ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN

# ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

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# ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

Department of Aeronautical Engineering

## 1. INTRODUCTION

This is the second in a series of quarterly reports on Contract No. DA-36-039 SC-15443 describing high-altitude meteorological experiments being carried out by the University of Michigan for the Meteorological Branch of the Signal Corps. This program is a continuation of one which was carried out between July 1946 and August 1950 on Contract No. W-36-039 sc-32307 and from August 1950 to December 1951 on Contract No. DA-36-039 sc-125. For background material the reader is referred to the final reports on these contracts.

## 2. SUMMARY

The work during the second quarter of 1952 was devoted entirely to the preparation and firing of sphere Aerobee SC-23 on May 14th and sampling V-2 59 on May 20th.

## 3. SPHERE AEROBEE SC-23

The proposed redesign of the sphere and ejection system for SC-23 was discussed in the previous report. A new sphere of .020-inch thick nylon-impregnated nylon fabric was made by the Goodyear Tire and Rubber Co. Essentially the same gore patterns were used as in the rubberized spheres, but only a single thickness of fabric was used, and the sections were joined by heat-sealed lap joints. The valve and doors shown in Fig. 10 of the previous report were fabricated. The latter were sealed to the fabric of the sphere by means of a thermosetting plastic joint made under pressure. The inner cylinder and doppler structure were also completed and assembled in the sphere. Measurements made on the completed sphere are summarized as follows:

Sphericity: Any diameter within ±1 per cent of the mean.

Elasticity: Change in diameter less than 1 per cent for change in pressure from 1.0 psig. to 2.5 psig.

Smoothness: Discontinuities in the fabric about .010-in. amplitude. Discontinuities at the door-fabric joints about .030-in. amplitude.

Leakage: .08 psi per hour for sphere. 1.1 psi per hour for inner cylinder.

Weight: Total - 48.5 lbs.

C.G.: 2-1/8 in. from center, toward doppler end.

Color: Yellow; one 90° section, red.

Upon completion, the sphere and the outer cylinders were taken to the high-altitude chamber of the Aero Medical Laboratory at Wright Field for an ejection test. The test was similar to the one performed on the rubberized sphere except that the doppler unit was not included. The inner cylinder was pressurized to 50 psig and the sphere to 6.5 psia. The chamber was then pumped to 100,000 feet, and the sphere released. The removable half-cylinder came off with considerable force, and the sphere was ejected easily without damage. It tumbled 180 degrees before striking the floor. It was observed to inflate in 10 to 20 seconds, and it remained inflated until the chamber pressure was increased to 1 atmosphere several minutes later.

During the time the sphere ejection tests were being performed, the doppler unit was completed and taken to the Ballistic Research Laboratory for final modifications and test. A crossed-loop antenna system was mounted on one door of the inner cylinder. Each antenna was fed by a co-ax running up the side of its respective loop. The connections to the loops were made through variable condensers for adjusting the impedance match and loop balance. The antennas were tuned by a cut-and-try process to allow for the presence of the inner and outer cylinders. Once accomplished, the tuning was found to be very stable. Field strength measurements showed that approximately the theoretical patterns for a small loop were obtained and that with a signal of about 0.5 watt into the 74-mc sphere transmitting antenna, a signal of about 30 microvolts could be expected on the ground from 80 miles. The doppler ground receivers require about 0.5 microvolts.

Some difficulty was experienced with oscillations in the doppler transponder caused by feedback of 37 mc from the 74-mc transmitting antenna to the 37-mc receiving antenna. A 37-mc trap in the input to the transmitting antenna eliminated the difficulty. The only other modification required in the transponder was to lower the screen voltage of the output tube to lengthen its life.

Upon completion of the ejection and doppler tests the equipment was shipped to White Sands for the firing scheduled on 14 May. Figs. 1 to 7 show the major components of the equipment. The complete, inflated sphere is seen in Fig. 1. Fig. 2 shows the loop antennas mounted on the lower end plate of the inner cylinder. The inflation valve is mounted on the upper end plate. The inner cylinder is wrapped with .040-inch diameter Fiberglas cord which is covered by protective tape. Figs. 3 and 4 are two views of the doppler unit; and Figs. 5, 6, and 7 show respectively the empty fixed half-cylinder, the sphere packed in place, and the assembled sphere section of the Aerobee. The

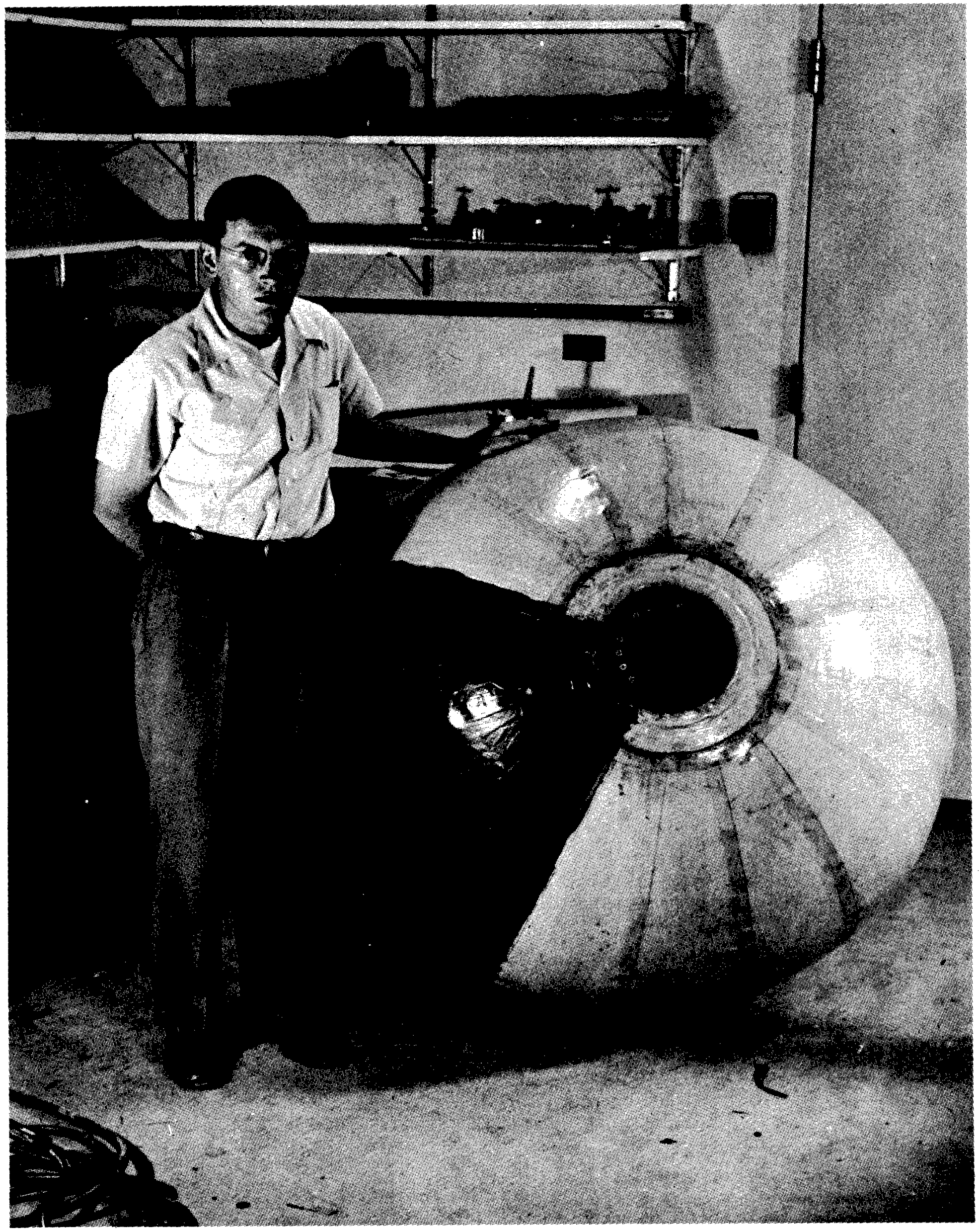

Fig. 1. Inflated Sphere, SC-23.

