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Quarterly Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

(May 1, 1957 to July 31, 1957)

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Project 2387

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Figures 4 through 8 are

U. S. Army photographs.

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ABSTRACT

Two grenade Aerobee rockets were flown successfully at Ft. Churchill in July. Data reduction and analysis of records on SM1:01 has continued. Theoretical studies have continued on the subjects of the explosion-produced modulation of DOVAP records, finite amplitude of propagation effects, the effect of variation in velocity of propagation of electromagnetic radiation on the DOVAP system, the possibility of measuring ambient pressure at very high altitudes, and the dynamics of rarefied gases.

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1. INTRODUCTION

This is the ninth in the 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 (IGY);

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 WARHEAD REDESIGN

The engineering changes incorporated into the 1957 grenade rocket warhead fall into three categories: 1) aerodynamic clean-up, 2) functional improvement, and 3) weight reduction. All these have been discussed at least briefly in earlier reports.

Aerodynamic clean-up involved a nose angle reduction which increased the weight by approximately 4 pounds for a net reduction of approximately 7 pounds. The reduced drag, however, was calculated to be equivalent to a weight saving of 16 to 20 pounds.

Additional aerodynamic clean-up, probably the largest drag reduction was accomplished by BRL in the redesign of the DOVAP antennas. A by-product was a weight saving of approximately 5 pounds. University of Michigan personnel participated in conferences regarding the redesign of the DOVAP antennas.

Functional improvement can be categorized into 1) elimination of unnecessary electronic gear (i.e., grenade-ejection indicators, grenade flash detectors), 2) greater field accessibility and replaceability of electronic components, and 3) more severe inspection.

Figures 1, 2, and 3 are views looking into the three instrumentation-section compartments. The instrumentation section is placed on the rocket in such a fashion that, when the rocket is in the launching tower, the doors are located in the space between the tower rails. Each door can be removed for ready accessibility to all electronic gear.

Figure 1 shows the compartment which contains the DOVAP unit, the arm-disarm stepping relay, and the program stepping relay. The compartment shown in Fig. 2 contains the RADAR beacon cut-off receiver, and timer. (In this photo, the timer cam and cut-off receiver are not shown.) Figure 3 shows the battery compartment. Except for cables, all instrumentation-section wiring is contained on the wiring panel shown in this compartment. Electrical connections between compartments are made by cables which plug into connectors mounted on this wiring panel. Each component in each compartment, including relays and the wiring panel, is easily removed by merely disconnecting its electrical cables and unfastening a few screws. Thus each electrical component is easily replaced even when the missile is in the tower.

Two of the individual components are shown separately in Figs. 4 and 5. The timer (Fig. 4) is mounted as shown in Fig. 2 and is connected electrically by one cable. The program stepping relay and its electrical cable are shown in Fig. 5. It is mounted up against the rear wall of the compartment of Fig. 1 by slipping the mounting edges (bent down at left of Fig. 5) into pockets on the wall and then fastening one screw through the hole shown at top left of Fig. 5.

Weight reduction involved the unglamorous job of separating the structural fat from the muscle and then reducing them both. Like humans, missiles can get along with less muscle if they don't have to carry extra fat.

Table I gives a weight comparison of major warhead components between the pre-IGY 1956 warhead and the redesigned 1957 warhead. Table II gives a weight comparison of individual items of the '56 and '57 model rockets. The table is limited to those items for which significant weight reduction was accomplished.

2.2 ROCKET FABRICATION

During the quarter ending July 31, the following items were constructed or reworked and shipped to Ft. Churchill:

1. 6 complete warheads, including nose cones, grenade sections, and instrument sections.
2. 160 grenades, including 4 pounders, 2 pounders, and red destruction grenades.
3. 4 Aerobee rockets.

All items were received at the destination, and assembled and checked ready for firing on schedule.

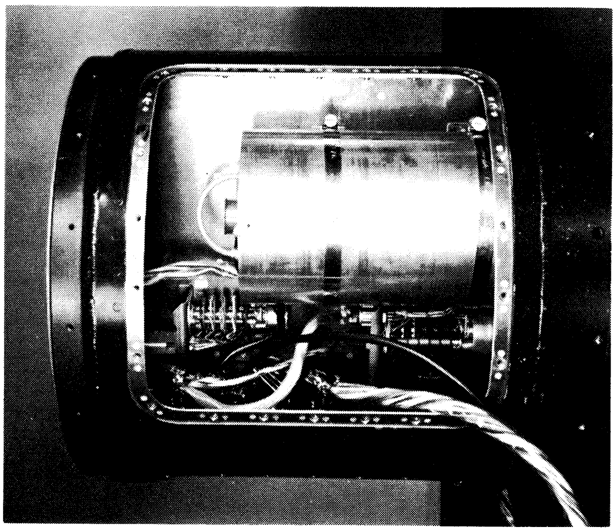

Fig. 1. Compartment containing DOVAP unit and stepping relays.

