,000 Angstroms.

The peak intensity of the explosion flash of the flash-and-sound units previously used was about 10^6 candles.** The explosive charge consisted of 80% Comp. A-3 (91% RDX, 9% desensitizer) and 20% powdered aluminum. If we assume that the high explosive now to be used (45/35/20/5-RDX/TNT/Al/wax) will give the same peak candle power, then the luminous flux at 15 feet would be

$$\frac{10^6}{(15 \cdot 30 \cdot 48)^2} = 4.8 \text{ lumens/cm}^2 \quad .$$

If an effective explosion temperature of 3000°K is assumed, the luminous efficiency would be 28 lumens/watt; for 2000°K explosion temperature, the luminous efficiency would be 8 lumens/watt.*** Thus, at 15 feet the total radiation from the explosion would be

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*M. A. Ellison, The Sun and Its Influence, The Macmillan Company, New York, 1955, p. 219.

**See J. R. Walsh et al., "Description of Instrumentation and Procedures for the Velocity of Sound (Grenade) Experiment," SCEL Eng. Report E-1140, April, 1954.

***F. W. Sears, Principles of Physics III, Optics, Addison-Wesley Press, Inc., Cambridge, Massachusetts, 1947, p. 280, Fig. 12-3.

0.172 watt/cm^2 (3000°K explosion), or
0.6 watt/cm^2 (2000°K explosion).

Assuming that perhaps only 50% of the radiation is received by a device with area of 1 cm^2, the energy received would be

0.086 watt/cm^2 (3000°K) or
0.3 watt/cm^2 (2000°K).

For 3000°K, approximately 75% of the radiation lies in the range 8,000-25,000A, about 25% in the visible. For 2000°K, approximately 80% of the radiation lies in the range 8,000-25,000A, about 20% in the visible.

We can, therefore, prepare the following table for the signals received from the sun and the explosion in the two different devices.

	Visible 3,400-6,000A (watts/cm^2)	Infrared 8,000-25,000A (watts/cm^2)
Explosion (3000°K)	.021	.065
Explosion (2000°K)	.06	0.24
Sun	.063	.053

These data, based on the above assumptions, favor the use of the infrared-sensitive device, for with it the estimated signal from the explosion is equal to or greater than the signal from the sun, whereas, in the visible, the signal from the explosion would be less than or equal to the signal from the sun.

Accordingly, it has been decided to use the Kodak Ektron infrared detectors. These lead-sulfide photoconductive cells are characterized by their insensitivity to microphonics and by a short time constant (under 1 msec). Experiments are being conducted to test the detectors under illumination intensities of the order of 2 lumens/cm^2. The required illumination is obtained at a short distance (4 cm for 2 lumens/cm^2) from a 32-cp automobile lamp. When operated at its design voltage, the filament temperature of these lamps is approximately 2800°K, which lies in the anticipated range of the temperature of the explosion. The experimental results to date confirm the calculated expected signal amplitudes for these photocells.

The useful photosensitivity of the Ektron detectors ranges from 2,500A to 35,000A, with maximum sensitivity at about 20,000A. The actual sensitivity-vs-frequency curve is not available. To minimize the possible signal from the sun, as discussed previously, an infrared filter will be used. The filter (Polaroid XRX-20 or XRX-40 plastic filter) has a relatively sharp cutoff at 9,000A and transmits more than 80% of the radiation in the range 10,000-25,000A.

In order to improve the probability of obtaining an unambiguous signal from the explosion, it has been decided to use three photoelectric pickups located symmetrically around the circumference of the rocket. The photocells will be oriented toward illumination coming from the region directly ahead of the rocket. With this arrangement, considering the almost vertical orientation of the rocket and the low zenith angle of the sun at the latitude of Fort Churchill, the spurious signal from the sun is rather unlikely; and if it occurs, only one photocell can be exposed to sunlight at any particular time. The flash from the explosion is expected to reach all three photocells. Even if the explosion does not occur directly ahead of the rocket, and one photocell is exposed to the very first stages of the fireball and other photocells receive the signal only after the diameter of the fireball has grown to several meters, the time lag would be of a very few milliseconds only. Thus, the time of the explosion can be established by the first of three almost coinciding signals from the three photocells (or two signals if one cell is illuminated by the sun).