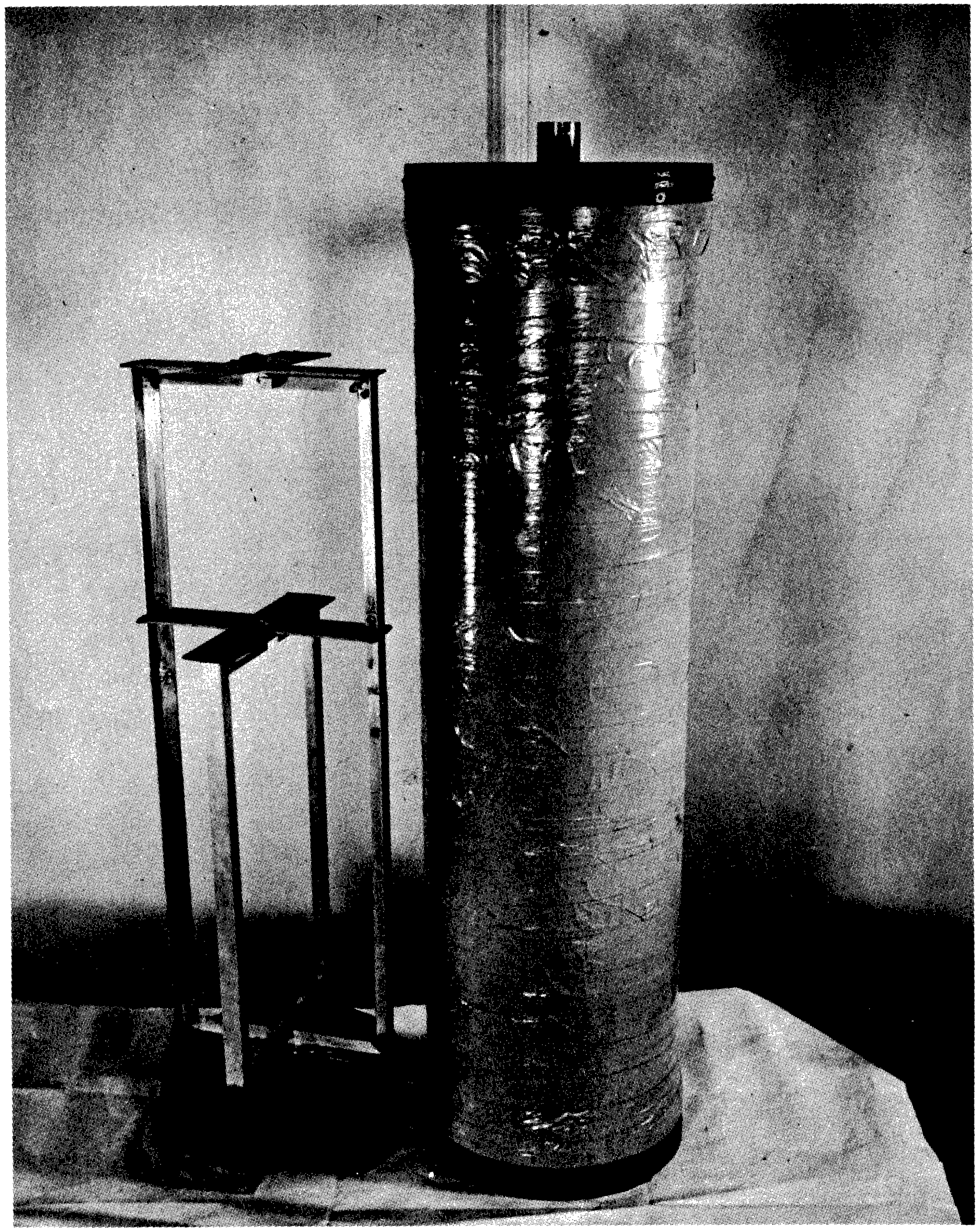

Fig. 2. DOVAP Antennas, Inner Air Cylinder, SC-23.

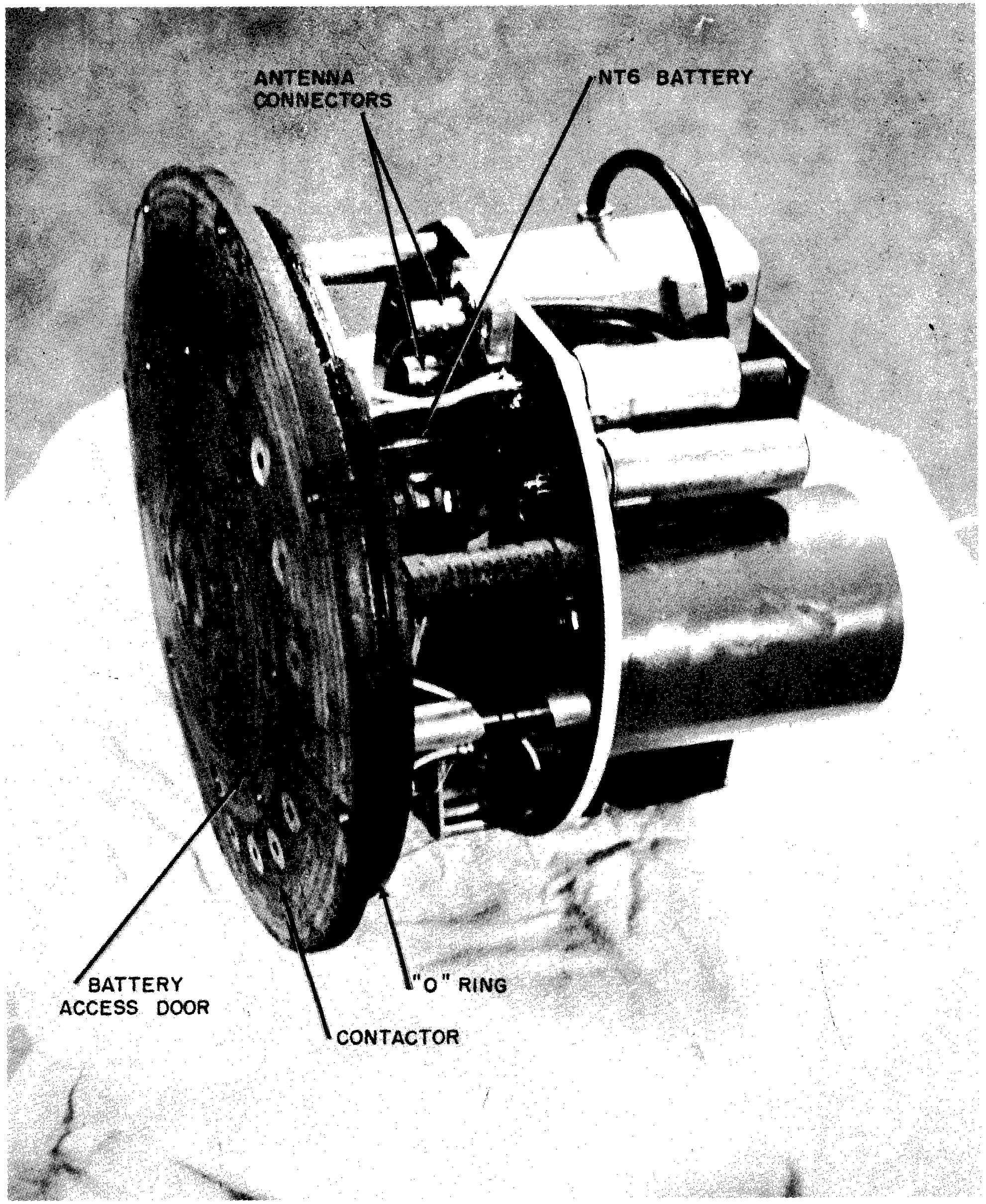


Fig. 3. DOVAP Transponder, SC-23.

