ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

Department of the Army
Contract No. DA-36-039 SC-15443
(Meteorological Branch, Signal Corps)

Progress Report No. 7   Quarterly Report

for the period

July 1, 1953 to September 30, 1953

Department of the Army Project No. 3-99-07-22
Signal Corps Project No. 172B

Submitted for the project by:

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ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

Department of Aeronautical Engineering

1. INTRODUCTION

This is the seventh 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 and the previous ones of this series.

2. SUMMARY

The work during the quarter was devoted to the firing of sphere Aerobee SC-31, further work on the data reduction of sphere Aerobees SC-23 and SC-29, further investigation of adsorption, and the preparation of sampling Aerobee SC-34. Note: The sphere Aerobee fired 29 September was SC-31; the sampling Aerobee now being prepared was referred to in the previous report as SC-31, but is now SC-34.

3. SPHERE EXPERIMENT

3.1 SC-31

Preparation of sphere Aerobee SC-31 scheduled for firing at White Sands on 29 September was begun. A newly designed 20-pound sphere, described in the previous report, together with the use of the RTV-A-1A Aerobee were the major departures from the equipment used on SC-30.

Two nylon spheres were ordered from Goodyear. The fabric and seams were the same as before. Small corrections to the patterns were made, however; and the gores were extended up to the rigid end-fittings in an attempt to eliminate distortions caused by the use of flat end-discs. This latter change was unsatisfactory, however, because at the ends the convergence of the longitudinal seams increased the relative area of double fabric compared to single fabric, which resulted in non-uniform stretching. The end sections were cut out and replaced with four-gore truncated cone sections. The revised spheres were then quite satisfactory, being very smooth and with excellent sphericity.

A large fraction of the nearly 30-pound saving in weight of the new sphere was in the air inflation bottle seen in Fig. 1. The bottle was fabricated by the Young Development Company, Rocky Hill, New Jersey, by weaving Fiberglas impregnated with epoxy resin. The following specifications were met:

1.	Linear Dimensions	.070 in. wall 23.75 in. max. length 5.25 in. O.D. max.
2.	Weight	3.6 lbs. max.
3.	Volume	0.24 cu. ft.
4.	Test Pressures	
	Ultimate	1440 psig
	Proof	600 psig
	Fatigue	725 psig 25 cycles

The bottle, which is nearly the same size as the sampling bottles used on this project, was actually pressurized at 500 psig for the flight.

Fig. 1. Pressure Bottle, Valve, Antenna Cylinder, SC-31.

Mounted on the top end of the bottle (Fig. 1) is seen the combination pressurizing, evacuation, and inflation valve. In the photograph is also seen, surrounding the valve, the brass counterweight of about 2.3 pounds used to place the center of gravity of the sphere on the geometrical center. This compares with a 6-pound weight used in SC-30. The details of the valve are seen in Fig. 2. With the sphere and nose cone installed in the rocket, plunger A is held down by a short hollow tube (not shown) mounted on the nose cone and pressing on A. The glass pressure bottle is filled to 500 psig through port C, which is fitted with a standard tire valve (not shown). During the rocket ascent the sphere is evacuated to ambient air through port B. At ejection, plunger A is no longer held in place and is forced up by the bottle pressure. Oil dash-pot D delays this motion to insure that the sphere is free before inflation. With plunger A in the up position, port B is closed; and the sphere is inflated by air from the bottle passing through ports E, F, and G. The ejection and inflation process is complete in 14 seconds.

Referring again to Fig. 1, the pressure bottle may be seen located inside the woven Fiberglas cylinder on which is mounted the combination receive-transmit antenna of the DOVAP transceiver. The antenna and one matching network are also shown in Fig. 3. The sliding bottle and cylinder structure provide a very light-weight mount for all components and also permit collapsing the sphere to a 33-1/2 - inch length. This feature was originally designed to permit packing in the Deacon rocket.

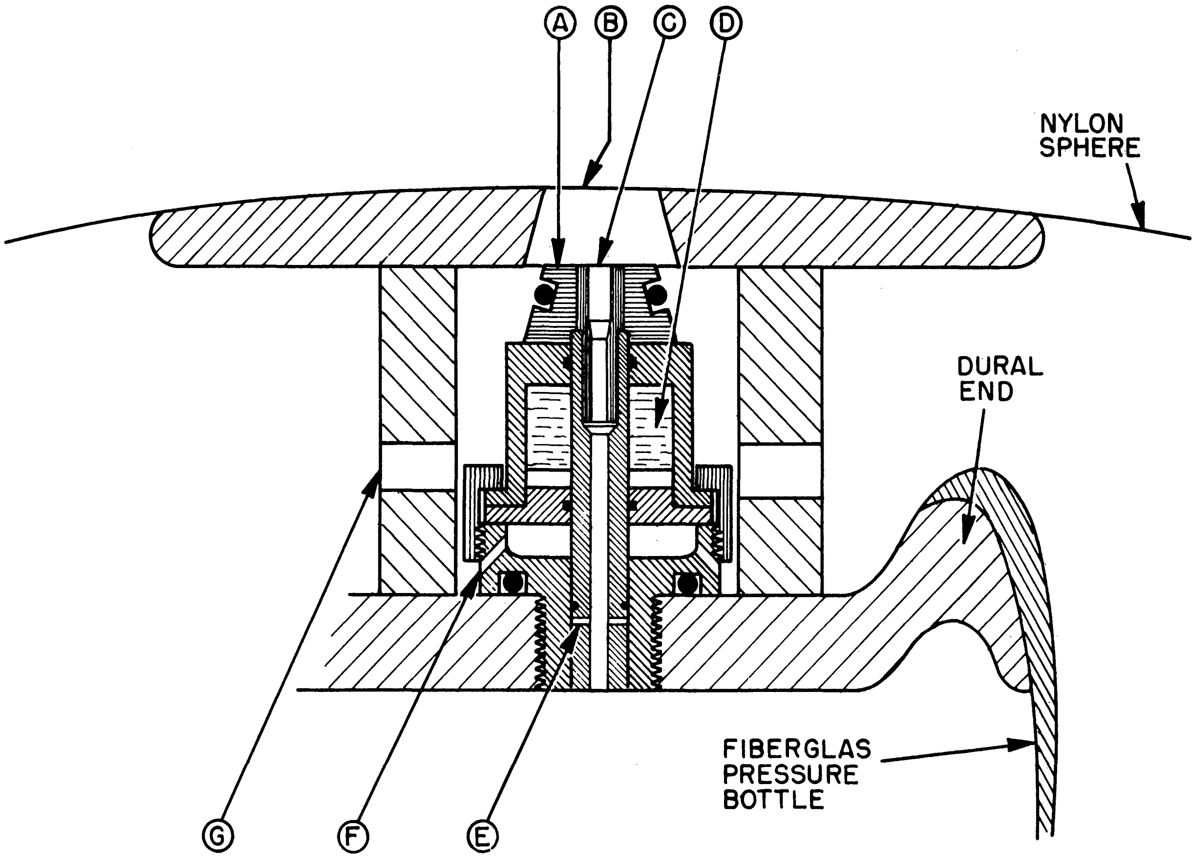


Fig. 2. Combination Valve, SC-31.