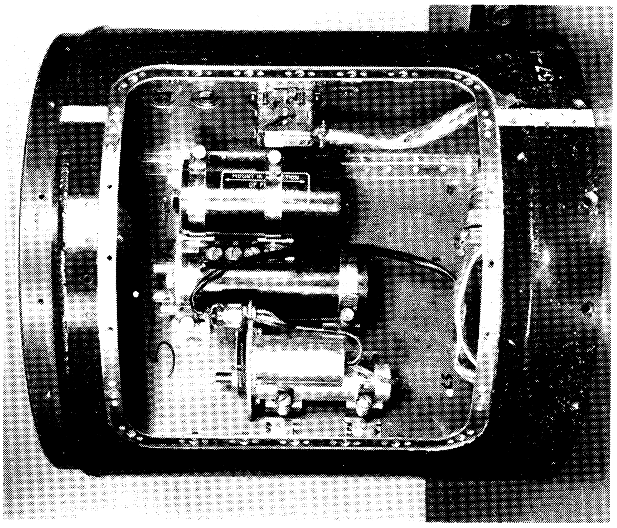

Fig. 2. Compartment containing RADAR beacon and timer (cut-off receiver not shown).

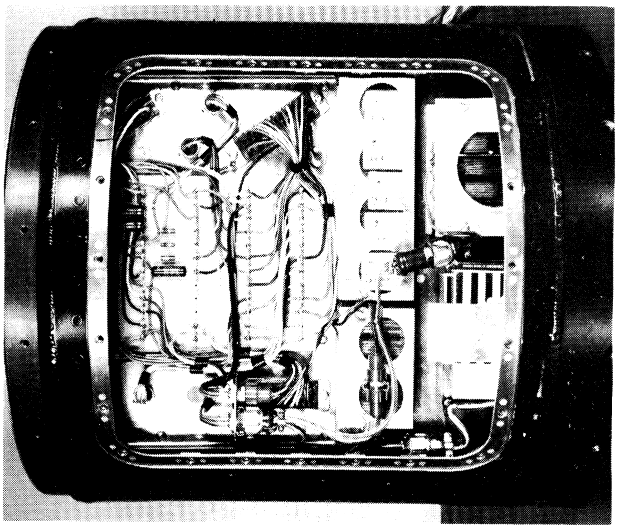

Fig. 3. Battery and wiring panel compartment.

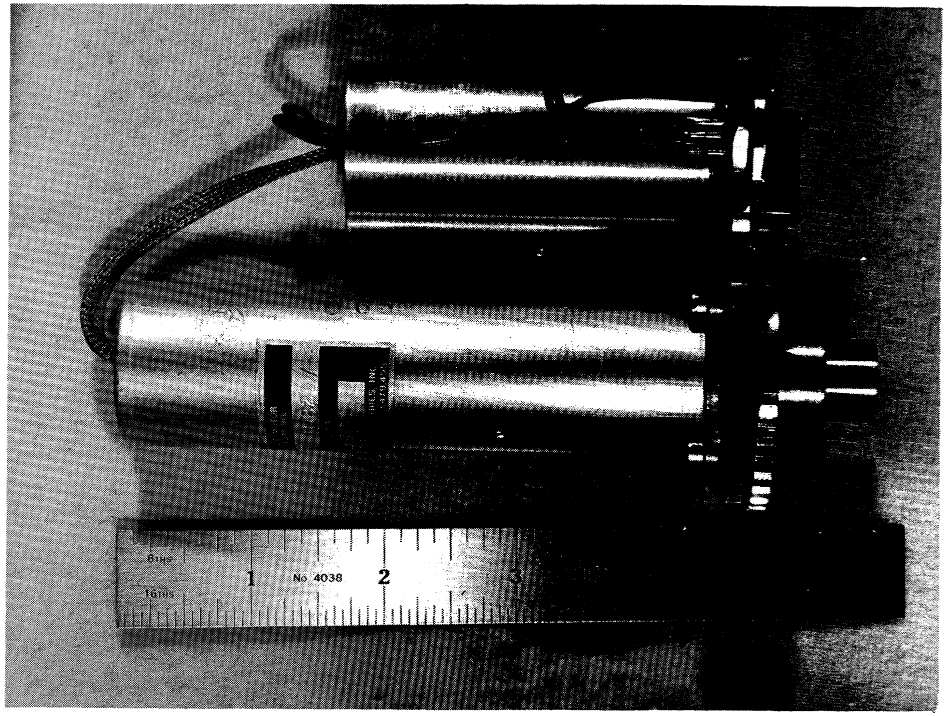

Fig. 4. Timer for grenade Aerobees SM1:02-SM2:06.