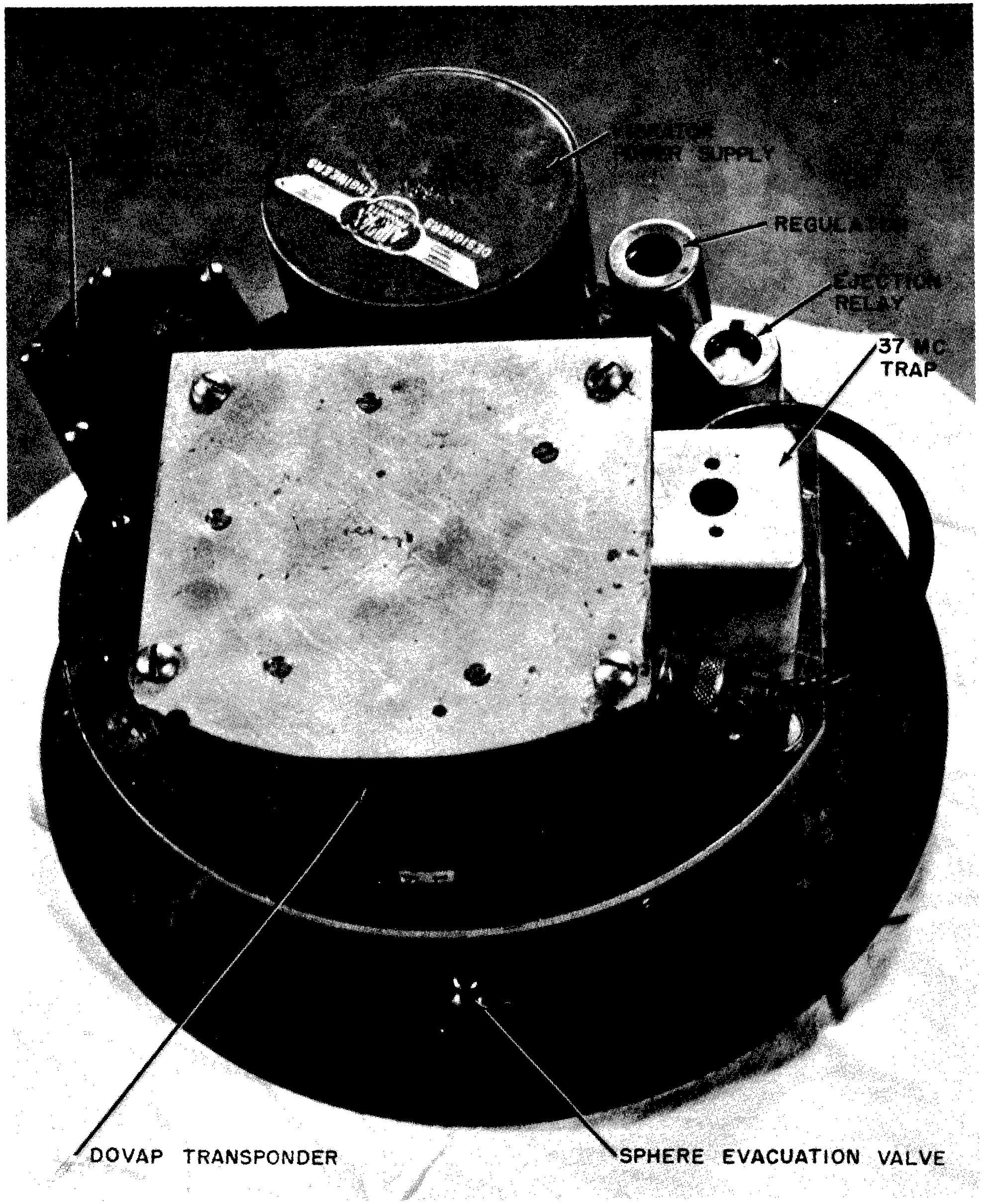


Fig. 4. DOVAP Transponder, SC-23.

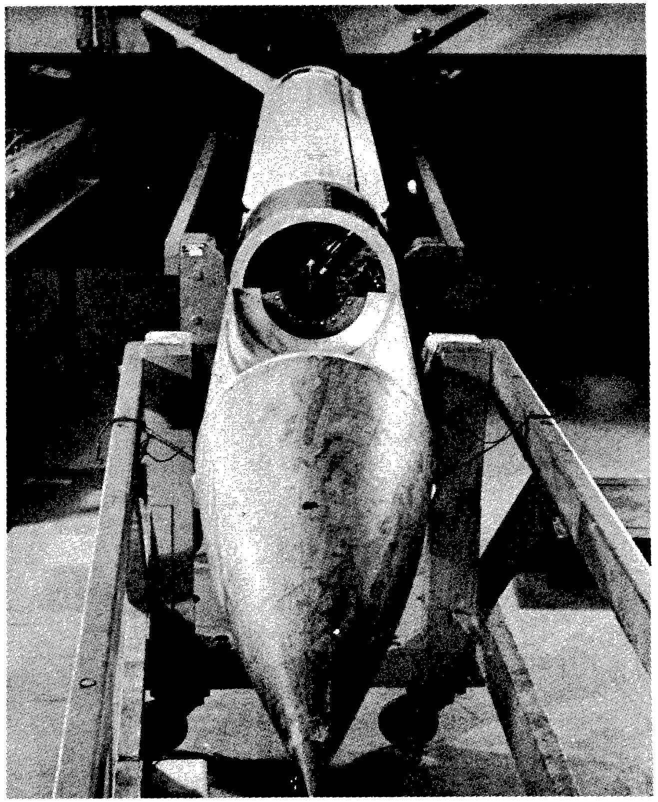

Fig. 5. Sphere Compartment, SC-23.

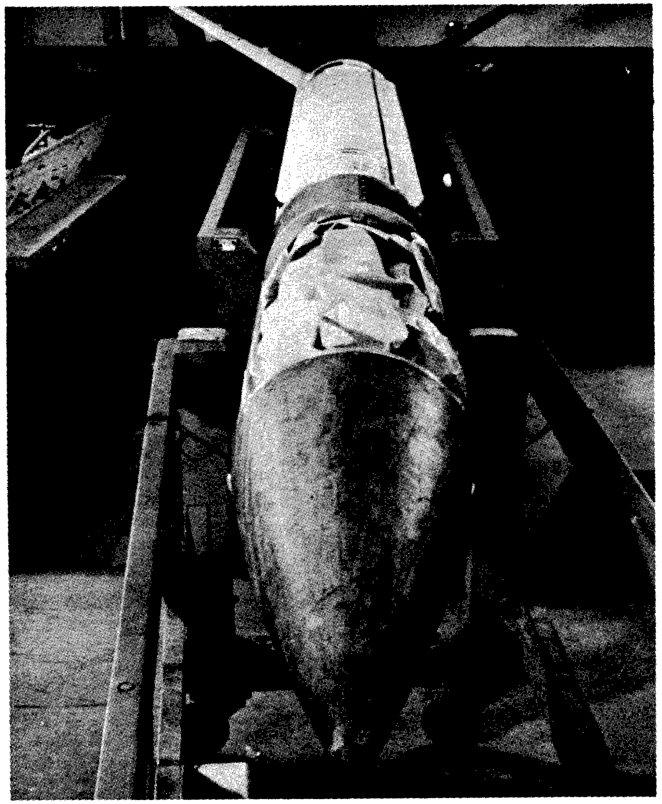

Fig. 6. Sphere Packed in Place, SC-23.