2.5 THE TELEMETER CIRCUIT

The DOVAP single-channel telemeter will be used. The input signal will be 0-5 volts into an impedance of about 100 k. The photocell associated circuit is tentatively aimed at providing an output in the range of 0 to +4.5 volts. The circuit will be additive, i.e., will provide signals of 1.5, 3.0, and 4.5 volts depending on whether one, two, or all three photocells are illuminated. Moreover, the telemeter circuit will provide a signal of an additional 0.5 volt as an indication that the grenade has moved within its tube. A four-resistor additive network is planned, which would require the signal V_p (see Fig. 3) to be at least 4 x 1.5 = 6 volts (on the assumption of unity gain of the cathode follower) and the signal from the grenade-moved indicator to be at least 4 x 0.5 = 2 volts.

2.6 PROGRAMMING FOR MIDAC

The MIDAC program for the process of spin correcting the DOVAP cycle counts has been checked out. A test run, using data from the SC-31 sphere experiment, was made and the correct results were obtained. Another test run is being made on the program for calculating position from spin-corrected DOVAP data.

3. SAMPLING

The major effort on sampling during the quarter was expended in preparing and testing bottles and preparing parts and instrumentation for

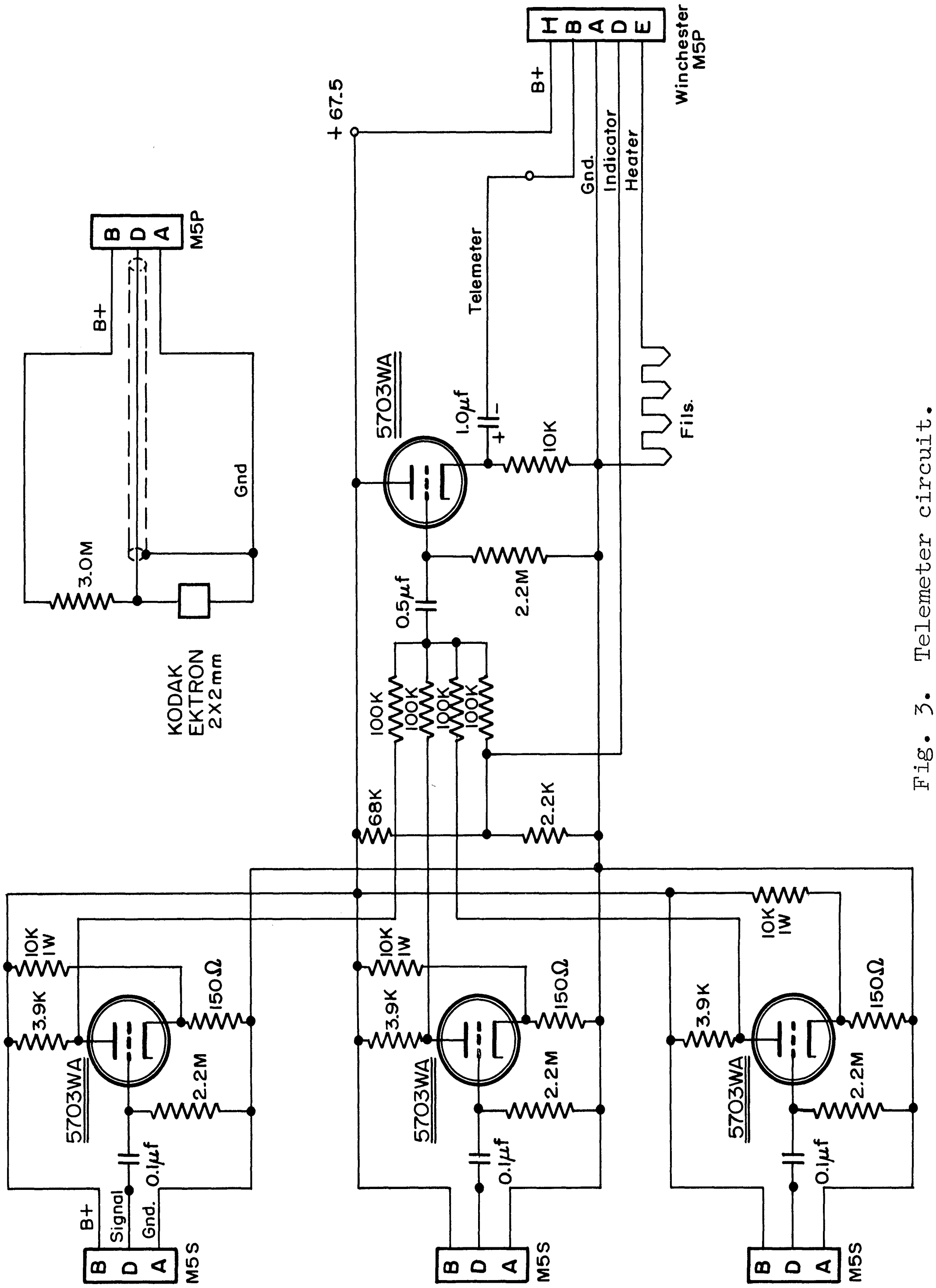

Fig. 3. Telemeter circuit.

sampling Aerobees SC-34 and SC-35 scheduled for firing in August.

3.1 ROCKET INSTRUMENTATION

The general configuration of the sampling rocket was described in a previous report.* Two minor modifications of the original plans were made: first, the DPN-19 cutoff receiver at the request of WSPG Flight Safety Section; second, the parachute section was vented rather than pressurized. It was felt that atmospheric pressure in this unit might give a violent ejection of the parachute at altitude with possible damage to the parachute.

It is planned to load the nose cone of the rocket so that peak altitude will be 260,000 feet. At this altitude the ambient pressure of 9.3 μHg should yield a sample of approximately 0.098 cc NTP, which sample would give three determinations on the new analyzer.

Two complete identical instrumentations were prepared for Aerobee rockets SC-34 and SC-35. Each included three sampling bottles, timer for operational sequence, DPN-19 beacon for trajectory data and monitor of sample-bottle opening and closing altitudes, cutoff receiver, parachute and ejection mechanism, and spring separation mechanism for separating the instrumentation section from the tank section.

The program planned calls for the following sequence of events** from take-off:

x-0 sec	Rocket fired.
x+2.5 sec approx.	Booster separates; timer starts; cutoff receiver in operating condition.