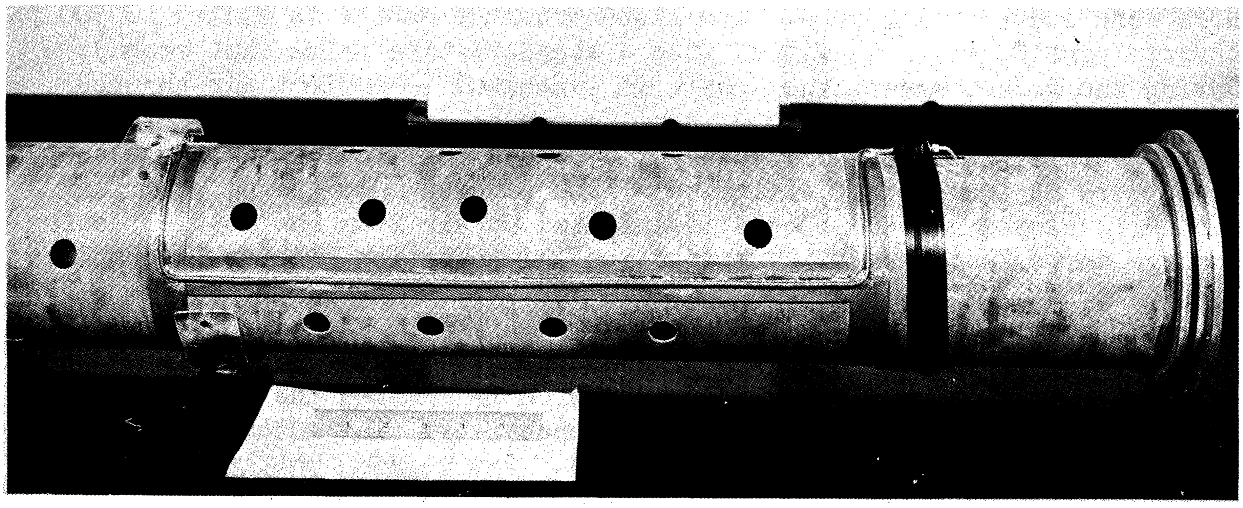


Fig. 3. Antenna and Glass Cylinder, SC-31.

The flight DOVAP tranceiver, which is pictured in Fig. 4, is mounted in the left or lower end of the tube in Fig. 3. The unit was provided by the FDL group at White Sands. It was powered by 4 Eagle-Picher BA-437/U A-batteries and 12 Eagle-Picher BA-450/U B-batteries. The batteries were one-shot KOH wet cells. A single FM telemeter channel was added to the DOVAP unit to monitor sphere pressure. The pressure end-organ was a Gianinni type 47132-A-1.5-20 pressure gage. The gage was originally manufactured to operate from 0 to 15 psia absolute but, for the flight, was modified to operate from 0 to 5 psia. The weight of the DOVAP unit, including batteries but excluding the pressure gage, was about 2.5 pounds.

Two miniature DOVAP transceivers were constructed at Michigan. One, using subminiature tubes, was completed and operated at 2.5 watts output. However, because tests could not be completed in time for the firing, it was not used. The other unit, using miniature tubes, was constructed but not tested. The circuit of the subminiature unit is shown in Fig. 7. In order to save weight, both of these units were designed to operate on the Eagle-Picher KOH batteries which were finally used on the flight unit as mentioned above. The results of typical load tests performed on the A- and B-batteries are shown in Figs. 5 and 6.

Upon completion of the construction of the flight instrumentation, the usual ejection test was carried out successfully in the high altitude chamber at Wright-Patterson Air Force Base. Also, matching of the antennas and the measurement of radiation patterns were accomplished at Ballistic Research Laboratories. The instrumentation was shipped to White Sands on 12 September.

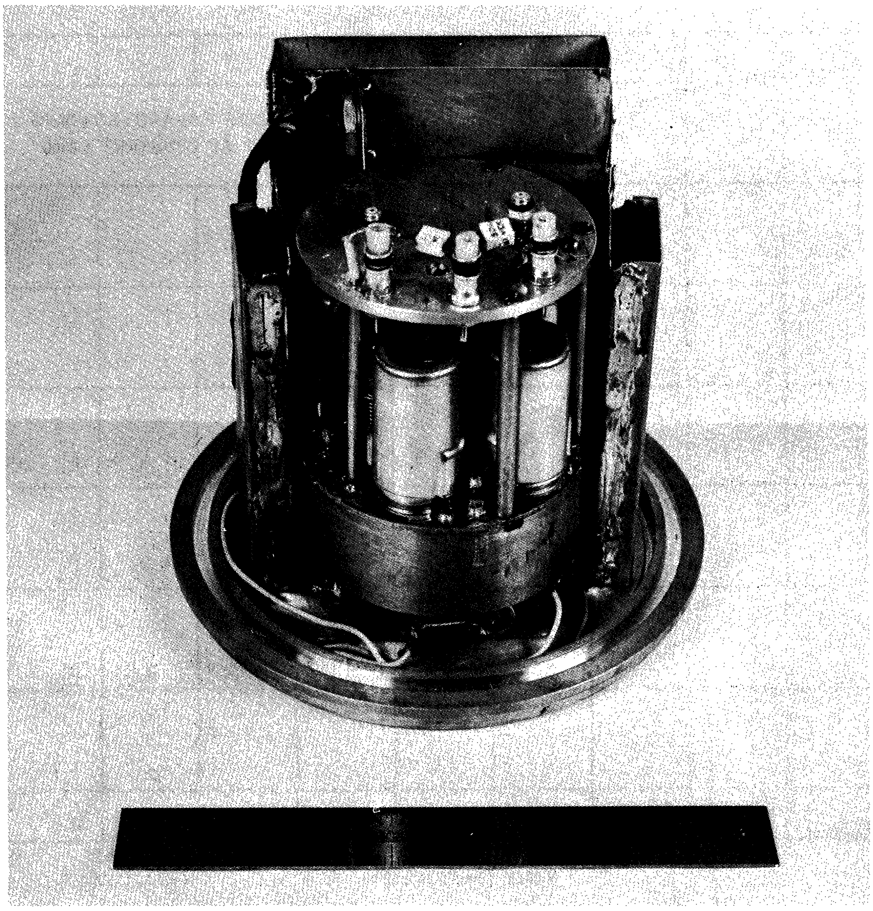


Fig. 4. DOVAP Transceiver, SC-31.