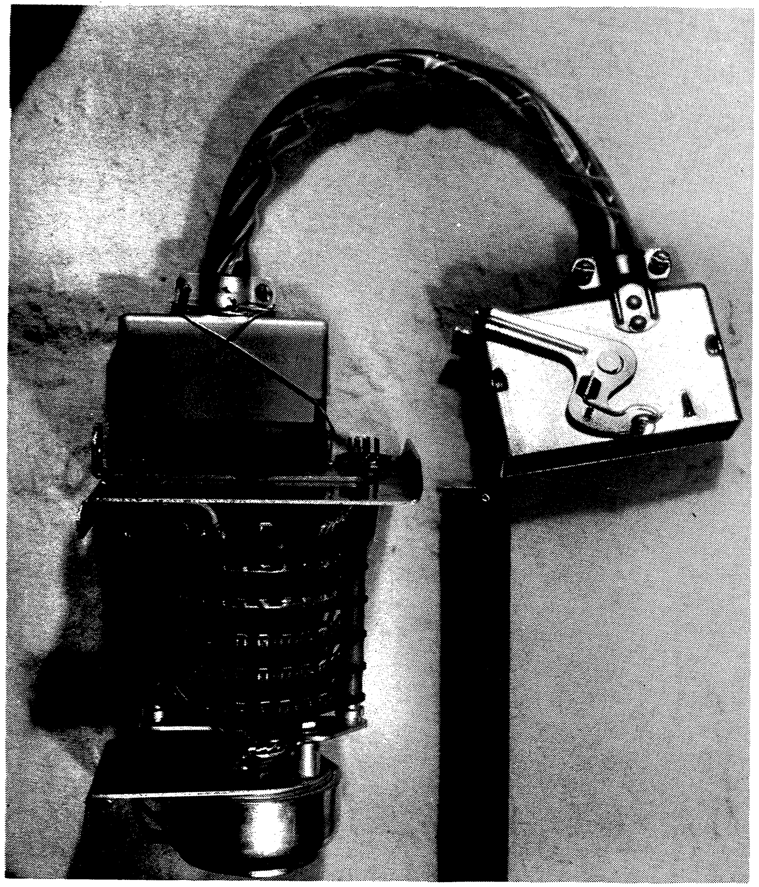

Fig. 5. Program stepping relay used on SM1:02-SM2:06.

TABLE I

WEIGHT COMPARISON - MAJOR COMPONENTS

Item	1956 wt (lb)	1957 wt (lb)	Remarks
Nose cone (complete)	23.8	16.5	See Note 1
Grenade section (complete)	47.5	31.3	See Note 2
Instrument section (complete)	50.8	38.3(42.3)	See Note 3
Complete warhead	122	86(90)	See Note 3

Notes:

1. The '56 model nose cone was a 30° right circular cone. The '57 model nose cone is a 25° right circular cone. Had the '57 nose been 30°, the weight saving would have been 4 pounds more.
2. The '56 grenade section carried 18 grenades of 4-pound size. The '57 grenade section carries 7 grenades of 4-pound size and 12 of 2-pound size. Grenade sizes are designated by weight of explosive charge only. Actual grenade wt is greater by approx. 1 pound.
3. Two '56 model instrument section were reworked to '57 models. Reworked units were of heavier material and weighed approx. 4 pounds more than new units. Reworked unit weights are in parentheses.

TABLE II

WEIGHT COMPARISON - INDIVIDUAL PARTS

Item	1956 wt (lb)	1957 wt (lb)	Remarks
4-pound grenade (metal parts)	1.0	1.0	18 used in '56 7 used in '57
2-pound grenade (metal parts)	---	.88	None used in '56 12 used in '57
Mortar barrel	1.17	.76	18 used in '56 19 used in '57
Mortar base	.21	.19	18 used in '56 19 used in '57
Bulkhead - grenade section, forward	1.42	Eliminated	
Bulkhead - grenade section, rear	3.25	2.73	
Ejection switch assembly	4.12	Eliminated	
Grenade section skin	7.75	5.0	
DOVAP container	2.1	1.1	
Timer	2.0 approx.	1.0 approx.	
Instrument section can	10.0 approx.	6.0 approx.	Reworked Aerobee 15-in. extension

2.3 GRENADES

The 1957 grenades are virtually identical to those used in 1956. The principal difference is the use of 2-pound and 4-pound grenades as against just 4-pound grenades in 1956.

A 5% sample consisting of 9 grenades (5 2-pound grenades, 3 4-pound grenades, and 1 red) was fired in early June with no malfunctions.

A complete warhead of 19 grenades was fired on the ground in early July with one grenade failing to fire. All grenades ejected properly but one lanyard broke. The dud was recovered and examined to determine the cause. Approximately 5 turns of lanyard still remained in the grenade, one of which was pulled by hand to check the adhesiveness of the potting material. The potting was normal. The lanyard showed no evidence of damaged coating or burning. The failure was a characteristic tension break.

Examination of the mortar barrel disclosed several smears of lanyard rubber, one of which coincided with the lanyard break. The smears indicated unusual whipping of the lanyard. No previous difficulties of this type had been encountered.

Because this failure was encountered only once in approximately 200 launchings of live and dummy grenades, and because the failures from all causes accounted for less than 5% of the grenades fired, no immediate corrective action was deemed advisable.

During the ground firings, one grenade caused damage to the nose cone from shrapnel. The damaged nose cone presented sharp edges which could cut lanyards if they were dragged across the damaged area. No lanyards were so cut during the ground firings. The damaged nose cone was repaired for use at Ft. Churchill.

2.4 MODIFICATION OF AEROBEE ROCKETS

The peak altitude of the AJ10-25 Aerobee rocket with the present grenade experiment design is about 58 miles under optimum conditions (see Section 2.6). With such a trajectory it is possible to get grenade explosions up to about 90 kilometers. Theoretical analysis indicates that the altitude range 90-95 km may be the upper-altitude limit from which sound arrivals from 4-pound grenades may be received with microphones of the type now used.

To determine experimentally the altitude limit for the sound arrivals, it is desirable to explode several grenades above 90 km, and this requires a rocket peak altitude considerably higher than 58 miles.