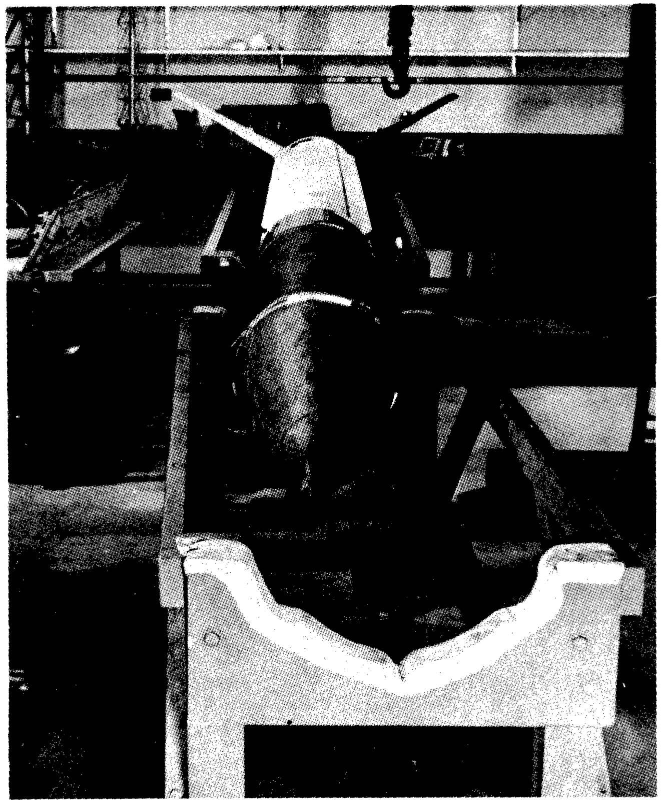

Fig. 7. Removable Half-Cylinder In Place, SC-23.

outside Fiberglas cord wrapping is not shown. The buttons on the sphere access door seen in Figs. 1 and 3 make electrical contact with the contactors seen at the base of the sphere compartment in Fig. 5 and carry the various circuits to the sphere.

The hangar and launching tower operations were completed without difficulty. The launching, which was scheduled for 1800 hours MST, occurred at 1815. The gross launching weight was 1067 pounds. With this weight the predicted peak altitude based on the performance of all previous Aerobees was 365,000 feet, and based on the performance of recent Aerobees 400,000 feet. The booster performance was somewhat above that of recent Aerobees and the velocity at 36 seconds, 3440 feet per second, sufficient to take the missile above 400,000 feet if the same thrust continued. However, burning ceased at about 36 seconds so that the peak altitude was only 241,000 feet MSL.

Peak time according to Askania tracking was 142.5 seconds. Peak time as indicated by doppler was at about the same time, and at 143.9 seconds the sphere was ejected by doppler command. A slight discontinuity in the doppler record indicated that ejection took place when the command was given, and the ejection was observed by Telescope 5. In the T-5 film the sphere is apparently inflated and falls with some tumbling until about 280 seconds when it is seen to be no longer spherical and is tumbling rapidly. The doppler signals received by ten receivers at four double stations and two single stations are excellent from take-off until 287 seconds when all doppler signals cease. Upon recovery of the sphere it was found that the doppler unit was missing. It was thought that the doppler unit might have come off when the doppler signals ceased. A careful re-examination of the T-5 film showed that this was indeed the case; a small object is seen to detach itself from the sphere at 280 seconds.

The above sequence of events was later verified by the telemeter record of the pressure gage within the sphere. See Fig. 8. Although the accuracy is poor, the following events can be clearly picked out:

0- 30 seconds - pressure drops as rocket ascends, and sphere expands inside outer cylinder.

30-145 seconds - sphere fills outer cylinder and pressure remains constant.

145 seconds - ejection occurs and pressure drops.

145-150 seconds - pressure rises as sphere inflates.

150-270 seconds - pressure drops slowly due to small leak.

270-280 seconds - doppler door loosens, pressure drops to ambient.

280 seconds - doppler unit detaches, signals cease.

Although the nominal pressure of the sphere was to have been 2.5 psia, tests showed it to be still rigidly spherical at 1.0 psia.

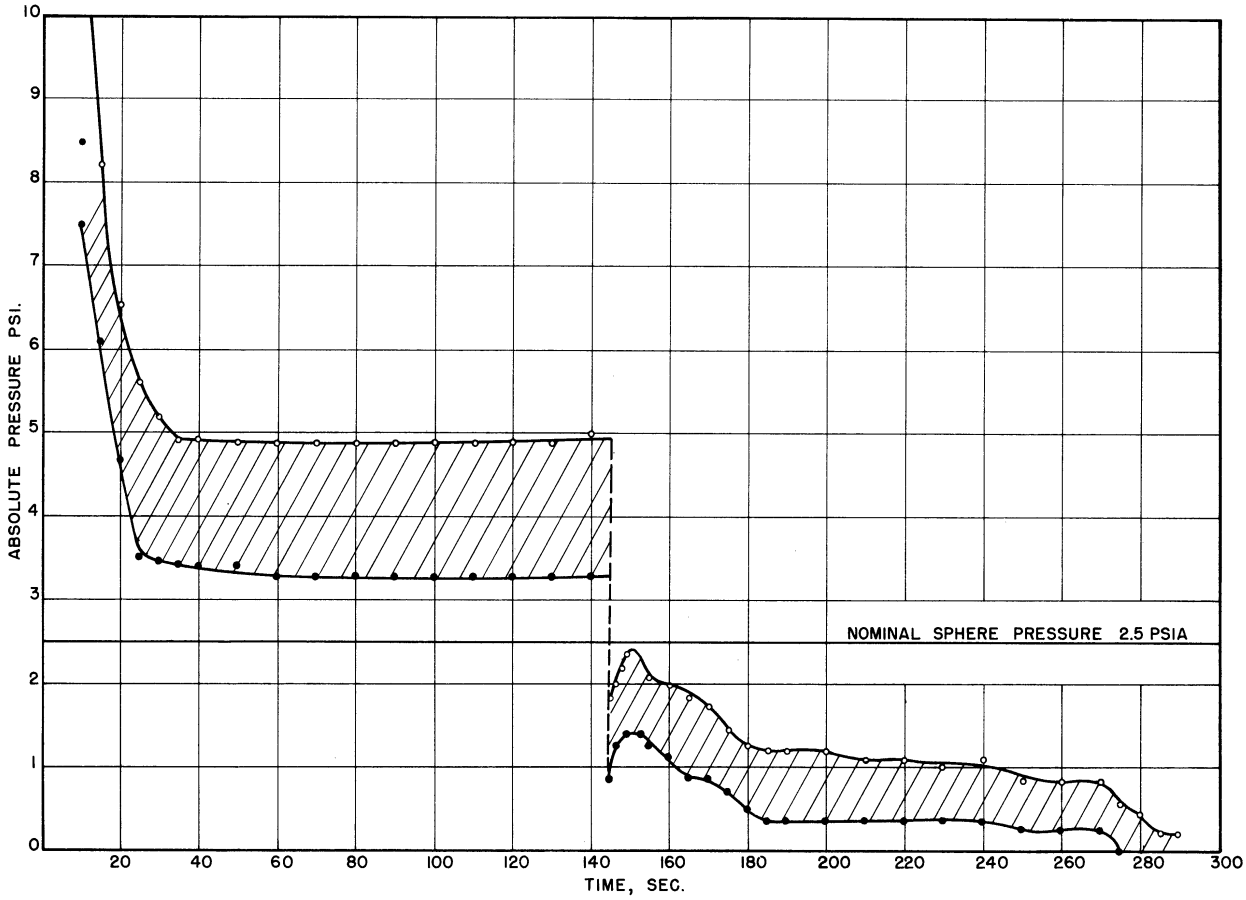


Fig. 8. Sphere Pressure In Flight, DOVAP Telemeter, SC-23.

