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Quarterly Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

(August 1, 1957 to October 31, 1957)

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ERI Project 2387

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ABSTRACT

Three grenade Aerobees were fired at Ft. Churchill in August, all successfully. Construction of the instrumentation for the final four grenade Aerobees to be fired in December and January was completed. The last Aerobee, SM2:10, will also carry a small falling sphere to measure density. Data reduction of SM1:01 was checked and errors corrected. Data reduction of SM1:02 was started.

Two analyses of gas accumulated in upper-air sampling bottle C-23-B were made. A new system for measuring helium leakage in sampling bottles was devised and used successfully.

Two papers on aerodynamic research by V. C. Liu were submitted for publication: "Theory of Flight of the Sounding Rocket" (J. App. Mech.) and "On the Drag of a Sphere at Extremely High Speeds" (J. App. Phys.).

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1. INTRODUCTION

This is the tenth 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 participate in the preparation and firing of the IGY rocket grenade experiments;

c. to collect and analyze upper-air samples; and

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

2. GRENADE EXPERIMENT

2.1 AEROBEE FIRINGS AT FT. CHURCHILL

IGY Grenade Aerobee rockets SM1:04, SM1:05, and SM2:06 were fired at Ft. Churchill August 12, 19, and 25, 1957, respectively. The schedule of operations is given in Table I. Figure 1 shows SM2:06 ready for installation in the launching tower and Fig. 2 shows the SM2:06 launching.

TABLE I

SCHEDULE OF OPERATIONS FOR AEROBEES SM1:04, SM1:05, and SM2:06

	SM1:04	SM1:05	SM2:06
Horizontal Test	August 8	August 15	August 23
Vertical Test	August 10	August 17	August 24
Firing	0959:31 CST August 12	2029:51 CST August 19	0808:05 CST August 25

Fig. 1. SM2:06 ready for installation in the launching tower.

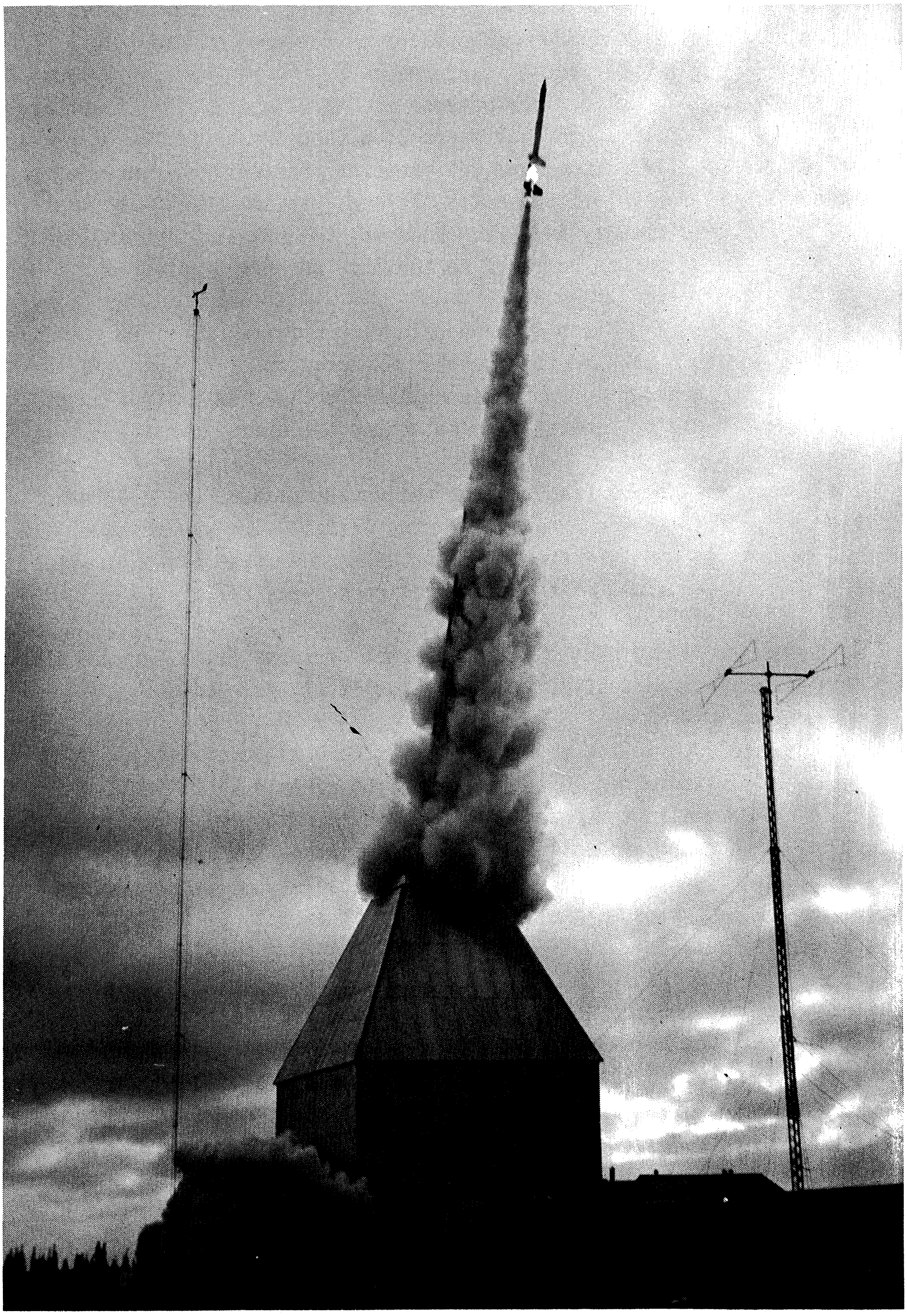

Fig. 2. SM2:06 launching.