This higher peak altitude can be achieved by lengthening the propellant tanks to increase their capacity. Aerojet General has developed a standard version of this modified Aerobee called the AJ10-34, five of which have been fired successfully.

It has been decided to have two AJ10-25 Aerobees modified as described above to achieve this higher peak altitude. One of these will be used as SM2:06 to be flown at Ft. Churchill on 26 August; the other is to be flown at Ft. Churchill in the winter.

Trajectory calculations were made for this AJ10-34 Aerobee with the aerodynamic configuration and payload that it will have on the rocket grenade experiment. The results are listed in Table III. Comparison is made with the results of a similar calculation by the Aerojet General Corporation.

TABLE III

AEROBEE SM2:06 PREDICTED PERFORMANCE

	Peak Velocity (ft/sec)	Peak Altitude (miles)	Peak Time (sec)
U.M.	4720	81	188
Aerojet	4970	88.5	201

Examination of the data used in the calculations shows that the Aerojet General Corporation used 4100 pounds for the value of sea-level thrust, whereas we used the value of 4000 pounds as we have for the AJ10-25 Aerobee. (Aerojet also uses the value of 4000 pounds for the AJ10-25 Aerobee.) This discrepancy will be investigated.

2.5 TESTS AT ABERDEEN PROVING GROUND

Although Ballistic Camera photographs were obtained for the SM1:01 grenade Aerobee, Ballistic Research Laboratories personnel were not satisfied with the quality of the grenade explosion images. The images were relatively large light saturated dark spots on the plates. Although grenade-explosion-position data can be obtained from these plates, it is felt that better images and thus better data can be obtained for the IGY firings.

It has been suggested that several grenades be exploded on the ground at Aberdeen Proving Ground and that photographs, light intensity, and spectral distribution measurements be made for these explosions. These data would be used to determine the lens openings to be used on the Ballistic Cameras at Ft. Churchill for the IGY grenade rockets.

It was decided that the occasion of these optical tests would be a good time to try to study the modulation produced on the DOVAP record by the explosion-produced shock wave (as observed on SM1:01), and in particular to try to correlate the modulation with the propagation of the shock wave toward the DOVAP antennas.

A copy of a letter summarizing plans for these tests is shown in the Appendix. The tests were run during the week of May 13, 1957, as planned. Ballistic Camera photographs, Horizon camera photographs, light-intensity-vs.-time measurements, spectral distribution measurements, Fastex Camera photographs, DOVAP records, pressure-gauge records, and meteorological data were obtained for nine grenade detonations.

The data from these tests have not yet been completely evaluated. A technical note covering the measurement techniques and test results will be prepared by the Ballistic Research Laboratories. A report on the results of the DOVAP modulation and its correlation with shock-wave propagation will be issued by The University of Michigan.

2.6 AEROBEE FIRINGS AT FT. CHURCHILL

The IGY Grenade Aerobee rockets SM1:02 and SM1:03 were fired at Ft. Churchill on July 21, 1957, and July 23, 1957, respectively. A brief summary of the schedule of operations is given in Table IV. Figure 6 was taken during the horizontal test of SM1:02 and shows one of the test squibs simulating grenade number 1 being detonated. Figure 7 shows Aerobee SM1:02 on the removable launcher rail, ready for installation in the launching tower.

TABLE IV

SCHEDULE OF OPERATIONS FOR AEROBEES SM1:02 AND SM1:03

	SM1:02	SM1:03
Horizontal test	July 12, 1957	July 16, 1957
Vertical test	July 17, 18	July 23
Firing	2216:28.5 CST July 21	2329:50 CST July 23