x+50 sec	Cutoff receiver off.
x+95 sec	Instrument section separates from tank section.
x+150 sec	$C^{14}O_2$ contaminant released.
x+155 sec	Bottles open; beacon signal off.
x+160 sec	Bottles close; beacon signal on.
x+200 sec	Parachute ejection; tail blow (in event of failure of separation between tank section and instrumentation).

The parachute assemblies to be used on SC-34 and SC-35 will be similar to those used on previous sampling Aerobees. The parachutes are of 8-foot reinforced white nylon. There will be no special deployment such as drag chutes or pull-out sleeve containers.

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*Univ. of Mich., Eng. Res. Inst. Final Report 2232-18-F, January, 1955.

**Final times will be selected after a final trajectory has been predicted at WSPG.

Radioactive carbon dioxide will be released within the instrumentation section 5 seconds before bottle opening. Four 1-1/4-inch vent holes were cut as far back on the instrumentation section as possible (about 41 inches from the intake). This arrangement was calculated to have a time constant of less than 1 second. It is believed that residual air will be flushed out by the $C^{14}O_2 + CO_2$, and any remaining gas in the instrument section will then be mixed with $C^{14}O_2$. The relative contamination of the upper-air sample will be estimated from radiation-counter checks of the sample. The nose cone is vented to give an extremely small evacuation time constant and will exhaust so rapidly that it is not a factor. The time constant of evacuation of the vented parachute and parachute section is difficult to calculate. Extra large vents were used. The parachute section being 48 inches from the intake tubes, it is thought that serious contamination is unlikely.

3.2 SAMPLE BOTTLES

Prior to the final preparation of the rocket instrumentation a cold-closure bottle design had been developed. Several bottles of the new design were made and tested. These proved easy to close and handle. Some were retained for rocket sampling. Later, however, dimensional changes in the final rocket design necessitated the fabrication of all new bottles for the rocket. Parts were machined for ten bottles, four with 2-inch intake tubes and six with 1-inch intake tubes. Although no difficulties had arisen earlier in sealing the bottles with the cold-closure method, it was nearly impossible to obtain a seal on the newly constructed bottles. Considerable investigation brought out the following points:

a. axis of the solder threads was not at right angles to the seat,
b. axis of the nut thread was not at right angles to the seat,
c. disk seal was not uniform in thickness, and
d. copper gasket was too thin.