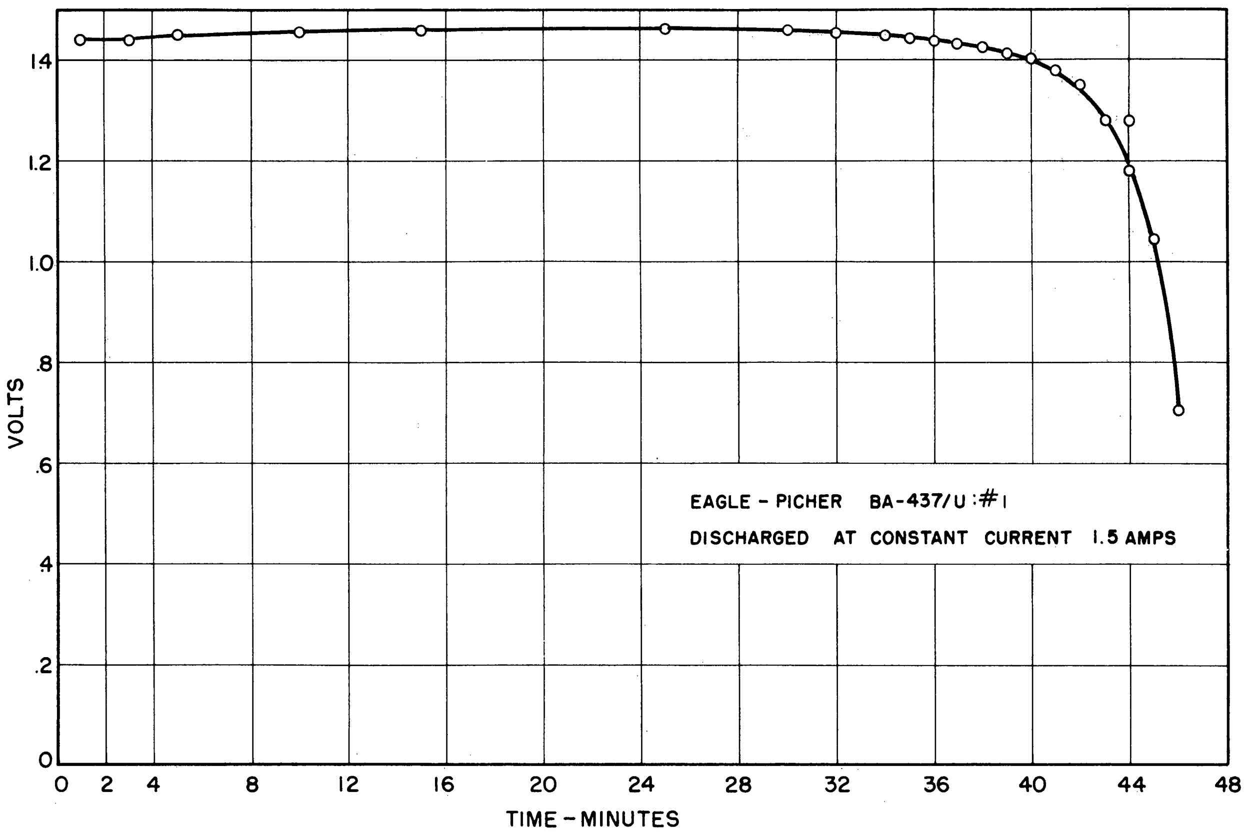


Fig. 5. Load Test One-Shot A-Battery.

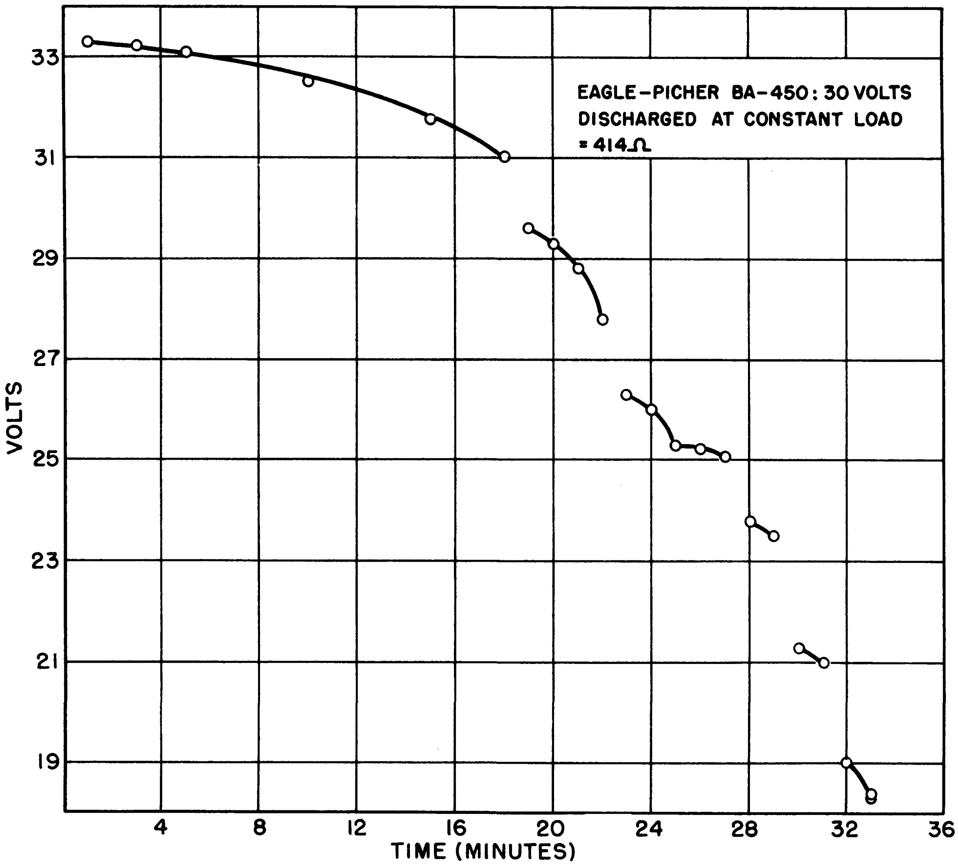


Fig. 6. Load Test One-Shot B-Battery.