Aerobee SM1:04 performance was below normal. The estimated peak altitude was 46 miles instead of the predicted 58 miles. On this rocket, the size of the mixture-ratio orifice had been modified a few days before firing, according to instructions from the Aerojet General Corporation. This modification, based upon calculations made from records of performance of previous Aerobees, was intended to improve the rocket performance. But the poor performance of SM1:04, together with the good performance of SM1:02 and SM1:03, immediately made the change in orifice diameter suspect, although examination of the performance data available so far does not pinpoint precisely the cause of poor performance. Burn-out velocity was 3560 ft/sec (preliminary DOVAP) instead of the 4000 ft/sec predicted by Aerojet. However, the burning time was about normal, 32.5 - 33.0 seconds as compared to the 33.2 seconds predicted.

The rocket struck a forested area, starting a forest fire, so that a recovery party was able to find the rocket. Examination of the area indicated that an appreciable amount of unburned aniline remained in the rocket at impact; however, it was not possible to determine the exact quantity.

The rocket engine was removed from the rocket remains and examined for possible anomalies, but none was found. The orifice size was measured and found to be exactly the size specified by the Aerojet General Corporation. Figure 3 shows three views of the recovered rocket engine.

Aerobees SM1:05 and SM2:06 yielded normal performance. The peak altitudes of 58 and 86 miles, respectively, were approximately as predicted.

The grenade experiments on these rockets were all successful. On SM1:04, grenades 1 and 7 did not explode, and on SM1:05 grenade 14 did not explode; however, on SM2:06 all grenades were successfully detonated. The cause of failure of the three grenades that did not explode is not known exactly. Several possibilities for the failure exist as outlined in the last quarterly report, 2387-27-P. The most likely possibility appears to be the cutting of the lanyard by shrapnel.

Sound arrival records were obtained for all three flights. On SM1:04, a generator failure at Twin Lakes prevented equipment from operating in the interval of from 54 to 78 seconds approximately. Fortunately, however, the generator came back on again in time to record all sound arrivals. On SM1:05 all sound arrivals were recorded; however, the re-entry wave caused by the missile came in early enough to interfere with the arrivals from the last four grenades. On SM2:06 sound arrivals were recorded for the first thirteen grenades. The last six arrivals were not obtained. The last arrival obtained was for the grenade which was exploded at about 90 km, the theoretical high-altitude limit from which sound arrivals can be recorded with the equipment used.

The Aerobee rocket for SM2:06 was modified so that it would reach a peak of 86 instead of 58 miles and thus enable the determination of the upper-altitude limit for the grenade experiment as it is now performed. The experiment