These items were corrected by making new parts and remachining where possible, but minute leaks were still encountered in the ends.

Vent holes were drilled in the collar near the seal point to facilitate helium-leak checking. The bottles still leaked but apparently not at the cold-closure seals. To assure ourselves on this point, the cold-closure seal was glyptal sealed. The leak continued. Point by point, all soldered joints were checked in this manner. Finally, it was found that the 2-1/2-inch diam by 1/8-inch-thick mild-steel plates at the ends of the bottle were causing the trouble. Check of a number of these plates gave the same result. It is believed, therefore, that certain types of high machinability still are slightly permeable to helium. The leaks found were of the order of 10^{-7} cc/sec.

New disks were made to replace some faulty ones and some old disks were tinned on the inside with 60-40 soft solder. With these modifications the bottles checked vacuum tight on the helium-leak detector.

Originally, it was planned to release ground air in each evacuated upper-atmosphere sample bottle before flight. This gas would then be extracted and examined for separation before using the bottle. However, it was only possible to obtain checks on E-1 and B-25 in our laboratory. Dr. Paneth had previously checked B-17 and B-18. Further checks of the flight bottles will be made after analyses of the upper-atmosphere air.

To correlate the sampling results of the new cold-closure bottles with the old type silver-soldered closure, one of the old-type bottles will be flown on each rocket.

In several bottles, gas was given off by the Philips gage after seal-off from the system. This effect had not been noted on bottles previously assembled. The bottle could be sealed off from the system for several days. The internal Pirani would show no change of pressure during this period. Yet, when the Philip gage was operated, the pressure in the bottle built up to as much as 1 or 2 μHg. This was checked on the bottle Pirani. If the gage was allowed to operate for a sufficient time, a clean-up would be indicated; and, after operation for several hours, the bottle would again clean up to a good vacuum. The Philips gage was allowed to outgas for 20 minutes to 1 hour before seal-off from the vacuum system so the source of this gas is not apparent.

Further difficulties were encountered in obtaining consistent seals on the 2-inch intake tubes. Earlier, a series of tests seemed to indicate that 7.5 grams of black powder was satisfactory for sealing. Later, even increased quantities failed to yield satisfactory results. In an attempt to determine the cause of failure, a Fastax camera was used to photograph the sealing action at 5000 frames per second, using a 9-gram charge. This seal was perfect. Further tests with this charge were satisfactory. No measurable quantity of gas was emitted during the sealing of the bottles tested.

It was thought desirable to include, inside the bottles, some means to monitor bottle pressure after recovery to insure that bottle pressures are safe for the analyzer, and to keep a record of bottle pressures until analysis. For this purpose a simple Pirani was installed on the extraction end of all new-type bottles. It consisted of a 0.0001" x 2.5-mil nickel ribbon about 1.5 inches long. The wire was attached to a 0.4-inch brass post at one terminal and a Kovar-to-glass—feed-through insulator at the other. Both the post and the insulator were soft-soldered in place on the steel disk. Since these were used only as an indicator, they were not calibrated. However, changes of pressure of 0.1 μ near the best vacuum point of roughly .001 μ were readily noticeable.

Figures 4-9 show various features of the sampling instrumentation as follows:

Fig. 4 shows three bottles mounted in position. In these rockets the bottles were inverted; that is, the intake tubes face downward.

Fig. 5 shows the springs which separate the bottle section from the tank section of the rocket.

Fig. 6 shows the parachute canister and pyrotechnic piston charges for separating the nose cone and releasing the parachute.

Fig. 7 shows, in an inverted position, the intake tubes with the pyrotechnic openers and yokes. The 2-inch tube is at the left.

Fig. 8 shows the timer and cutoff receiver.

Fig. 9 shows the $C^{14}O_2$ contaminant container and automatic opener.

4. RESEARCH INVESTIGATIONS

4.1 MISSILE TRAJECTORIES

A brief research note,* "On the Motion of a Projectile in the Atmosphere," has been accepted for publication by Zeit für angewandte Math. und Phys. A summary of its content is given here.