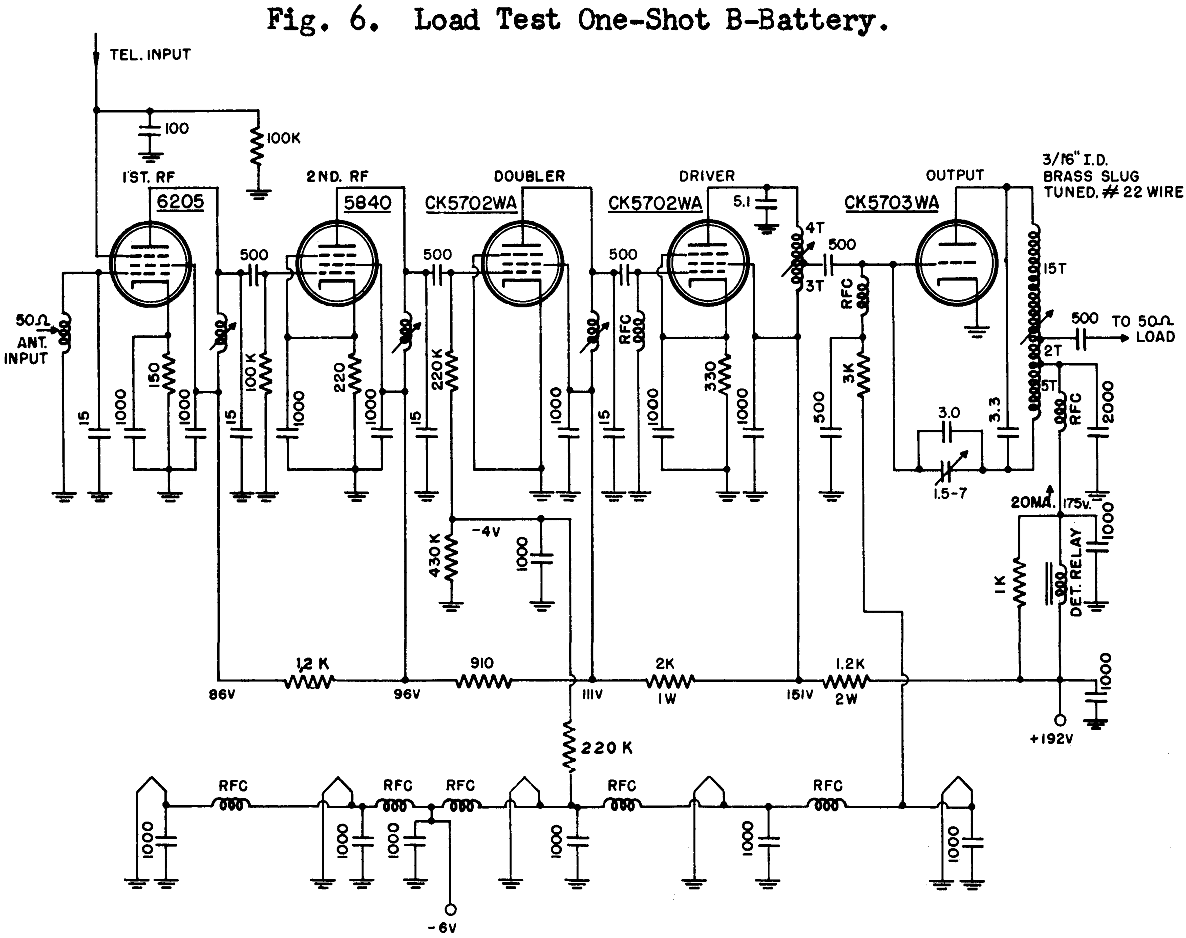


Fig. 7. Circuit Diagram of Subminiature DOVAP Transceiver.

Hangar and tower operations at White Sands were routine. The firing, which was scheduled for 0900 on 29 September, was accomplished at 1349 on that day, the delay being caused by damage to the batteries resulting from dropping the DOVAP unit.

The following information concerning the flight is strictly preliminary and is based on visual observation and a cursory examination of data. A more complete description of the flight and the resulting evaluation will be reported after the final data have been studied.

Burning time and thrust were apparently normal, the burnout velocity being approximately 4,800 feet per second. At about burnout the angle of attack began to increase, approaching 90 degrees in a few seconds. Shortly, the sphere was ejected prematurely. It inflated correctly, however, and the DOVAP operated properly throughout. Because of the aerodynamic spoiling, the missile went to an estimated 250,000 feet (radar beacon) and the sphere to an estimated 190,000 feet (DOVAP) instead of the predicted 400,000 feet for both. Density and temperature results should be available from perhaps 180,000 feet to 60,000 feet.

At recovery the forward instrumentation was found with the missile, and there was no evidence of gross failure. See Figs. 8 and 9. The sphere, nose cone, and tail assembly have not been recovered.

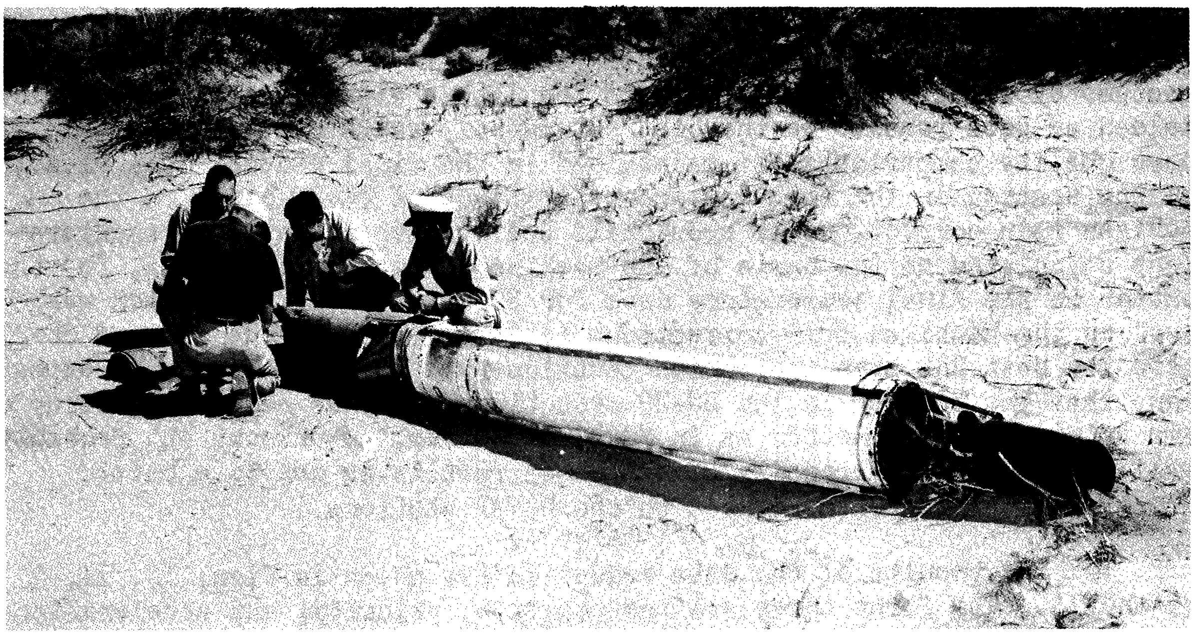


Fig. 8. Main Body Impact, SC-31.

Fig. 9. Forward Section at Impact, SC-31.

3.2 SC-29

The reduction of the data from sphere Aerobee SC-29 (fired 11 December 1952) up to the point of the ORDVAC calculation of the trajectory at BRL was described in the previous report. During the quarter the computed trajectories of position, velocity, and acceleration were received from BRL. Two sets were supplied - one based on the spin corrections performed at Michigan, the other based on machine spin corrections made at BRL. As noted previously the former method resulted in corrected count data smoother by a factor of 2 compared to the latter although neither technique yielded as good results as the best BRL method, which was used on SC-23. These quality comparisons are maintained in the final reduced data, i.e., (a) the scatter in the calculated accelerations of SC-29 based on the Michigan spin corrections is about half the scatter in the same accelerations calculated on the basis of the machine corrected count data, (b) the scatter in the final temperature data for SC-29, see Fig. 14, which was based on the Michigan spin corrections is larger than in the case of SC-23 where the best BRL spin correction technique was used. It is to be expected then, that the scatter in the SC-29 reductions could be reduced by using the same spin correction method as in SC-23. However, an unknown but probably small part of the superiority of the SC-23 results is due to a better geometric situation with respect to the DOVAP stations.

The results of the data reduction are shown in Figs. 10, 11, 12, 13, and 14. The first three are the position, velocity, and acceleration versus time trajectories, respectively. In Fig. 11 the "Michigan" and "BRL" velocities may be compared. Fig. 13 is a plot of density versus altitude with the UARRP density curve included for comparison. Fig. 14 is a plot of temperature versus altitude. In this figure the error bands due to a $\pm$ 0.1 cycle per half second DOVAP count error are shown together with the UARRP temperature. Also shown is a parabola fitted by least squares to the SC-29 points.