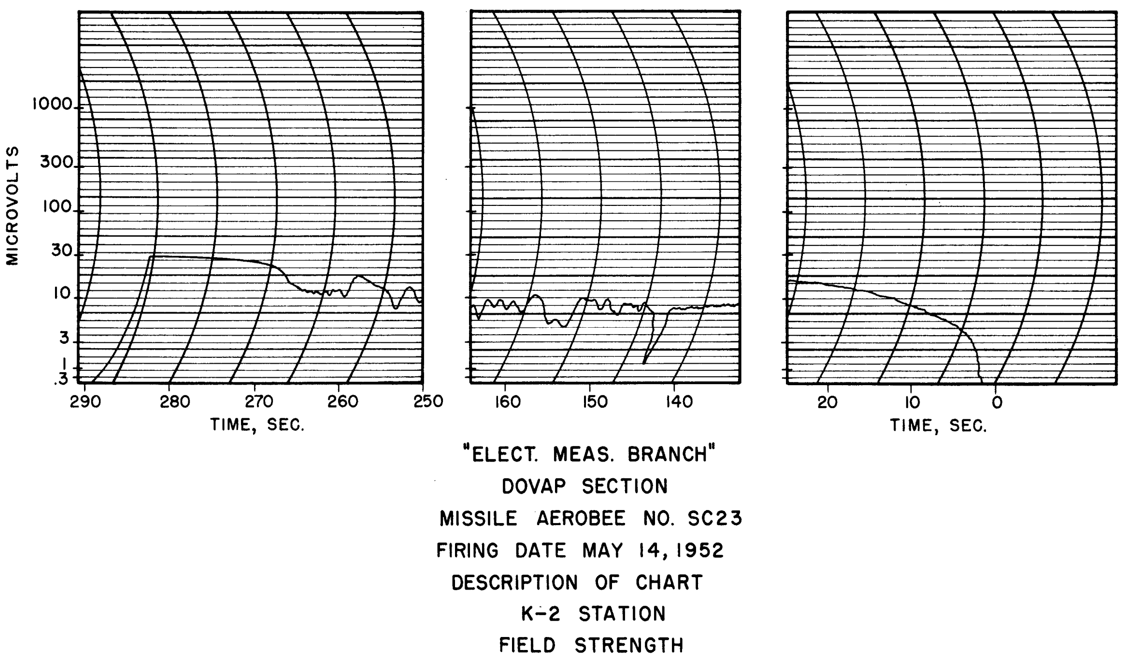


Fig. 9. Signal Strength Record, SC-23.

The sphere and main body were recovered on 9 June. Fig. 10 shows the impact site of the sphere. A preliminary investigation of the missile did not reveal the cause of the short burning time.

Several values of $C_D$ at Reynolds numbers and Mach numbers within the range of the sphere experiment have been provided by NOL since the previous report. They are as follows:

| Shot | $C_D$ | M | Re x $10^{-4}$ |
|---|---|---|---|
| 389B | 0.9570 | 3.26 | 8.7 |
| 489C | 1.0026 | 3.00 | 4.047 |
| 490A | 1.0219 | 2.39 | 3.15 |
| 490B | 0.9850 | 2.45 | 6.710 |
| 490C | 0.9864 | 2.70 | 7.115 |
| 491A | 1.9332 | 2.27 | 3.083 |
| 491B | 0.9952 | 2.19 | 5.593 |

In all, 51 determinations of $C_D$ for Reynolds numbers from 84 x $10^{-4}$ to 0.26 x $10^{-4}$ and Mach numbers from 4.7 to 0.82 have been made by NOL. These are sufficient to perform a satisfactory reduction of the sphere experiment data.

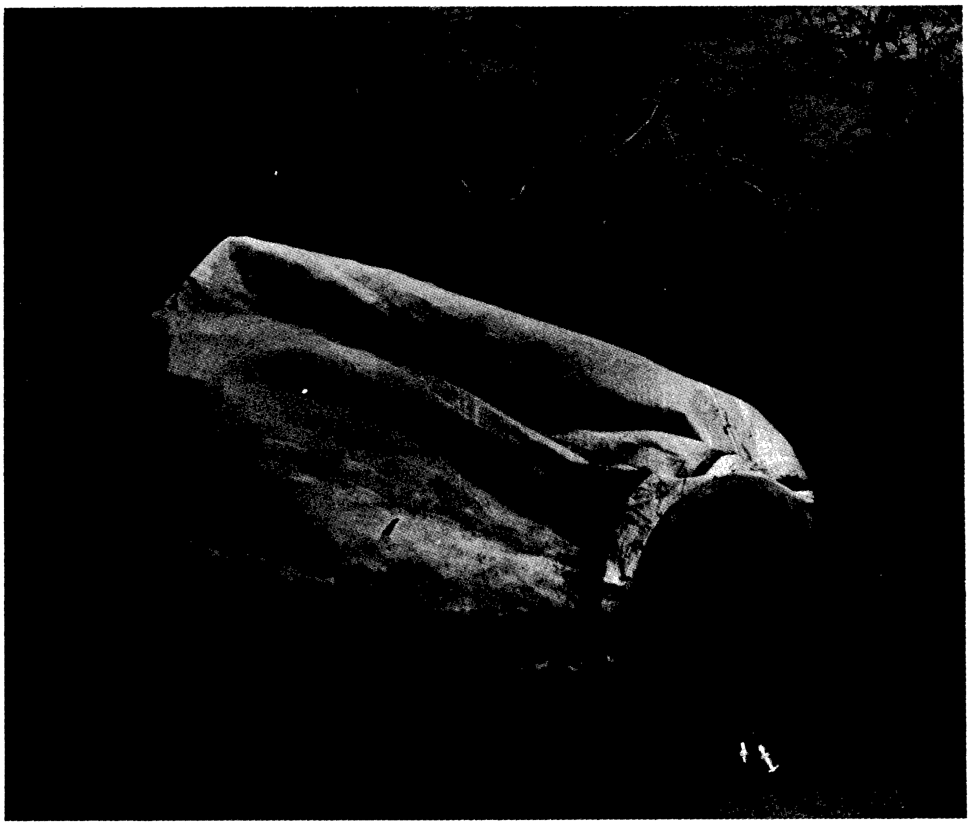

Fig. 10. Sphere Impact, SC-23.

## 4. SAMPLING V-2 59

Preparation of the equipment for V-2 59 was continued. The ejectable nose cone was fitted with a Jato and static fired at the Willow Run Aeronautical Research Center. A thrust-time measurement was made by taking motion pictures of the deflection of a calibrated spring. Approximately the same performance as in the Aerobee cone was obtained; that is, a net thrust of 530 pounds for 0.7 seconds. The test set-up is shown in Fig. 12.

Three silicone-rubber-coated Fiberglas parachutes were received from Aerojet Engineering Corporation and forwarded to Holloman Air Force Base for drop test. The chutes, which were 8-foot reinforced ribbon FIST type, were dropped from 6,600 feet above ground level with 120-pound total loads. They deployed and descended with good stability in about the same time as previous nylon chutes and showed no damage.