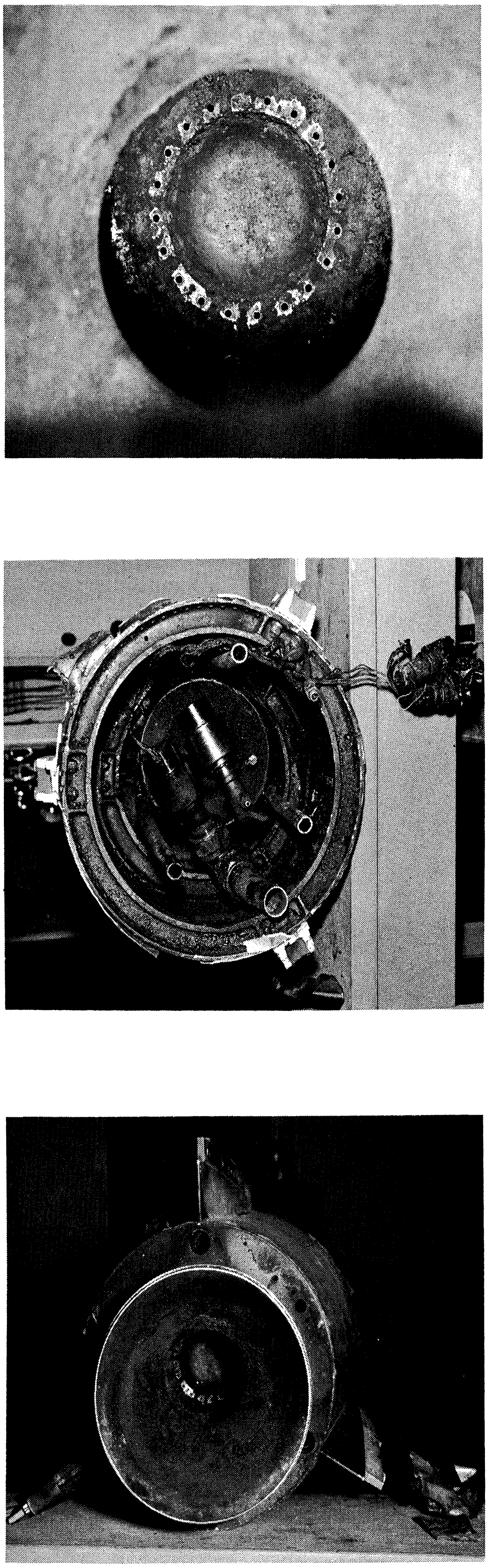

Fig. 3. Aerobee engine recovered from SM1:04.

was successful. The failure to record any of the sound arrivals from the last six grenades demonstrates experimentally that this upper-altitude limit is approximately 90 km.

On SM1:04, ground flash detector signals were obtained for all except grenades 6 through 11. Those missed detonated during the time of the Twin Lakes generator failure. All ground flash detector signals were obtained for SM1:05; however, since SM2:06 was fired on a cloudy day, no ground flash detector signals were obtained for that flight. All grenade detonation times were recorded because of the explosion-produced modulation of the DOVAP record.

Preliminary data summarizing the results obtained on these flights are given below.

TABLE II

Flight	SM1:04	SM1:05	SM2:06
Date	12 Aug. 1957	19 Aug. 1957	25 Aug. 1957
Hour	0959:51 CST	2029:51 CST	0808:05 CST
Burn-out velocity	3560 ft/sec	4040 ft/sec	4850 ft/sec
Burn-out altitude	61,000 ft	73,400 ft	100,000 ft
Peak time	141 sec	155.5 sec	196 sec
Peak altitude	46 miles	53.5 miles	86 miles
Grenades not exploded	1,7	14	-
Sound arrivals recorded	2-6, 8-19	1-15	1-13
Altitude range of experiment	23-73 km	26-71.5 km	27-91 km
DOVAP telemeter records	Excellent	Excellent	Excellent
DOVAP cycle-count data	Good	Good	Good
Ballistic Camera photographs	-	Excellent	-
Supporting meteorological data	Excellent	Excellent	Excellent

2.2 CONSTRUCTION OF EQUIPMENT FOR THE FIRINGS IN DECEMBER AND JANUARY

Construction of the equipment for the last four grenade Aerobees was nearly completed during the quarter. These rockets will be fired at Ft. Churchill in December and January. The design of the various components is the same as it was for those fired in July and August.

Seventy-eight grenades were constructed, loaded, and x-rayed. The rigid inspection criteria developed since the beginning of this program were adhered to. Three of these grenades were 4-lb destruct grenades; the other seventy-five were 2-lb grenades. Six of the seventy-five 2-lb grenades have been loaded with a special mixture of high explosive. This special mix contains RDX and TNT, but no aluminum (see Section 2.4). A 5% sample (four grenades) was tested at the National Northern firing range at Camp Edwards in Massachusetts. These four grenades all functioned properly.

Five complete instrumentation sections were prepared for the four firings. This procedure carries through the philosophy of having one complete set of spare parts for each rocket grenade experiment.

Aerobee SM1:07 is of exactly the same design as Aerobees SM1:02, SM1:03, SM1:04, and SM1:05, which were fired in July and August, 1957. On SM1:08 and SM1:09, eighteen 2-lb grenades and one 4-lb grenade will be used (instead of twelve 2-lb grenades and seven 4-lb grenades). The resulting saving in weight of 17 lb will increase the peak altitude of the rockets by approximately 3 miles, thus helping to make sure that the highest explosion takes place at approximately 90 km, even for rockets whose performance may not be quite up to normal.

2.3 COMBINED FALLING-SPHERE AND GRENADE EXPERIMENT

The results of Aerobee SM2:06 indicate conclusively that 90 km is the highest altitude from which sound arrivals can be recorded with the present design of the grenade experiment. It is apparent that the grenade experiment as now flown would not utilize profitably, from a scientific point of view, the 85- to 90-mile peak-altitude capability of the AJ10-34 Aerobee rocket.

To utilize this peak-altitude capability more profitably, it has been decided to fly both the falling-sphere experiment for upper-air density and the grenade experiment on the remaining AJ10-34 Aerobee. This experiment will be IGY rocket SM2:10 at Ft. Churchill. It is scheduled to be flown on 27 January 1958 during the day.

The "grenade" part of this rocket will have the same design as Aerobees SM1:02 through SM2:10; however, only eighteen 2-lb grenades will be used. These grenades will be ejected from the rocket at 3.6 km intervals in the altitude range of approximately 28 to 90 km.

The "sphere" part of the experiment will be contained in a 15-in. extension which is inserted in the rocket at a point directly in front of the rocket tank section, thus moving the grenade instrumentation section and the nose cone forward on the rocket by 15 in. The sphere will be ejected from its section after the grenades have been ejected.