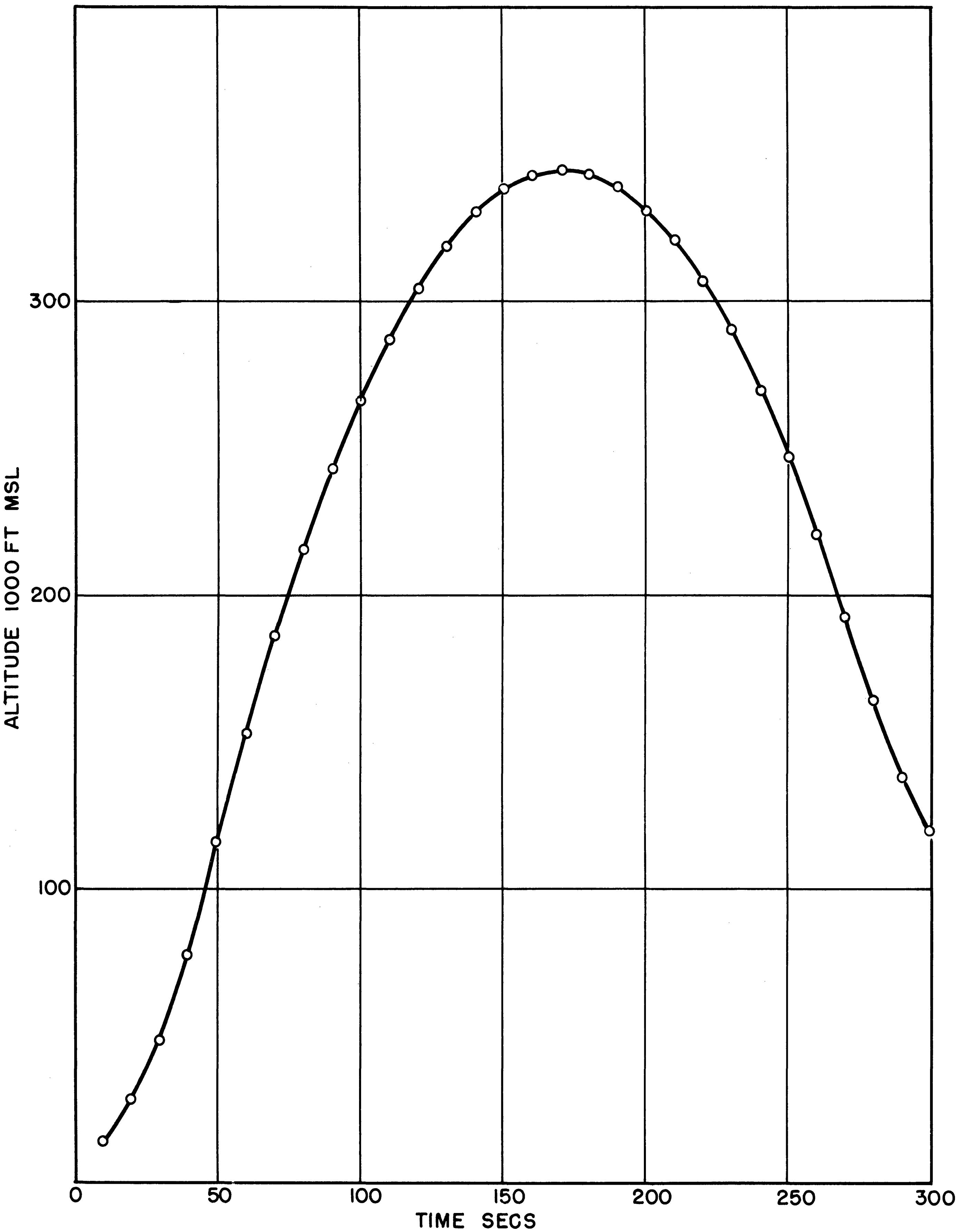


Fig. 10. Altitude vs Time, SC-29.

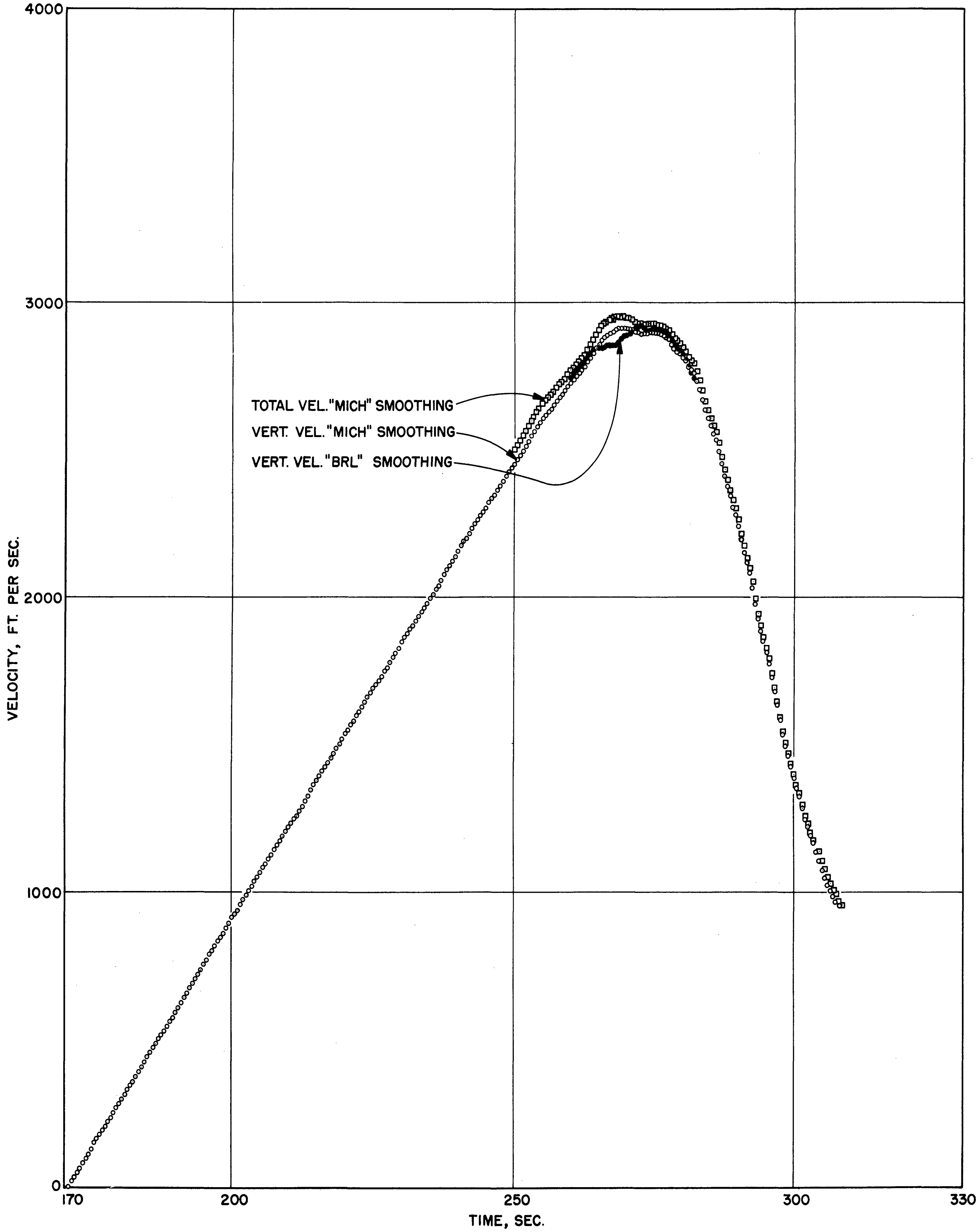


Fig. 11. Velocity vs Time, SC-29.