The theory of flight of a ballistic projectile in a resisting medium dates back to Newton. Since then various approximations for the flight parameters which are involved in the equation of motion have been used. The most important ones are the aerodynamic-drag coefficient of the projectile and the ambient-air density. The former is usually considered as a function of Mach number, the latter as a function of the altitude.

The theory of flight of a sounding rocket during the free-flight period deals essentially with the same problem as that of a ballistic projectile. The only difference is that the air-density factor is more critical because of the extreme altitude attained by the former; hence, a more realistic approximation to the ambient-air density is necessary. In view of the multiplicity of parameters involved, the equation of motion of the projectile (or rocket) is generally treated either by a laborious method of step-wise integration or by the analog-computer technique.

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*V. C. Liu, Univ. of Mich., Eng. Res. Inst. Report 2387-14-T, 1956.

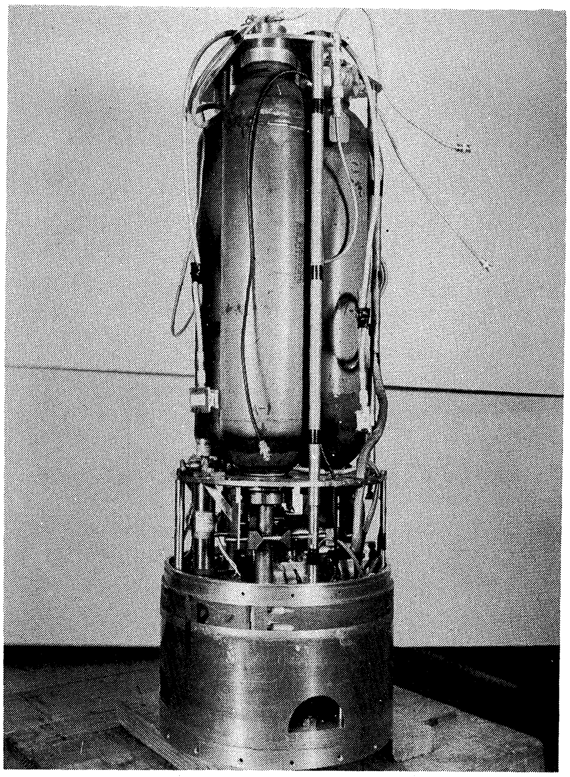

Fig. 4. Bottle assembly.

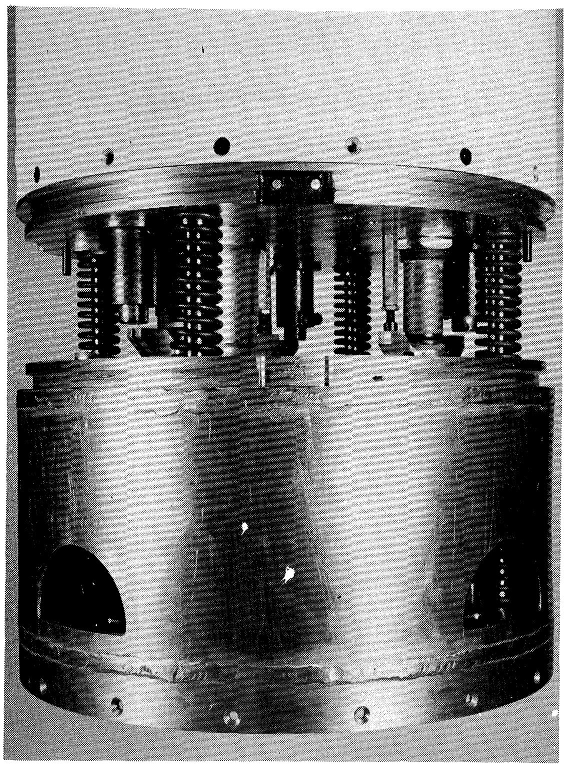

Fig. 5. Spring ejection system.