An operational check of the timer and associated circuit was completed satisfactorily. Preparation of the flight and spare bottles was completed. The bottles were not all prepared in the same way. Some carbon-steel and some stainless-steel bottles were used. Some bottles were buffed using the technique described in the previous report, and some were not. A summary of the bottles flown is given in Table I. In general, it was found that the stainless-steel bottles pumped down faster but returned to a higher equilibrium residual pressure after aging than the carbon-steel bottles. In both cases, however, the residual pressure was of the order of a few hundredths micron Hg so that either type was satisfactory for flight. It was also found that bottles buffed using the technique described in the previous report also reached a higher equilibrium residual pressure after the final buffing operation. Since this

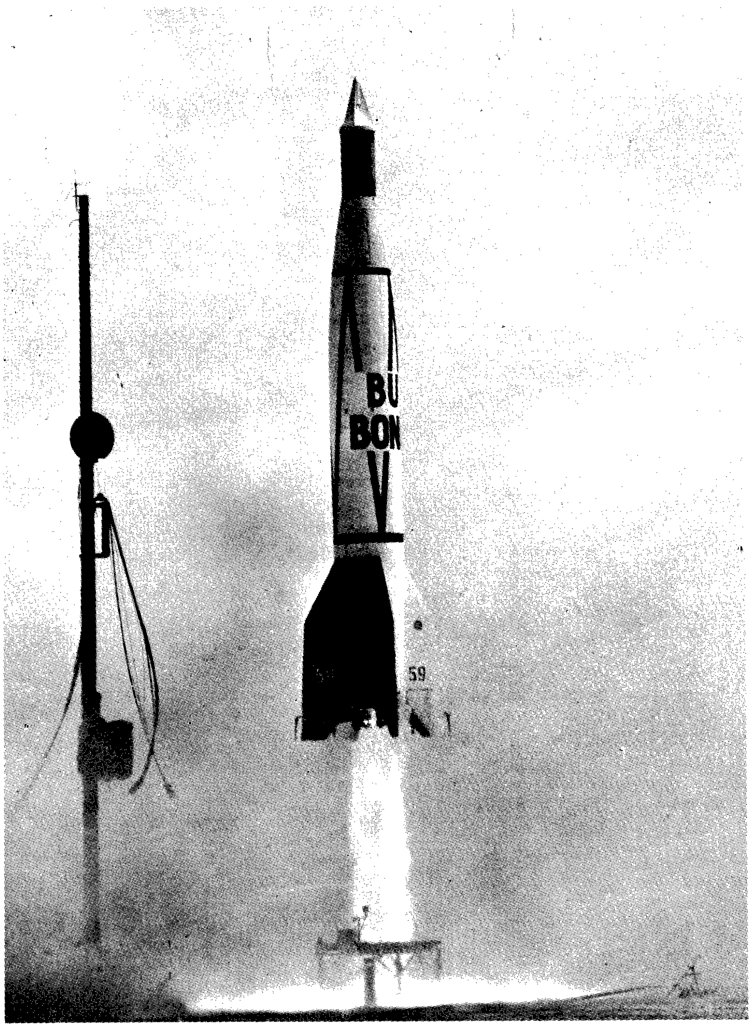


Fig. 11. V-2 59.

Fig. 12. Static Firing Jato Nose Cone, V-2 59.

Table I

| Bottle | Open | | Close | | Mean | Steel | Buffed‡ |
|---|---|---|---|---|---|---|---|
| | Time Secs | Km MSL | Time Secs | Km MSL | Km MSL | | |
| C-6-B-L* | 136 | 102.7 | 141 | 105.8 | 104.3 | Stainless | Yes |
| C-3 | 120 | 90.8 | 126 | 95.7 | 93.3 | Carbon | No |
| C-1 | 114 | 85.9 | 120 | 90.8 | 88.4 | Carbon | No |
| C-7-B | 107 | 79.9 | 114 | 85.9 | 82.9 | Carbon | Yes |
| C-4 | 100 | 73.5 | 105 | 78.0 | 75.8 | Carbon | No |
| C-5 | 93 | 66.1 | 100 | 73.5 | 69.8 | Carbon | No |
| C-11-B | 86 | 58.5 | 93 | 66.1 | 62.3 | Stainless | Yes |

* 2100 cu. in., others 500 cu. in.

‡ Final operation omitted.

residual pressure was more than 0.1 micron Hg, the final buffing process was not used on any flight bottles. The buffing technique will be investigated further to determine the source of residual gas.

The instrumentation was shipped to White Sands and installed in the rocket. Hangar and preliminary gantry operations were completed without difficulty. Fig. 13 shows the three bottle canisters mounted in place; the one containing the single large bottle for 100-km sampling is on the right. The canisters are mounted on rings bolted to the top of a sawed-off warhead. They can be swung out for servicing. Fig. 14 shows the Jato cone mounted in place over the canisters, and Fig. 15 the timer junction box and batteries mounted in the instrument compartment.

The firing was originally scheduled for the afternoon of 20 May. However, because of other missile schedules, it was moved to 0815 on 20 May. Preparations on the firing day proceeded without serious difficulty. Optical tracking conditions just prior to oxygen loading were marginal because of high cirrus clouds. However, since optical data were of secondary importance, it was decided to continue. The missile was launched at 0915 at which time tracking conditions were extremely poor. The standard program angle of 7° North was used and, as in V-2 60, the radar plotting boards were provided with altitude vs. vertical velocity plots so that the missile could be cut off to limit the peak altitude to 400,000 feet. In the flight of V-2 59 this technique was successful, and a peak altitude of about 407,000 feet MSL was achieved. Although the radar beacon operated, the pulse widening feature which is used to telemeter instrumentation operation did not. However, previous experience has shown that the timers used are reliable to ± 0.5 seconds in 200 seconds. Using the known timer times the radar trajectory to 240,000 feet and a vacuum trajectory thereafter, the bottle altitudes shown in Table I were calculated.

The impact point of the main body was located immediately, and the parachutes and bottle canisters within a few hours. Recovery of the aspect camera in the midsection and of the bottles was made on the day of the firing. The camera was found to be in reusable condition, and development of the film later showed that excellent pictures had been obtained beyond peak. The canisters and bottles were also found to be in excellent condition. All of the sealers, openers, and two out of three of the $C^{14}O_2$ contaminators had operated. A subsequent preliminary pressure check of the seals on the upper half of the copper intake tubes showed that all were good with the exception of C-7-B (82.9 km). Further examination showed that the blasting caps which break the parachute clamp rings had operated but that the piston charges which eject the canisters were unfired. This was later found to be due to a wiring error. However, inasmuch as the fracture of the clamp rings frees the canisters completely from their bases, it was thought that the canisters would, because of pitching and yawing, separate almost immediately from the missile. The possibility that the canisters did not separate until warhead separation at about 200,000 feet is discussed below. In any case, the canisters were separated at an altitude at which drag is small so that it is felt that the parachutes had a satisfactory test. The parachutes, described in the previous report, apparently were completely successful. They were deployed without fouling and lowered the canisters with practically no damage. The condition of the parachutes and canisters at impact was found to be excellent in each case. There was little fraying of the heavier chutes as seen in Figs. 16 and 17, but an appreciable amount in the case of the light chute seen in Figs. 18 and 19. The parachutes were shipped to Aerojet Engineering Corporation for inspection and reconditioning. The pertinent data on the parachutes are summarized in Table II.