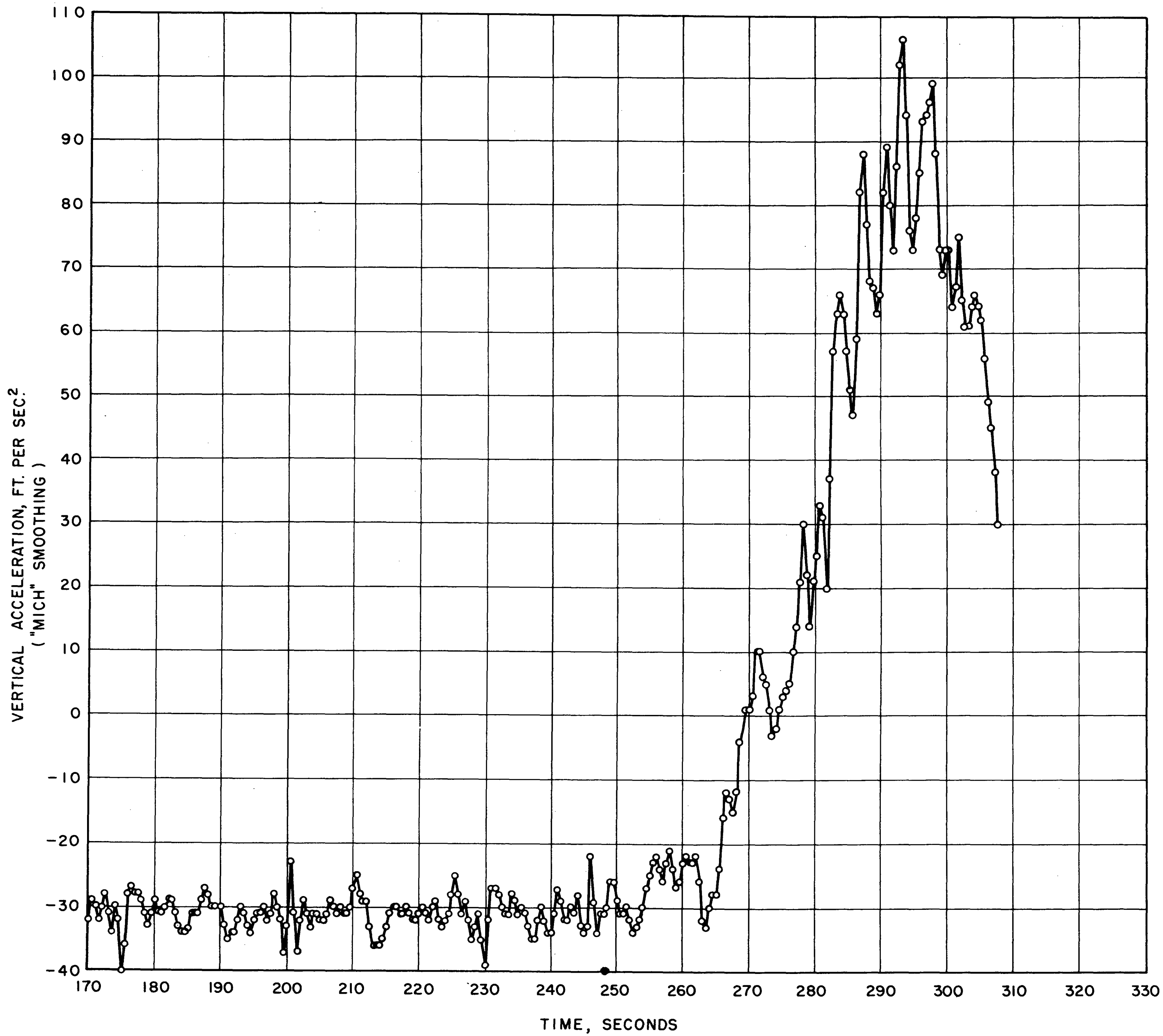


Fig. 12. Vertical Acceleration vs Time, SC-29.

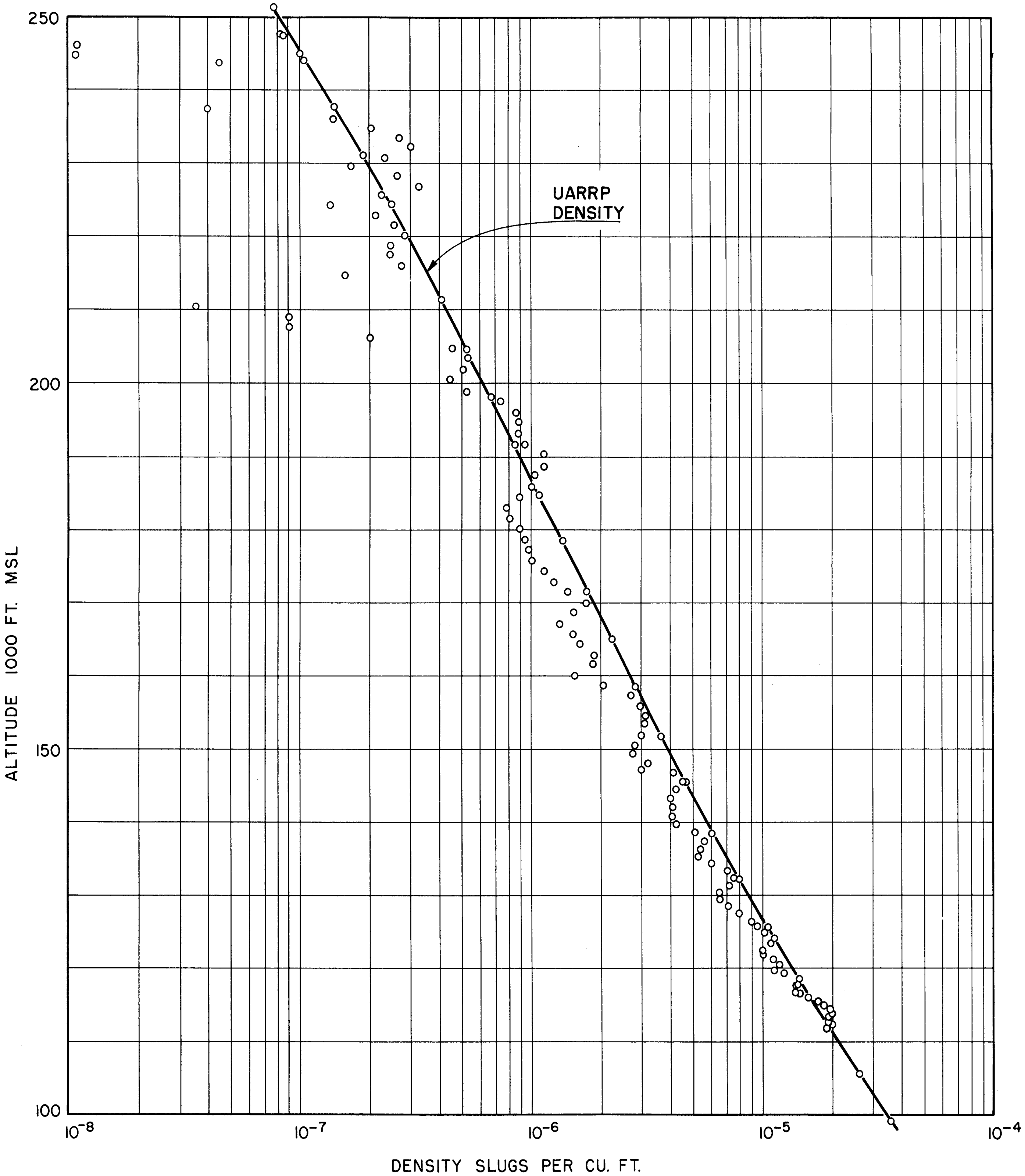


Fig. 13. Density vs Altitude, SC-29.