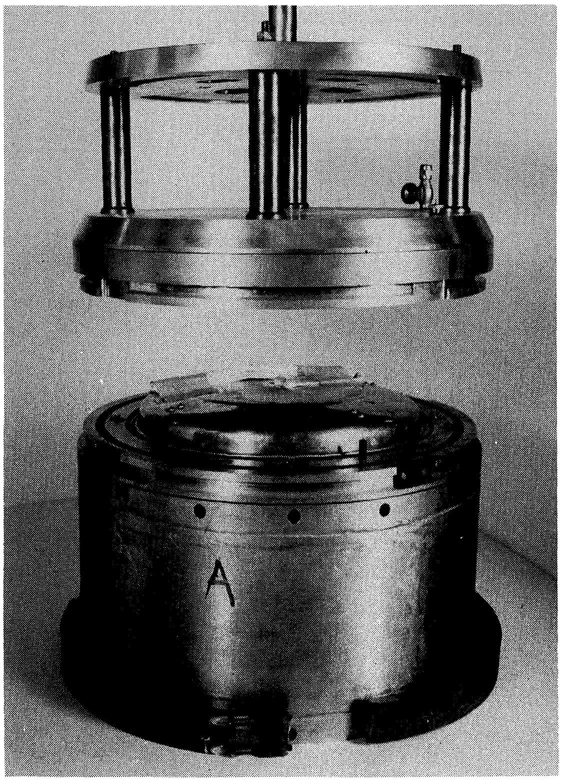

Fig. 6. Parachute section.

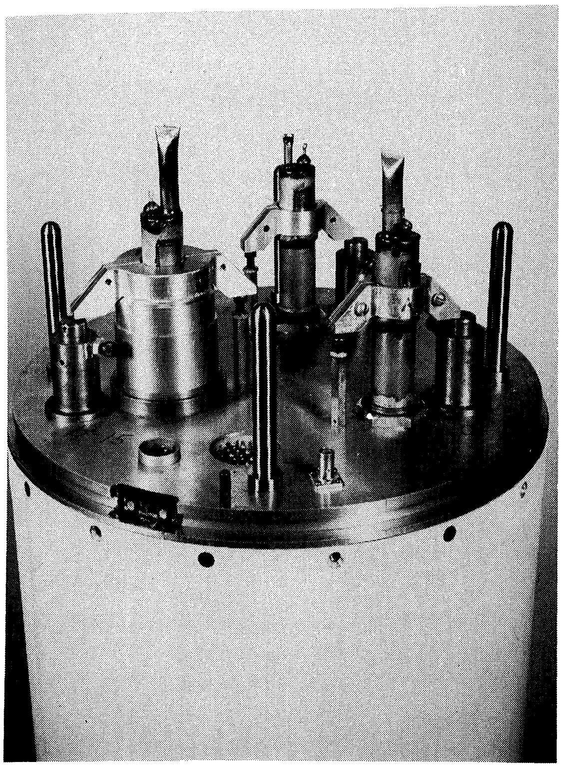

Fig. 7. Bottle intake tubes and openers.

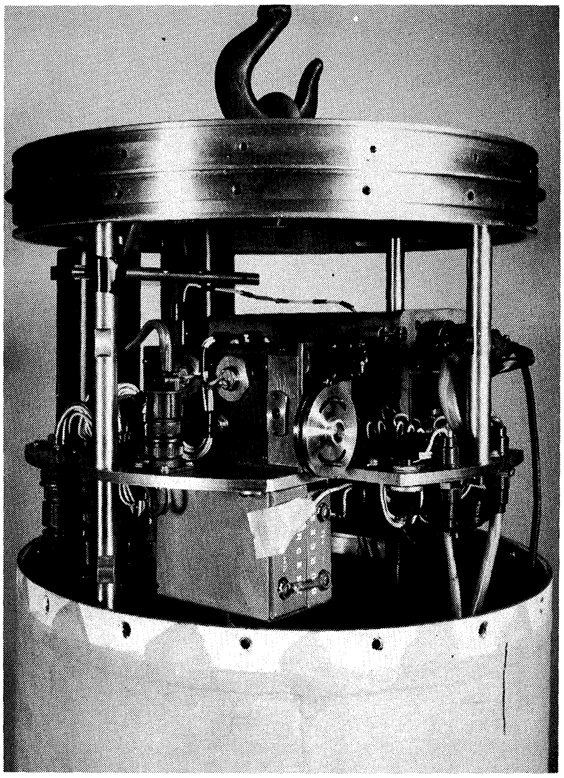

Fig. 8. Timer and cutoff receiver.