An effort has been made to utilize design work already done on the grenade experiment for the "sphere" portion of SM2:10. The 15-in. extension which contains the sphere is of the same basic design as the 15-in. instrumentation section of the grenade experiment. It has the same T-section bulkhead and three doors. The sphere is contained in a canister similar in design to that of a grenade. The sphere is ejected from the rocket through one of the doors by the same type of ejection mechanism used for the grenades. A black powder charge, when burned, builds up pressure in a chamber; holding rivets are sheared and the sphere is ejected.

In this experiment, then, after the grenades have all been ejected and detonated, the sphere will be ejected. It will rise on up over the peak of the trajectory, and as it falls its time-of-flight accelerometer will measure drag acceleration and its transmitter will send data to the telemetry ground station.

Comparison of the data from these two experiments will serve to check the accuracy of the results from each of them. In the grenade experiment average temperatures and horizontal wind velocities in a layer between two grenades are obtained. The direct data of the falling-sphere experiment can be plotted as a curve of upper-air density vs altitude. By means of the density curve, using the hydrostatic equation and equation of state of a perfect gas, one can calculate temperature as a function of altitude.

2.4 MODULATION OF THE DOVAP RECORD BY THE GRENADE EXPLOSIONS

The last two quarterly reports have contained a description of the modulation of the DOVAP cycle-count record produced by the grenade explosions. A possible theory for part of this modulation effect is that secondary doppler cycles are produced on the cycle-count record by portions of the DOVAP carrier radiation being reflected by some agent which travels with the shock front from the explosions.

The agent in the shock front may possibly be ionized gas particles. However, another possible source of reflecting material is the aluminum powder contained in the grenade high-explosive(H.E.) material. This H.E. material is a mixture of RDX/TNT/Al/Wax,(45%/35%/15%/5%). Spectroscopic measurements of the light output from grenade explosions at sea level indicate a great deal of infra-red light coming from the burning aluminum, persisting for as long as 100 milliseconds and having a peak intensity of about 30 milliseconds after the detonation.

It is possible that the modulation of the DOVAP cycle-count data is produced by reflection of the DOVAP carrier from still unburned aluminum or vaproized aluminum which travels along with the shock wave.

To test this hypothesis, several grenades made of H.E., not containing aluminum powder, will be exploded. The DOVAP cycle-count data for the region of these explosions will be examined critically to see if the modulation is produced, and, if it is produced, whether it is similar to that produced by grenades having the aluminum containing H.E.

It will be necessary to perform the tests on rockets flown in clear weather, for in the event that an explosion from a test grenade does not produce the typical DOVAP modulation, it will be necessary to establish that the grenade did explode by means of ground flash detector signals.

2.5 DATA REDUCTION

2.5.1 Second Data Reduction on SM1:01.—The last quarterly report (2387-27-P) gives the results of the initial data reduction on SM1:01 and indicates that although satisfactory results were obtained for relative grenade position data, the absolute grenade-position data had standard deviations larger than should be obtained in a good DOVAP data reduction.

After a critical examination and modification of the data-reduction procedure, explained in that report, a second calculation of SM1:01 trajectory has been made. These calculations were done by hand because the MIDAC Computer has been shut down and the IBM 650 program for the DOVAP trajectory had not yet been completed.

The results of the second calculation are compared with the results of the initial calculation in Table III. As anticipated, the net effects in the trajectory of the modifications in the data-reduction procedure were:

a. Absolute positions are changed slightly; relative positions are changed a negligible amount.

b. The scatter in both absolute and relative positions was decreased.

An evaluation of the standard deviations in the absolute positions of the second data reduction are given in Table IV. In this table standard deviations are listed for grenades 3, 9, and 17. Theoretical values of σ_x/σ_u, σ_y/σ_u, and σ_z/σ_u obtained from graphs prepared by W. Dean of BRL are also given. The average values of σ_u calculated from the data are listed. According to Mr. Dean's lecture on DOVAP (at the SCIGY meeting of May 9, 1957), a σ_u of 8 ft would be normal for the Ft. Churchill DOVAP geometry; however, a σ_u of 15 ft would be too large. The values of σ_u of 10.4 ft and 10.9 ft are considered close to normal and thus the second SM1:01 data reduction should be considered to be satisfactory.

The standard deviations in relative grenade positions are well within the ± 10 meters for horizontal coordinates and ± 5 meters for vertical coordinates required by the grenade experiment.

2.5.2 Third Data Reduction on SM1:01.—At approximately the time that the second data reduction was completed, an error in the survey data for Metro R.H. antenna station was discovered by BRL. Completion of the BRL survey also showed that the line launch BC-4 pier to Twin Lakes Bilby Tower was not true north-south.

Accordingly it became necessary to recalculate the SM1:01 trajectory using the corrected survey data.