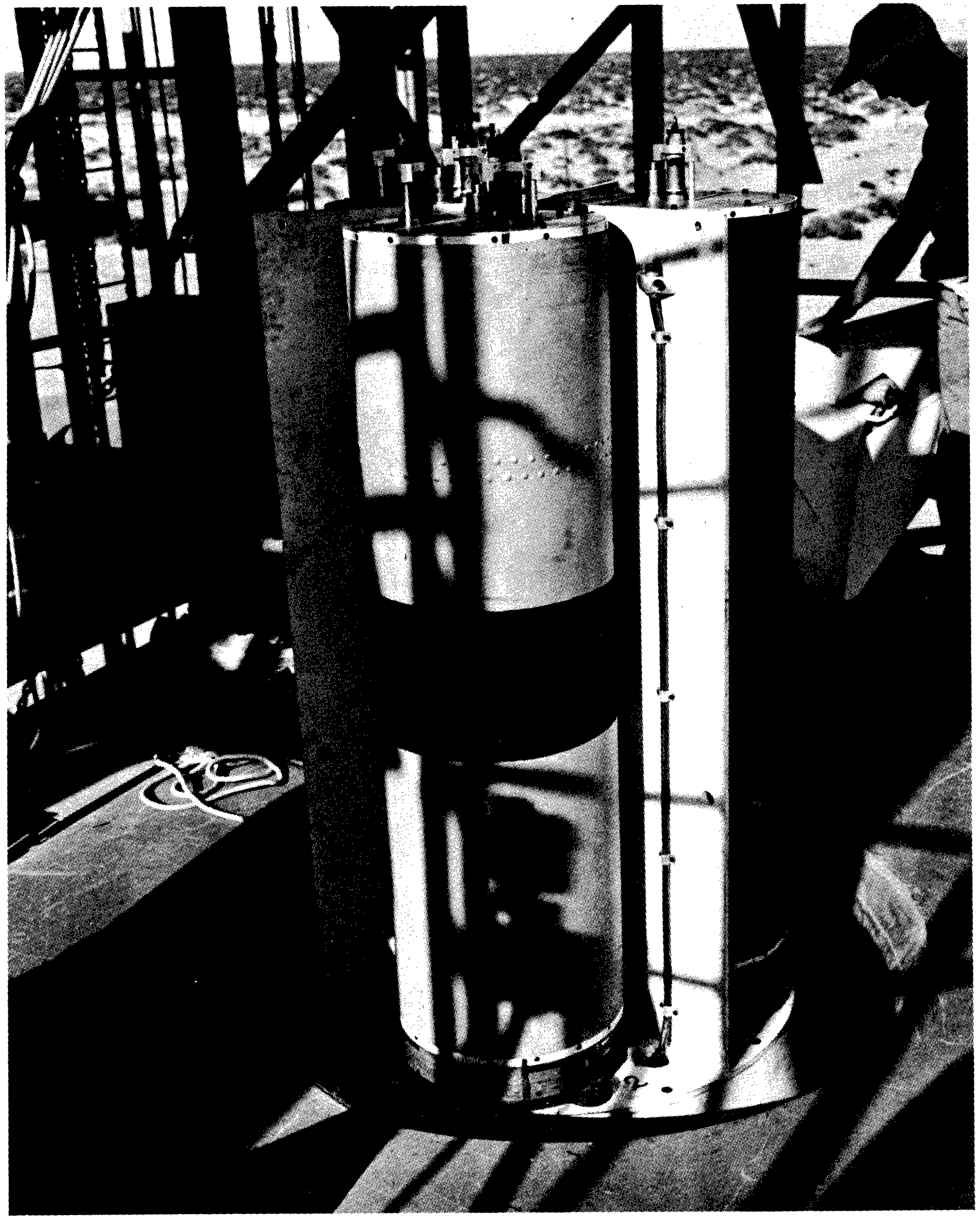

Fig. 13. Bottle Canisters and Separator Plates, V-2 59.

Fig. 14. Bottle Canisters and Jato Cone, V-2 59.

Table II

| No.* | Type | Canopy Diameter | Canopy Material | Shroud Material | Volume cu.in. | Weight lbs. | Drop Load lbs. | Altitude ft.** |
|---|---|---|---|---|---|---|---|---|
| 1 | FIST | 8 ft. | Silicone-rubber Fiberglas 1750-lb. test | Nylon | 1700 | 31 | 124 | 378,000 |
| 2 | FIST | 8 ft. | Silicone-rubber Fiberglas 1100-lb. test | Nylon | 1100 | 18 | 113.5 | 390,000 |
| 3 | FIST | 8 ft. | Silicone-rubber Fiberglas 1750-lb. test | Nylon | 1700 | 31 | 116.5 | 399,000 |

* Canister.
** Assuming correct ejection.

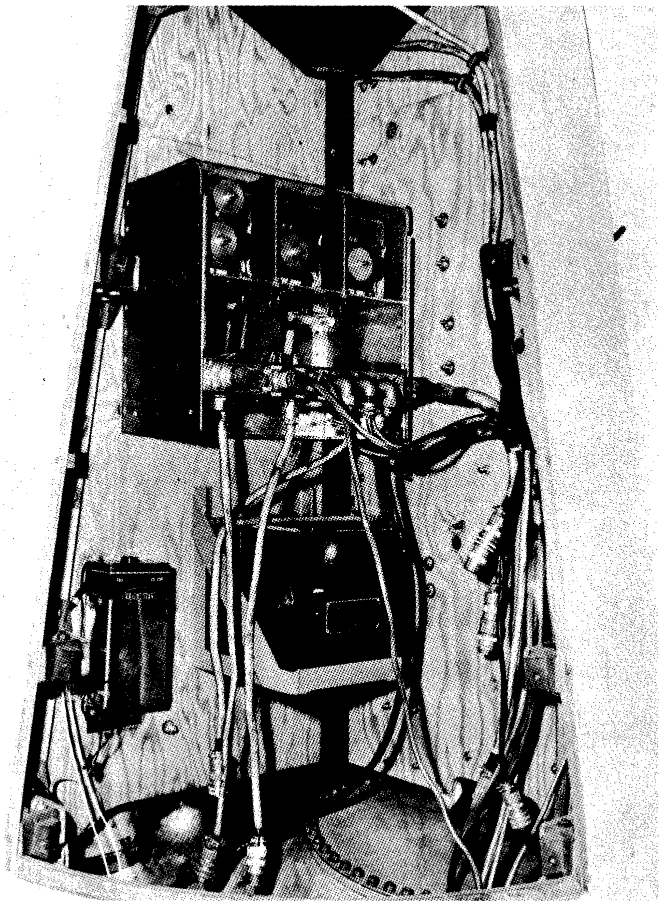

Fig. 15. Three-Unit Timer, V-2 59.

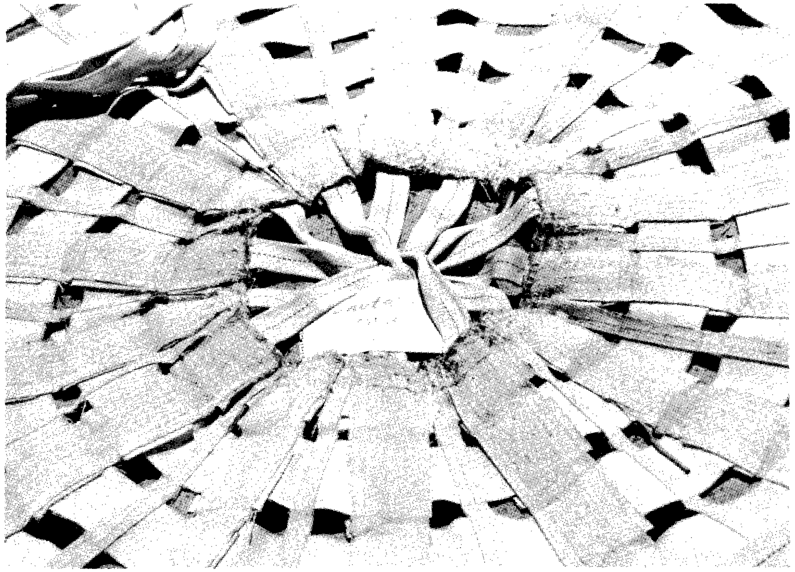

Fig. 16. Heavy Parachute Center, V-2 59.