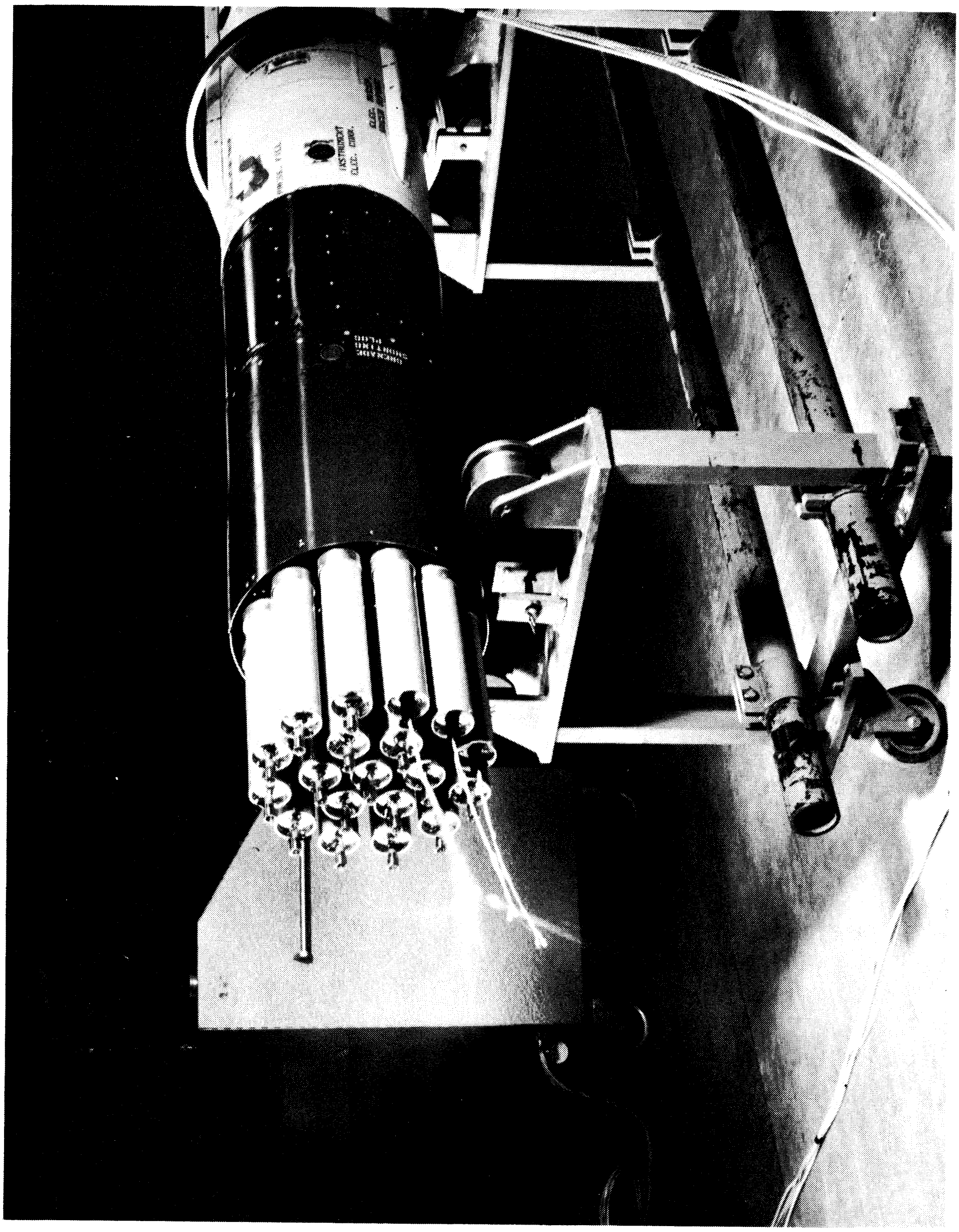

Fig. 6. Horizontal test of Aerobee SM1:02. Squib simulating grenade number 1 being detonated.