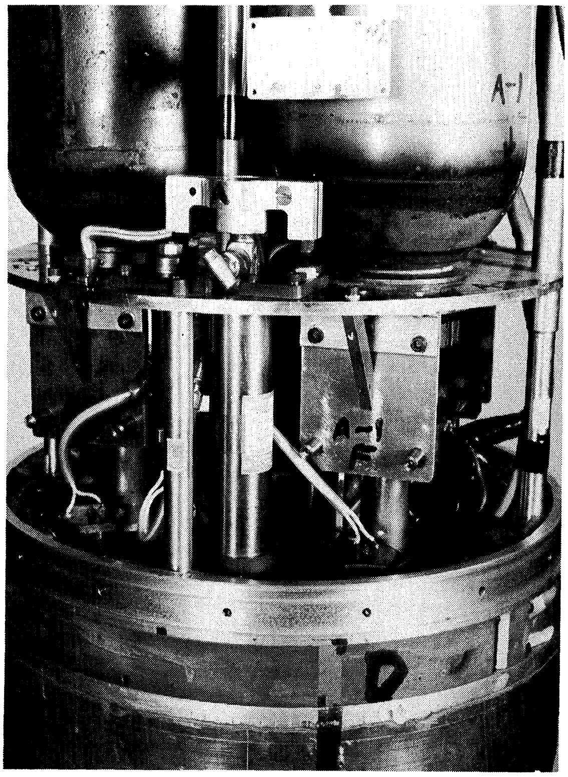

Fig. 9. $C^{14}O_2$ contaminator and opener.

The development of the falling-sphere experiment of measuring ambient temperature in the upper atmosphere stimulates new interest in the ballistic-trajectory problem.

In this note, new approximations to the aerodynamic-drag coefficient and ambient-air density, which are believed to be more accurate than previous representations,* are introduced. For the drag coefficient, C_D, a general semiempirical expression has been established through the use of aerodynamic theory, as follows:

$$C_D = C_0 + C_2M^2 + C_3M^{-2} ,$$

where C_0, C_2, and C_3 are empirical constants to be prescribed for each Mach-number range. The ambient-air density is prescribed as an exponential function of altitude interval.

The equation of rectilinear motion of a projectile thus obtained is highly nonlinear. Therefore, classical methods of solution fail to apply. After a unique transformation of variables, this equation becomes a linear equation of the confluent hypergeometric type. Solutions to the confluent hypergeometric equation are available, and some of the solutions are well tabulated.

A brief discussion of the application of this projectile theory to the problems of flight analysis of a sounding rocket and also the ambient-temperature calculation of the sphere experiment were included in the ERI report.

4.2 RAREFIED-GAS DYNAMICS

Work was started on the development of a physical theory of rarefied-gas flow, with particular application to Pitot-tube—pressure calculations and related problems.

5. LABORATORIES VISITED

During this quarter the following places were visited:

National Northern Fireworks Ordnance Corporation
Picatinny Arsenal
UARRP, SCIGY, and the Satellite Committee on
Internal Instrumentation (Washington, D. C.)

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*E. J. McShane _et al._, _Exterior Ballistics_, Univ. of Denver Press, 1953, p. 742.

6. FUTURE PROGRAM

6.1 GRENADES

Assembly of the grenades for use at Fort Churchill will be completed during the next quarter. Tests of completed grenades will be run both alone and in conjunction with the rocket instrumentation and nose-cone structures. Grenades and grenade structures will be shipped to Fort Churchill for the November pre-IGY firings.

6.2 ROCKET INSTRUMENTATIONS

Four complete rocket instrumentation sections will be constructed, complete with all electrical and electronic equipment, and inspected. A testing program, culminating in the test of two of these instrumentation sections as part of the final test of the complete rocket assembly (firing live grenades), will be carried out at National Northern's test site in September, 1956. The completed instrumentation sections will be shipped to Fort Churchill for the pre-IGY firings in November.

6.3 DATA REDUCTION

The data-reduction procedure is now almost completely checked out, except for the calculation of temperatures from position and time data (this will be done according to Signal Corps procedures).

6.4 UPPER-AIR SAMPLING

The upper-air samples obtained on the two Aerobee flights at WSPG (White Sands Proving Ground) will be analyzed.

7. ACKNOWLEDGMENT

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