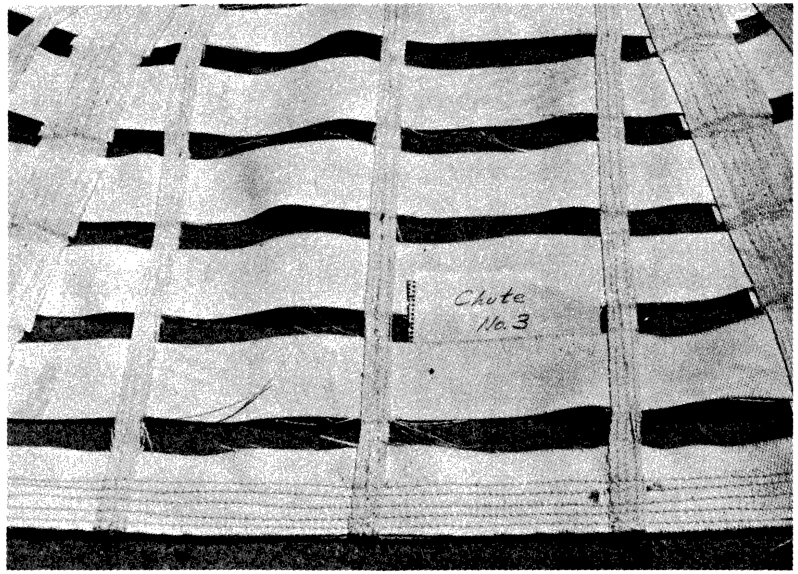


Fig. 17. Heavy Parachute Edge, V-2 59.

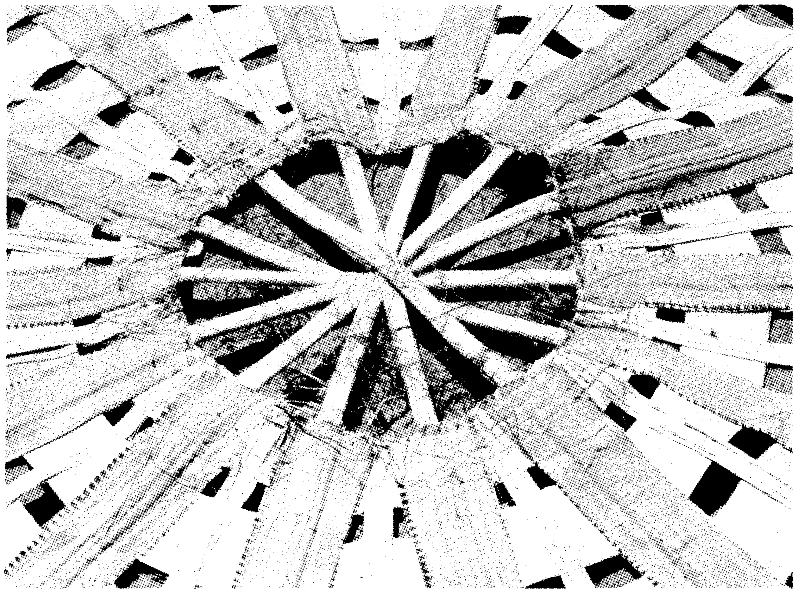

Fig. 18. Light Parachute Center, V-2 59.

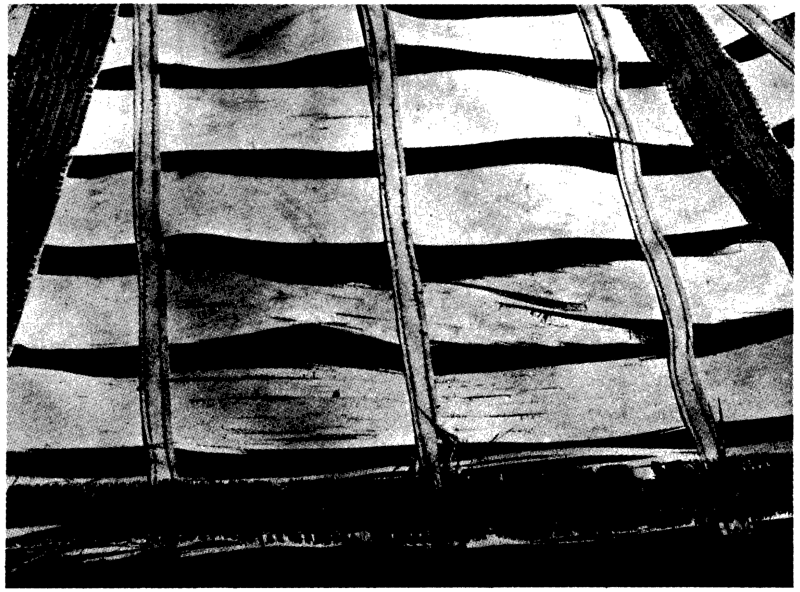

Fig. 19. Light Parachute Edge, V-2 59.

Recovery of the ejectable nose cone on the day following the firing revealed that the Jato was unfired. This would seem to indicate that the Jato cone was in place over the bottles at the time of sampling and that the samples are invalid. This is a very real possibility. However, since the Jato cone was not latched to the missile in any way and was free to move forward on linear ball bearings, the amount of force necessary to remove the Jato cone with the missile in free fall was very small. Estimates of the differential acceleration due to drag of the missile and cone at burnout and of possible impulses applied to the cone at burnout by the mass-spring system of the rocket were made. It appears possible that the Jato did not fire because the cone came off the missile at burnout. Various items of evidence were examined to determine what took place: a) The Jato was successfully fired on the ground, showing that it was not a dud. b) The aspect camera film did not photograph any of the bottle opener yokes at sampling times. However, since the optical angle is moderate, the cone and the yokes easily could have been missed. c) The inside of the Jato cone was examined for marks which might be expected if the cone were in place when the openers were operated. There were none. That such marks might be expected was shown by firing some openers in a laboratory set-up in which definite marks were obtained. d) The area around the impact point of the nose cone was minutely searched with the thought that of seven opener yokes firing up into the complicated understructure of the cone, one might have remained with the cone long enough to be found near it. None was found within a half-mile circle in a completely clear salt-flat area. e) The film from one Igor station which tracked beyond burnout was carefully examined. The cone was not observed to come off, but the images are so small that this was felt to be inconclusive.

The net result of these investigations is that it has not yet been possible to establish when the cone came off. The two most likely times are at burnout and at warhead separation. It is now felt that a measurement of gravitational separation would indicate that the cone was off during sampling since otherwise ground air trapped in the cone would have been sampled. No indication of separation would be inconclusive. Bottles C-1, 88.4 km, and C-5, 69.8 km, have been shipped to Dr. Paneth at Durham for analysis.

## 5. REPORTS WRITTEN AND LABORATORIES VISITED

No reports were issued during the quarter. The following places were visited during the course of the work:

Aero Ballistic Research Laboratory, NOL
Aero Medical Laboratory, WPAFB
Aerojet Engineering Corporation
Ballistic Research Laboratory, APG
Consolidated Engineering Corporation
Naval Research Laboratory
White Sands Proving Ground

## 6. FUTURE PROGRAM

The data from SC-23 will be reduced to density and temperature. The samples from V-2 59 will be analyzed. Preparation of sphere Aerobee SC-29 and sampling V-2 T-5 will be started. Preparation and analysis of control sample bottles containing ground air will be completed. An investigation of diffusion processes in the upper atmosphere which was started during the quarter will continue.

## 7. ACKNOWLEDGMENT

Thanks are due the Meteorological Branch of the Signal Corps for cooperation and support, to the Ballistic Research Laboratory for assistance in development of the doppler unit and antennas for the sphere, to the Aero Medical Laboratory at Wright Field for the use of the high-altitude chamber, and to the Aero Ballistic Laboratory at White Oak for additional $C_D$ data on spheres. Thanks are especially due to military and civilian personnel of many agencies at White Sands for their efforts in the launchings of SC-23 and V-2 59.