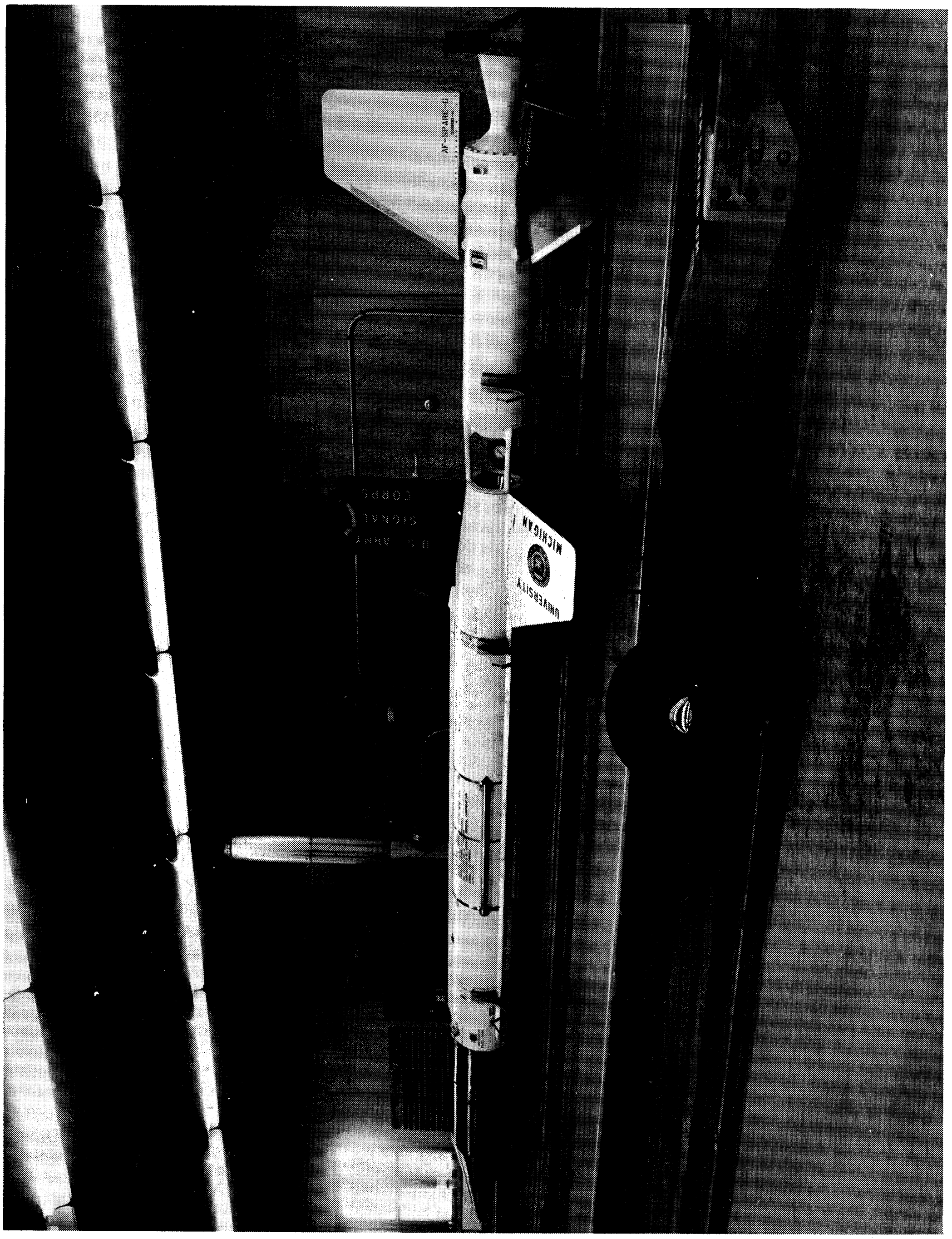

Fig. 7. Grenade Aerobee SM1:02 on launcher rail, ready for installation into launching tower.

These flights were both very successful. The Aerobee SM1:03 launching is shown in Fig. 8. Each rocket had 1 grenade out of 19 which failed to explode. Below are several possible explanations for these failures:

1. Grenade ejection squib did not receive current pulse.
2. Grenade ejected, lanyard failed by burning due to damaged rubber coating.
3. Grenade ejected, lanyard failed due to unusual dynamic whipping.
4. Grenade ejected, release pin pulled, firing pin jammed in cocked position.
5. Grenade ejected, firing mechanism functioned properly, explosive did not detonate.
6. Grenade ejected, lanyard cut by shrapnel damage to nose cone.

All the above possibilities have either occurred on previous firings or could have occurred if inspection did not reveal the faults which would cause them.

Evidence obtained from the DOVAP telemeter record indicates that in all cases current was applied to the ejection squib. Therefore possibility 1 must be eliminated.

Possibility 2 occurred twice during 1956 ground firings, but is believed to be virtually eliminated in 1957 by more severe inspection.

Possibilities 3 through 6 cannot be eliminated. However, possibility 6—lanyard cut by shrapnel damage—appears to be the most likely cause of the failure of the grenades to explode.

On SM1:02 the sound arrival from the last grenade appears to be hidden by the arrival of the ballistic wave due to the re-entry of the missile. It is possible that this arrival may be identified after an exhaustive examination of the record; however, the data on arrival times for this explosion will probably not be very accurate. All other sound arrivals on SM1:02 and SM1:03 were recorded by the sound ranging array.

Both of these rockets were fired shortly after sundown, so that, although the sun had set on the ground, the atmosphere above 100,000 ft was still sunlit. After each grenade explosion the expanding shock could be seen by the light scattered at the shock front. In addition, the smoke from each explosion could be seen and the smoke trails were photographed by the Ballistic Cameras. It is possible that some data on wind direction will be obtained from the Ballistic Camera plates.

Preliminary data summarizing the excellent results obtained from these flights are given below:

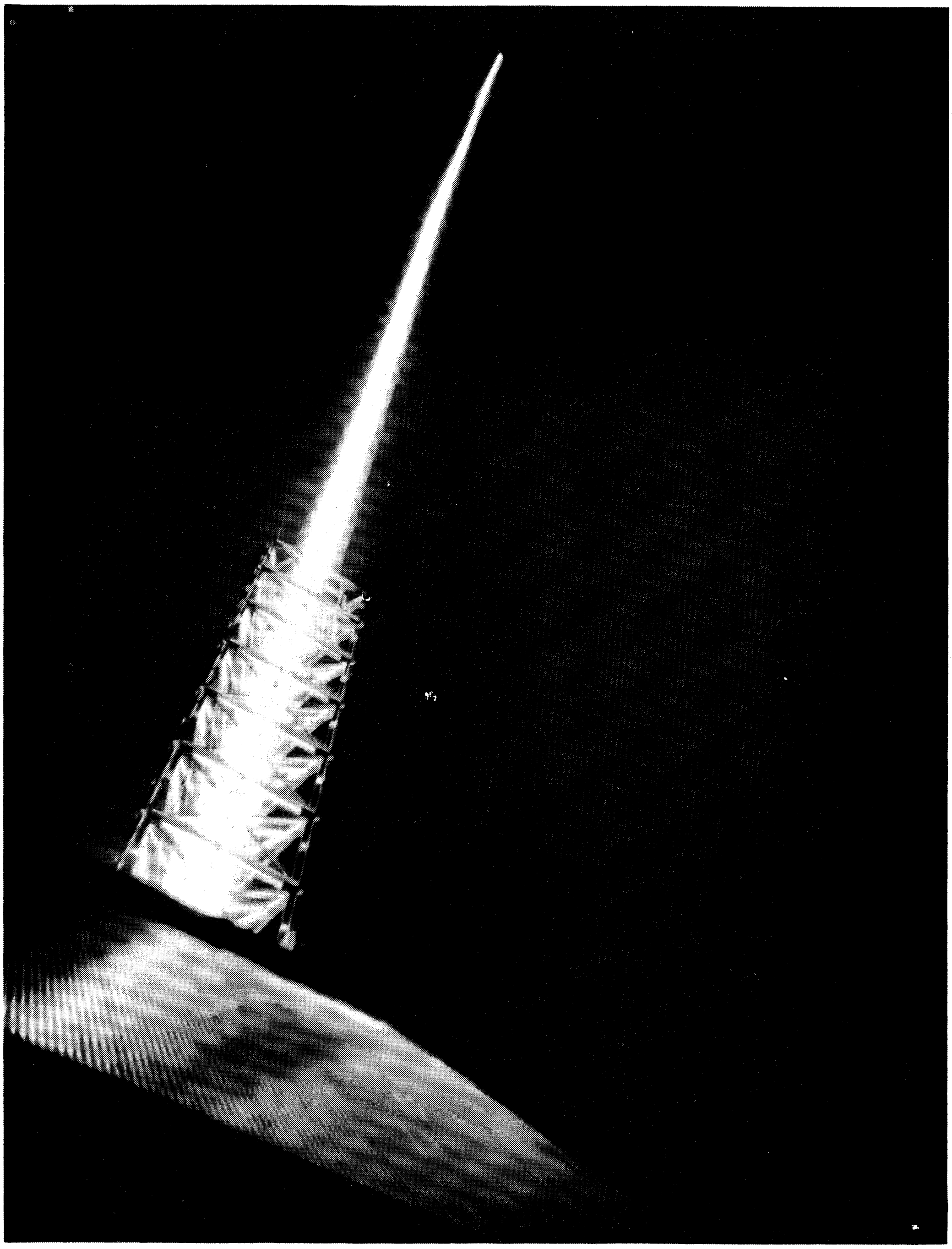

Fig. 8. Grenade Aerobee SM1:03 launching.

Flight	SM1:02	SM1:03
Date	July 21, 1957	July 23, 1957
Hour	2216:28.5 CST	2329:50 CST
Burn-out velocity	4110 ft/sec	4050 ft/sec
Burn-out altitude	77,000 ft	68,000 ft
Peak time	158 sec	151 sec
Peak altitude	58 miles	55 miles
Grenades not exploded	No. 14	No. 9
Sound arrivals recorded	1-13, 15-18	1-8, 10-19
Altitude range covered by experiment	26-87 km	25-82 km
DOVAP telemeter records	Excellent	Excellent
DOVAP cycle-count data	Excellent	Excellent
Ballistic Camera photographs	Excellent	Excellent
Supporting meteorological data	Excellent	Excellent

2.7 SM1:01 DATA REDUCTION

2.7.1 Evaluation of the initial SM1:01 DOVAP trajectory calculation.— The previous quarterly report (2387-25-P) summarizes the progress in the SM1:01 DOVAP trajectory calculation as of May 1, 1957, i.e.:

a. The trajectory up to 27.5 sec was obtained from MIDAC.
b. The grenade-explosion-position data were hand-calculated because MIDAC was shut down.
c. Examination of the deviations between the four independent solutions indicated that these deviations were larger than they should be.

The grenade-position data are shown in Table V. The four solutions for each grenade position, the average solution for each grenade position, and the standard deviation of each average are given. Data illustrating that these deviations are too large are shown in Tables VI and VII.

In Table VI, standard deviations are listed for grenades 3 and 9. Values of σ_x/σ_u, σ_y/σ_u, and σ_z/σ_u obtained from graphs of theoretical values of these ratios for 20 miles and 30 miles altitude over the Ft. Churchill range,* average values of σ_u calculated from these data, and values of σ_n ($\sigma_n = \sigma_u/\lambda$) are also listed. The values of σ_n obtained (0.65 cycle and 1.06 cycles) are much larger than the 0.1 cycle which is accepted as the standard for DOVAP cycle counting.

In Table VII, standard deviations for grenades 1, 9, and 17 are compared with data taken at corresponding altitudes for flight AM2:21.[1] Although the standard deviations for grenade 1 are about the same as those for AM2:21 at a corresponding altitude, the standard deviations for grenades 9 and 17 are about a factor of three larger than the corresponding standard deviations for AM2:21.

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*These graphs were prepared by W. Dean of BRL, Aberdeen Proving Ground.

TABLE V

INITIAL SM1:01 GRENADE - POSITION DATA

Horizontal coordinates are with respect to launching tower, vertical coordinate is with respect to sea level (x is positive north, y is positive west, and z is vertically upward, with the line from the launch BC-4 pier to Twin Lakes Bilby Tower assumed to lie in the true north-south direction).