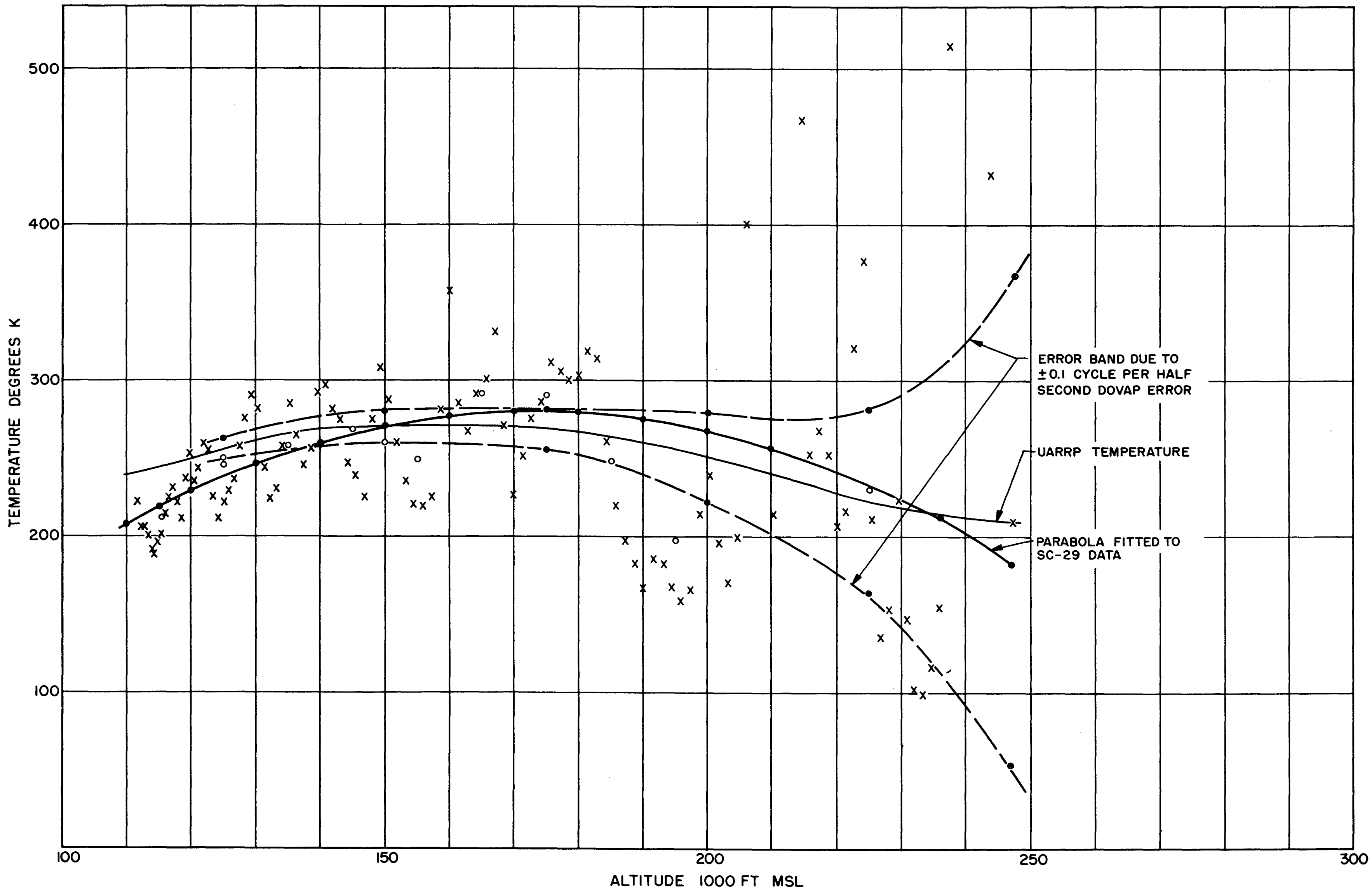


Fig. 14. Temperature vs Altitude, SC-29.

4. SAMPLING

4.1 Sample Analysis

The results of bottle C-11-B flown on V-2 59 on 20 May 1952 were received from Professor Paneth.

Bottle	Mean Altitude Km MSL	Amount of Sample cc NTP	Analysis[a]			
			Oxygen	Helium	Neon	Argon
C-11-B	62.3	0.40	0.77	1.133	1.040	0.962

(a) $\dfrac{\text{Vol. ratio to } N_2 \text{ in sample}}{\text{Vol. ratio to } N_2 \text{ in ground air}}$

Mean deviations based on a few runs usually less than ± 0.005.

The separations measured are consistent with results from other bottles on V-2 59. The significance of these results has been discussed in previous reports. One bottle, C6BL which sampled at 104.3 km on V-2 59, has yet to be analyzed.

4.2 Control Experiments

Discussions were held with Professor Paneth concerning experiments to be performed in verifying results obtained from recent upper air and control bottles. The status of each experiment is a follows:

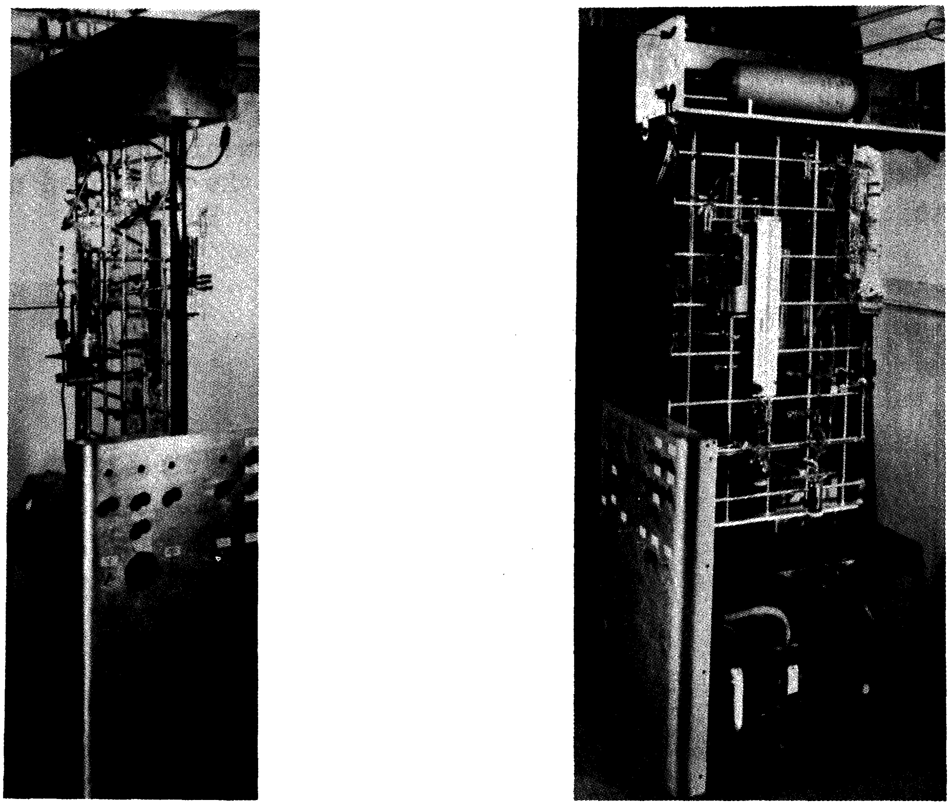
4.21 Re-check of B-18-P and B-20-P. These bottles were returned to Michigan and reworked using the same techniques as in the first preparation. The bottles were evacuated, sealed, and are being aged prior to breaking the vials and shipping the bottles to Professor Paneth for analysis.