TABLE III

COMPARISON OF DOVAP TRAJECTORY CALCULATIONS

Grenade No.	x(+N)				y(+W)				z(+up)			
	(1)		(2)		(1)		(2)		(1)		(2)	
	x	Δx	x	Δx	y	Δy	y	Δy	z	Δz	z	Δz
1	-17002.75±11.4	-2436.92±7.2	-17007.62±3.4	-2437.56±6.1	6228.12±12.3	+1192.75±1.8	6246.17±3.7	+1194.57±6.6	82735.64±1.9	+10484.41±1.2	82737.25±0.6	+10484.08±1.0
2	-19439.67±18.6	-2408.05±2.5	-19445.18±9.5	-2408.69±1.5	7420.87±20.3	+1185.07±2.7	1440.74±10.3	+1186.85±1.6	93220.05±3.1	+9987.35±0.6	93221.33±1.6	+9987.02±0.3
3	-21847.72±21.1	-2434.36±4.6	-21853.87±11.0	-2435.00±3.6	8605.94±22.7	+1198.52±5.0	8627.59±12	+1200.31±3.9	103207.40±3.5	+9715.76±0.9	103208.35±1.8	+9715.41±0.7
4	-24282.08±25.7	-2392.28±1.0	-24288.87±14.7	-2392.91±0.1	9804.46±27.7	+1182.88±3.3	9827.90±15.8	+1172.08±0.1	112923.16±4.3	+9112.69±0.3	112923.76±2.4	+9112.33±0.2
5	-26674.36±26.6	-2347.77±4.7	-26681.78±14.6	-2348.37±3.7	10987.34±38.9	+1143.52±9.2	10999.98±14.9	+1157.67±4.0	122035.85±4.5	+8622.11±1.0	122036.09±2.5	+8622.21±1.1
6	-29022.13±31.2	-2376.58±3.7	-24030.15±18.3	-2377.19±2.8	12130.86±33.7	+1174.30±4.0	12157.65±19.7	+1175.93±3.1	130657.96±5.4	+8344.34±0.9	103658.30±3.6	+8343.53±0.3
7	-31398.71±35.0	-4746.81±8.2	-31407.34±21.1	-4747.97±6.5	13305.16±37.7	+2349.66±8.9	13333.58±22.8	+2352.76±7.0	139002.30±6.2	+15511.91±2.0	139001.83±3.7	+15511.16±1.5
9	-36145.52±43.2	-2324.82±1.1	-36155.31±27.6	-2324.23±0.3	15654.82±46.6	+1159.52±1.2	15686.34±29.8	+1098.84±0.3	154514.21±8.1	+7033.16±0.5	154512.99±5.2	+7039.37±0.3
10	-38470.34±44.3	-2381.10±3.6	-38479.54±27.9	-2382.83±2.8	16814.34±47.8	+1187.13±3.9	16185.18±30.1	+1250.70±3.0	161547.37±8.5	+6842.84±1.0	161552.36±5.4	+6835.86±0.7
11	-40851.44±47.9	-2364.93±1.6	-40862.37±30.7	-2365.50±0.8	18001.47±51.6	+1181.69±1.7	18035.88±33.2	+1183.06±0.9	168390.21±9.5	+6398.48±0.7	168388.22±6.1	+6398.07±0.4
12	-43216.37±49.5	-2308.75±1.2	-43227.87±30.9	-2309.28±0.5	19183.16±53.4	+1159.01±1.3	19218.94±34	+1160.29±0.5	174788.69±10.1	+5876.13±0.6	174786.29±6.4	+5875.73±0.3
13	-45525.12±54.6	-2357.47±3.1	-45537.15±27.1	-2358.02±2.4	20342.17±54.7	+1180.41±3.3	20379.23±34.5	+1181.67±2.5	180664.82±10.6	+5632.25±1.0	180662.02±6.7	+5631.84±0.7
14	-47882.59±53.8	-2355.95±1.1	-47895.17±34.4	-2356.46±0.4	21522.58±58.0	+1190.11±1.2	21560.90±37.1	+1191.31±0.4	186297.07±11.6	+5233.23±0.6	186293.86±7.4	5232.79±0.3
15	-50238.54±54.9	-2323.00±0.5	-50251.63±34.7	-2323.52±0.2	22712.69±59.2	+1165.52±0.5	22752.21±37.5	+1166.66±0.2	191530.30±12.2	+4789.24±0.5	191526.65±2.7	+4788.81±0.2
16	-52561.54±55.4	-2344.36±4.9	-52575.15±30.9	-2344.87±4.3	23878.21±59.7	+1184.38±5.3	23918.87±37.3	+1185.43±4.6	196319.54±12.6	+4462.82±1.5	196315.46±7.9	+4462.40±1.2
17	-54905.90±58.0		-54920.02±38.8		25026.59±65.8		25104.30±41.9		200782.36±14.1		200777.86±9.1	

NOTES: (1) indicates first calculation, (2) indicates second calculation.
True north is assumed to lie on a straight line extending from the launch BC-4 pier to the Twin Lakes Bilby Tower.
Coordinates are given W.R.T. Aerobee launching tower. Altitude is with respect to sea level.

TABLE IV

THE STANDARD DEVIATIONS FOR SM1:01 DOVAP DATA; SECOND CALCULATION

Grenade	Altitude (ft)	σ_x (ft)	σ_x/σ_u	σ_y (ft)	σ_y/σ_u	σ_z (ft)	σ_z/σ_u	Avg σ_u (ft)
3	103000	±11	2.1	±12	2.3	±1.8	0.55	4.6
9	154500	±27.6	2.9	±29.8	2.3	±5.2	0.60	10.4
17	200800	±38.8	4.2*	±41.9	4.0*	±9.1	0.7*	10.9

*Extrapolated value.

Also, a request was received from Capt. W. Bandeen of USASEL to present the data with respect to a coordinate system tangent to the earth and having its origin at the center microphone in the geophone array at Twin Lakes.

The third calculation of SM1:01 data is to be done on the IBM 650 digital computer, inasmuch as a program for the DOVAP trajectory calculations has been completely checked out.

2.5.3 Data Reduction on SM1:02.—DOVAP cycle-count films for the summer firings arrived in two shipments during the month of October, one on the eleventh and the second on the twenty-ninth. Cycle-counting on SM1:02 was begun as of the end of the work period, the general editing of SM1:02 films was completed; and three of eight channels had been counted by one operator and one of eight channels by a second operator.

Additional data-reduction work included the reading of telemeter and field-strength records on SM1:02, SM1:03, SM1:04, SM1:05, and SM2:06. More accurate calculations of peak altitude and peak time for these rockets were made from recently received radar data.

2.6 FUTURE WORK

During the next quarterly work period, work on the grenade experiment will include:

1. Pre-flight testing and firing of grenade Aerobees SM1:07, SM1:08, and SM1:09 and the sphere — grenade Aerobee SM2.10 at Ft. Churchill.
2. Data reduction for all grenade Aerobees.
3. Analysis of data available on the modulation of DOVAP by the grenade explosions, and the formulation of plans for further tests on and possible uses of this effect.

4. Analytical work on:

   a. Finite amplitude of propagation.
   b. The variable velocity of propagation of electromagnetic radiation and its relation to DOVAP.

3. AIR SAMPLING

3.1 ANALYSIS OF GAS ACCUMULATED IN C-23-B.

Upon completion of the analyses of the upper air in bottle C-23-B, two analyses were made of gas collected in the bottle and connecting tubing. The first represented a collection for 90 days and the second, a collection for 69 days.

It was expected that the rate of collection of helium and neon in cc/sec determined in these analyses could be compared with the corresponding rate of collection in the entrance tubing alone (reported earlier) to determine the accumulation rate of the bottle. However, this was not correct, possibly because of the outgassing of the glass tubing during the first few days after exposure to atmospheric pressure.

The results of the two analyses are shown in Table V.

TABLE V

Accumulation Time	N.T.P. Gas*	Helium Ratio	Neon Ratio	Condensables: Before Oxidation		Condensables: After Oxidation		% Loss on Cu fil ($Liq.N_2$)
				$Liq.N_2$ %	Dry Ice %	$Liq.N_2$ %	Dry Ice %	
90 days	2.8×10^{-3}	12.7	0.505	42.5	1.0	54.5	2.2	29.4
69 days	1.02×10^{-3}	21.5	0.393	48	0.45	78.5	0.62	70.4

*With sample in bottle, on McLeod gage.

The results reduced to accumulation in cc/sec can be compared with the accumulation in entrance tubing alone in Table VI.

TABLE VI

Test	Days Test	Gas Collected cc N.T.P.	He Leak Rate cc N.T.P./sec	Neon Leak Rate cc N.T.P./sec
Entrance tubing including graded seal	9	1.5×10^{-3}	2.68×10^{-14}	2.34×10^{-15}
C-23-B and above tubing	90	2.8×10^{-3}	2.08×10^{-15}	2.86×10^{-16}
C-23-B and above tubing	69	1.02×10^{-3}	7.12×10^{-15}	4.55×10^{-16}

These data indicate that there is very little leakage in the bottle, as all the leakage can be accounted for in the graded seal. It is expected that it will be possible to check this point further with the helium leak detector. The neon leak rate is even lower than that of helium and is considered satisfactory.

3.2 BOTTLE LEAKAGE

Further checks of minute leaks which would be selective on a mass basis (as is diffusive separation) are possible on a laboratory helium leak detector. The magnitudes of the leaks which it is desired to detect, i.e., leaks large enough to account for the excess of helium and neon over ground air values (or appreciable fraction thereof) are shown in Table VII.

The helium leak detector may be calibrated for use with a standard glass leak yielding 2.66×10^{-6} cc atmos/sec at 84.2°F of helium which reads 60 units on the leak-rate meter. The smallest full-scale reading on the leak detector is one unit and the meter may be read under ideal conditions to 1/100 of full scale. This would represent a leak of 4.43×10^{-10} cc/sec. However, to assure that random noise pulses do not cause the deflection, a reading of at least 4/100 full scale is recommended. This would mean the smallest leak detectable with certainty would be 1.77×10^{-9}cc/sec.