4.22 Examination of vials used in B-20-P and B-21-P. Six vials prepared just as in the original preparation of B-20-P and B-21-P were shipped to Professor Paneth for analysis of the contents. The analyses will be made directly without first opening the vials in sample bottles. The results have not yet been received.

4.23 New vials. Professor Paneth is preparing vials of Durham air to be broken in new control bottles at Michigan. The contents will then be analyzed at Durham. The vials have not yet been received.

4.24 Flight bottle control experiment. A control experiment to be performed directly on the flight bottle and sample was described in the previous report. It was decided that those upper air bottles on which this experiment might have been performed have by now been open too long and the residual samples stored too long in glass for the experiment to be valid. The experiment will be performed on future upper air samples.

4.25 Total adsorption. An experiment in which the total adsorption in a bottle was measured was described in the previous report. This experiment was performed on an existing gas handling apparatus. Construction of a new apparatus for this work was completed. The schematic was shown in Fig. 7 of the previous report. The completed apparatus is shown in Fig. 15. Bottles were placed on both of these systems and evacuation begun in preparation for further adsorption measurements.



(a) (b)

Fig. 15. Apparatus for Total Adsorption Studies.

4.3 SC-34

The desirability of sampling at subsonic velocities to eliminate a possible "dynamic orifice selection" effect was discussed in Progress Report No. 5 and a sampling rocket to accomplish this was described. (This rocket was referred to as SC-31, the correct designation is now SC-34.) Work on the sampling rocket was slowed when separation was detected in control bottles B-20-P and B-21-P. A reconsideration of the problem led to the conclusion that sampling under conditions that eliminated orifice selection may yet be desirable. Consequently, work on SC-34 was resumed although the firing will not be scheduled until the results of current laboratory control experiments indicate a need for new samples.

A few changes in the instrumentation from that described in Progress Report No. 5 will be included. A modified T-7 DOVAP unit will be carried to provide velocity information and a command circuit to correctly open the bottles at peak. The DPN-19 radar beacon will be mounted on the outside of the bottle canister for easier servicing and will operate throughout the flight to facilitate bottle recovery. A new system of making the final seal of the bottles is being developed. Instead of soft soldering the top cap of the Philips gage as heretofore, the final seal will be made by press-fitting a two-inch diameter plug into a hole at the bottom of the bottle. The tube for extracting the sample after flight is mounted in the plug so that it is in its usual location after the bottle has been sealed. The new method has the following advantages: (a) the condition of the bottle surface may be visually inspected just prior to sealing, (b) no soldering or heating is done on the bottle after the final brushing, (c) the brush for finally brushing the sealing area of the copper intake tube need not be left in the bottle. The new arrangement is shown in Fig. 16.

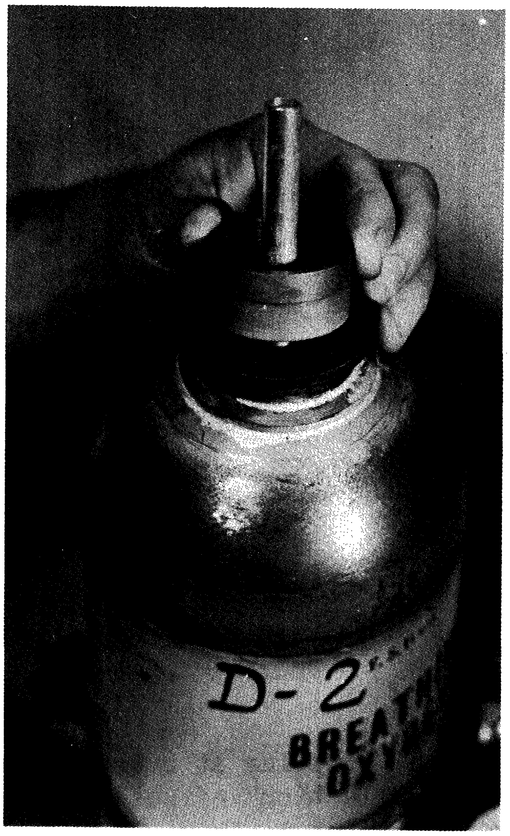


Fig. 16. New Bottle Sealing Plug.

5. REPORTS ISSUED AND LABORATORIES VISITED

The Oxford Conference on Rocket Exploration of the Upper Atmosphere, which took place on August 24 to 27 at Queens College, Oxford, was attended by F. L. Bartman and L. M. Jones, who presented two papers by the staff of the upper air research project as follows:

Falling Sphere Method for Upper Air Density and Temperature (presented by Bartman). "A method of calculating upper atmosphere densities and temperatures from the measured velocities and accelerations of a falling sphere is described. The sphere apparatus and the DOVAP (Doppler radar) tracking system are described. The equations used in the calculations are given, and the sources and magnitudes of errors are discussed. The results from one Aerobee flight are given, and this flight and two others from which the data are being reduced are described."

The Measurement of Diffusive Separation in the Upper Atmosphere (presented by Jones). "The experimental technique of collecting samples of the upper atmosphere in steel bottles carried aloft in rockets is described. The samples collected were analyzed primarily for helium, neon, argon, and nitrogen. The presence or lack of diffusive separation is based on the ratio of the relative abundance of the first three with respect to nitrogen in the samples to the relative abundance in ground air. The samples fall into three categories: a) Those collected in early V-2's up to 70 km. No separation was detected but the samples are in doubt because of possible contamination by ground air. b) Samples collected up to 60 km in Aerobees. These are thought to be valid samples, and the analyses show no separation up to 60 km. c) The most recent samples collected in Aerobees and one V-2 up to 100 km. In these samples separation increasing with the mass difference and with altitude was detected. However, small amounts of separation detected in ground air control bottles associated with these latter samples throw some doubt on the results. Further work is in progress."

The following places were visited during the course of the work:

Ballistic Research Laboratories
Cambridge University
Goodyear Tire and Rubber Company
Oxford University
White Sands Proving Ground
Wright-Patterson Air Force Base
Young Development Company

6. FUTURE PROGRAM

Reduction of data from SC-30 and SC-31 will continue. The investigation of possible sources of separation in upper-air samples other than upper-air phenomena will continue. Preparation of sampling Aerobee SC-34 will continue.

7. ACKNOWLEDGMENT

Thanks are due the Meteorological Branch of the Signal Corps for cooperation and support and to Ballistic Research Laboratories for continued cooperation in the sphere experiment. We are also indebted to personnel at White Sands Proving Ground for aid during the preparation and firing of SC-31, particularly to the DOVAP group of FDL for generous cooperation in preparing a DOVAP transceiver for the flight.