It is therefore desirable to improve the sensitivity of the leak detector in some manner. Much of the additional sensitivity can be gained by changing the atmosphere surrounding the bottle to pure helium. This would increase the leakage rate to helium $10^6/5.24$ or 1.9×10^5 times. The air leak detectable would then be $1.77 \times 10^{-9} \div 1.9 \times 10^5 = 9.3 \times 10^{-15}$. By comparison

TABLE VII

No. Bottle	Total cc N.T.P. Gas	Total cc N.T.P. Found	cc N.T.P. Ground Air Equiv.	cc N.T.P. Excess over Gnd. Air	Time sec sample to Analysis	cc/sec Leak Rate
			Helium			
B-10	0.0546	$2.97x10^{-7}$	2.0410^{-7}	$9.6x10^{-8}$	$1.48x10^{7}$	$6.48x10^{-15}$
B-15	0.0314	$2.55x10^{-7}$	$1.545x10^{-7}$	$1.00x10^{-7}$	$6.3x10^{6}$	$1.6x10^{-14}$
C-23-B	0.0206	$1.66x10^{-7}$	$1.34x10^{-7}$	$3.2x10^{-8}$	$2.26x10^{7}$	$1.42x10^{-15}$
			Neon			
B-10	0.0546	$7.67x10^{-7}$	$6.97x10^{-7}$	$7.0x10^{-8}$	$1.48x10^{7}$	$4.72x10^{-15}$
B-15	0.0314	$6.07x10^{-7}$	$5.37x10^{-7}$	$7.0x10^{-7}$	$6.3x10^{6}$	$1.11x10^{-14}$
C-23-B	0.0206	$4.75x10^{-7}$	$4.67x10^{-7}$	$9.5x10^{-9}$	$2.26x10^{7}$	$4.20x10^{-16}$

with the possible leak rates of the bottles, this is still too small for accurate results on all three bottles.

It is therefore necessary to improve the sensitivity further to permit its use in testing the bottles.

The valving system shown in Fig. 4 was devised to permit leak-rate meter readings of leaked-in helium accumulated for a period of time, and to provide a means of calibration which would correlate the leak-rate meter readings of the bottles with the accumulation from known values.

A leak check using this system consists of four steps:

1. A leak-rate meter reading taken after the bottle has been cut off from the system for some time. This test is run with ground air in the jacket around the bottle.
2. Helium from the standard leak is allowed to leak into the bottle for a suitable period of time after which a leak-rate meter reading is made.
3. The jacket around the bottle is filled with helium and the bottle is allowed to accumulate leaked-in helium. The leak-rate meter is again read.
4. The time and leakage rate of the standard leak and the bottle leak are compared and the leak rate determined.

Sensitivity of the leak detector can be checked periodically by reading the standard leak rate directly on the leak-rate meter.

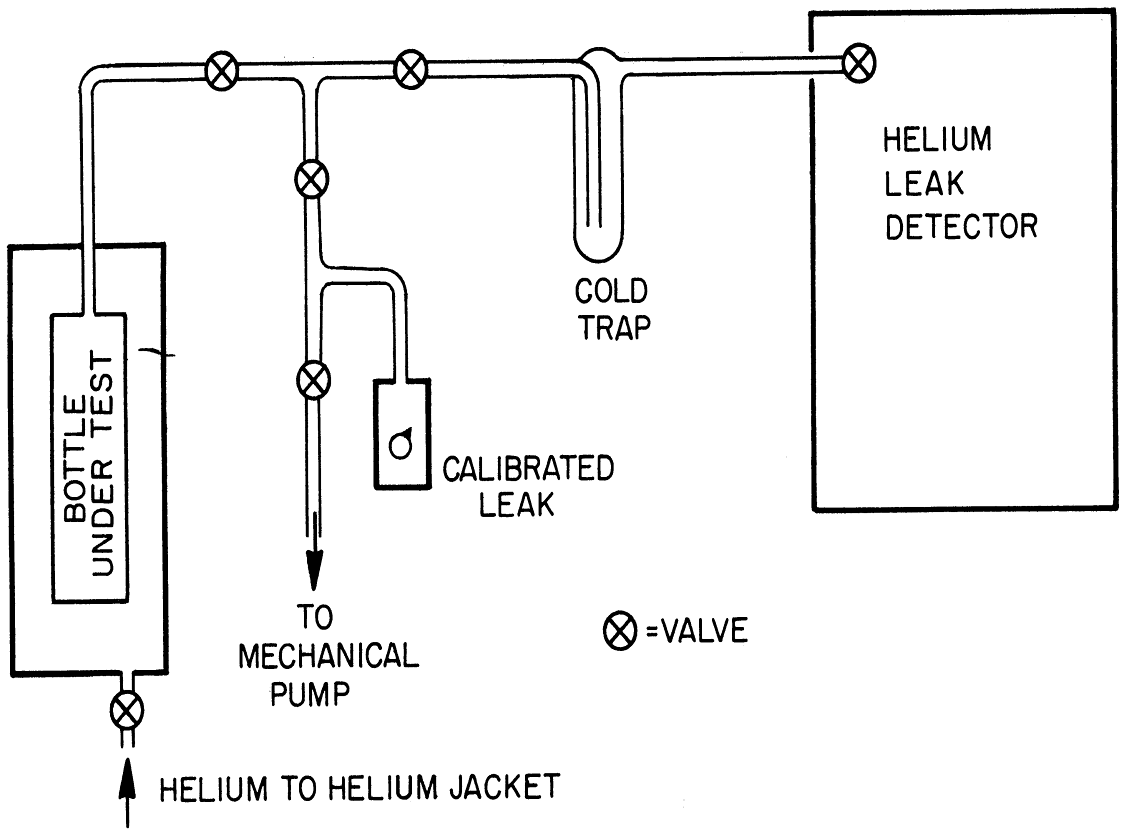

Fig. 4. Valving system for helium leak checks.

The computation of the leak rate is made by applying the formula:

$$\text{Leak rate of bottle} = \frac{\text{Rate meter reading of bottle x standard leak rate x standard leak time}}{\text{Rate meter reading of standard leak x time of bottle leak.}}$$

It can be seen that if the bottle is allowed to accumulate helium for a long period of time with respect to the leak time of a small standard leak of suitable value, the effective sensitivity can be increased by a factor of 100 or more. This increased sensitivity is sufficient to test the upper-atmosphere bottles with useful precision.

This system was used to test bottles B-10 and B-15 and the results appear promising. The data will not be completely reduced until after C-23-B has been checked.

3.3 LEAK TEST OF OTHER COMPONENTS

The selective leakage of helium through the graded seal on the analyzer reduced the chances of making accurate determinations of bottle leakage by long-term accumulation tests while the bottle was attached to the analyzer. Considerable time was spent in trying to find a vacuum-sealing material which would substantially reduce the leakage rate of helium through the graded seal.

Leak detector tests were made using the accumulation system described above. Because the volumes involved with the test parts were so small, the comparisons with accumulations from the standard leak could not be made.

A first test of Glyptal was made using a standard leak for the helium source. The inside surface of a quartz appendix, whose outside was exposed to pure helium, was coated with Glyptal. The initial leakage through the coating was very small but increased rapidly with time. The leak was reduced by such a small amount that this test was discontinued. A new leak was made with the Glyptal on the helium side of the quartz leak. The reduction of the helium leak rate was again unsatisfactory.

Leak reduction tests were then made using Apiezon vacuum wax, Apiezon vacuum grease, and electrically conductive silver paint. None of these materials reduced the permeation of helium sufficiently.

An example is given in Table VIII of the test of helium permeation of an Apiezon-waxed joint. Accumulation time of each test is one minute.

TABLE VIII

Test Time, min	Leak-Rate Meter Units/min	Test Time, min	Leak-Rate Meter Units/min
0	0.06 (background)	20	8.2
1	0.08	25	9.4
2	0.01	28	10.0
6	0.16		
10	3.4		
15	6.1		

After 30 min a direct reading could be made on the leak detector of about 4.4×10^{-8} cc/sec.

A graded seal of 0705-0080 graded glass seal was similarly tested and showed a similar increase in leakage rate with time. The leak rate was considerably lower than the wax, as can be seen from Table IX.

TABLE IX

Days	Leak-rate meter units/hour
1	0.4
2	0.9
3	4.74
4	17.5
5	29.7

3.4 FUTURE WORK

During the next quarter, results of helium leak checks are expected to be completed on bottles B-15, B-10, and C-23-B. Analyses will be made on bottles prepared with the above flight bottles. These bottles have never been opened so the accumulation in them over the period since preparation should prove interesting and give further data on bottle leakage as well as the separation which may be expected from this source.

4. AERODYNAMIC RESEARCH

During the quarter, two independent items of research related to the upper atmosphere have been completed in final form and have been accepted for publication by the Journal of Applied Mechanics and Journal of Applied Physics, respectively. The abstracts of these papers are given in the following.

"Theory of Flight of the Sounding Rocket," by V. C. Liu, J. App. Mech. "Solutions of the equations of motion of vertically ascending rockets (both in power flight and in free flight) are given in closed form. Atmospheric density is assumed to vary exponentially with altitude, and the variation of the drag coefficient of the rocket with Mach number is assumed to follow a definite pattern. (The validity of the latter assumption is established by its close agreement with measured results.) These solutions, given in terms of higher transcendental functions, most of which are available in tabulated forms, can be used for rapid estimation of sounding-rocket performance, eliminating the often used laborious process of step-wise integration. The general rocket-performance parameters prescribed in the analysis can also be used to advantage in comparing and selecting multi-stage sounding rockets."

"On the Drag of a Sphere at Extremely High Speeds," by V. C. Liu, J. App.

Phys. "The formula for the pressure-drag coefficient of a sphere which moves at extremely high speeds is derived. In the derivation it is assumed that the nose of the shock contour follows exactly the frontal half of the spherical surface and the local pressure on the frontal spherical surface corresponds to the pressure behind the shock wave after the statistical equilibrium between the various degrees of freedom of the molecule has been reached. The chemical dissociation of the molecules behind the shock wave is taken into account in the analysis. The theoretical results of the drag coefficient of the sphere agree with the corresponding available measured value within the experimental error for the range of Mach number between 5 and 10.

5. LABORATORIES VISITED

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