Grenade	Time, sec	Solution	x, ft		y, ft		z, ft	
1	41.870 (after lift)	1	-16,982.64	+20.11	6,205.77	-22.33	82,738.93	+ 3.29
		2	-16,983.57	+19.18	6,254.85	+26.73	82,735.26	- 0.38
		3	-17,024.47	-21.72	6,208.82	-19.30	82,730.31	- 5.33
		4	-17,020.30	-17.55	6,243.02	14.90	82,738.05	+ 2.41
		Avg	-17,002.75	±11.4	6,228.12	±12.3	82,735.64	± 1.9
2	45.330	1	-19,406.87	+32.80	7,384.47	-36.40	93,226.13	+ 6.08
		2	-19,408.38	+31.29	7,465.02	+44.15	93,219.71	- 0.34
		3	-19,475.52	-35.85	7,389.47	-31.40	93,211.72	- 8.33
		4	-19,467.91	-28.24	7,444.53	+23.66	93,222.63	+ 2.58
		Avg	-19,439.67	±18.6	7,420.87	±20.3	93,220.05	± 3.1
3	48.789	1	-21,810.53	+37.19	8,564.71	-41.23	103,214.97	+ 7.57
		2	-21,812.24	+35.48	8,656.44	+50.50	103,207.27	- 0.13
		3	-21,888.71	-40.99	8,570.40	-35.54	103,198.25	+ 9.15
		4	-21,879.41	-31.69	8,632.21	+26.27	103,209.12	- 1.72
		Avg	-21,847.72	±21.1	8,605.94	±22.7	103,207.40	± 3.5
4	52.314	1	-24,236.71	+45.37	9,754.22	-50.24	112,933.10	+ 9.94
		2	-24,238.80	+43.28	9,866.46	+62.00	112,923.26	+ 0.10
		3	-24,332.37	-50.29	9,761.18	-43.28	112,912.27	-10.89
		4	-24,320.42	-38.34	9,836.00	+31.54	112,924.01	+ 0.85
		Avg	-24,282.08	±25.7	9,804.46	±27.7	112,923.16	± 4.3
5	55.776	1	-26,627.47	+46.89	10,922.95	-64.39	122,046.77	+10.92
		2	-26,629.64	+44.72	11,089.22	+101.88	122,036.18	+ 0.33
		3	-26,726.59	-52.23	10,930.16	-57.18	122,024.79	-11.06
		4	-26,713.76	-39.40	11,007.03	+19.69	122,035.66	- 0.19
		Avg	-26,674.36	±26.6	10,987.34	±38.9	122,035.85	± 4.5

TABLE V (Continued)

Grenade	Time, sec	Solution	x, ft		y, ft		z, ft	
6	59.206	1	-28,967.04	+55.09	12,069.93	-60.93	130,671.46	+13.50
		2	-28,969.58	+52.55	12,206.78	+75.92	130,658.57	+ 0.61
		3	-29,083.69	-61.56	12,078.42	-52.44	130,645.13	-12.83
		4	-29,068.20	-46.07	12,168.31	+37.45	130,656.66	- 1.30
		Avg	-29,022.13	±31.2	12,130.86	±33.7	130,657.96	±5.4
7	62.686	1	-31,337.04	+61.67	13,236.98	-68.18	139,018.15	+15.85
		2	-31,339.88	+58.83	13,390.42	+85.26	139,003.21	+ 0.91
		3	-31,467.83	-69.12	13,246.50	-58.66	138,988.08	-14.22
		4	-31,450.10	-51.39	13,346.76	+41.60	138,999.78	- 2.52
		Avg	-31,398.71	±35.0	13,305.16	±37.7	139,002.30	± 6.2
9	69.653	1	-36,069.40	+76.12	15,570.74	-84.08	154,535.41	+21.20
		2	-36,072.92	+72.60	15,760.50	+105.68	154,515.80	+ 1.59
		3	-36,231.16	-85.64	15,582.50	-72.32	154,496.81	-17.40
		4	-36,208.59	-63.07	15,705.55	+50.73	154,508.81	- 5.40
		Avg	-36,145.52	±43.2	15,654.82	±46.6	154,514.21	± 8.1
10	73.071	1	-38,392.28	+78.06	16,728.14	-86.20	161,569.90	+22.53
		2	-38,395.89	+74.45	16,922.89	+108.55	161,549.21	+ 1.84
		3	-38,558.29	-87.95	16,740.21	-74.13	161,529.54	-17.83
		4	-38,534.88	-64.54	16,866.13	+51.79	161,540.82	- 6.55
		Avg	-38,470.34	±44.3	16,814.34	±47.8	161,547.37	± 8.5
11	76.588	1	-40,767.07	+84.37	17,908.32	-93.15	168,415.43	+25.22
		2	-40,770.97	+80.47	18,118.96	+117.49	168,392.41	+ 2.20
		3	-40,946.64	-95.20	17,921.37	-80.10	168,370.92	-19.29
		4	-40,921.08	-69.64	18,057.23	+55.76	168,382.09	- 8.12
		Avg	-40,851.44	±47.9	18,001.47	±51.6	168,390.21	± 9.5
12	80.081	1	-43,129.17	+87.20	19,086.90	-96.26	174,815.63	+26.94
		2	-43,133.20	+83.17	19,304.75	+121.59	174,791.17	+ 2.48
		3	-43,314.88	-98.51	19,100.40	-82.76	174,768.67	-20.02
		4	-43,288.24	-71.87	19,240.61	+57.45	174,779.29	- 9.40
		Avg	-43,216.37	±49.5	19,183.16	±53.4	174,788.69	±10.1

TABLE V (Concluded)

Grenade	Time, sec	Solution	x, ft		y, ft		z, ft	
13	83.497	1	-45,435.77	+89.35	20,243.56	-98.61	180,693.30	+28.48
		2	-45,439.91	+85.21	20,466.87	+124.70	180,667.56	+ 2.74
		3	-45,626.14	-101.02	20,257.39	-84.78	180,644.21	-20.61
		4	-45,598.66	-73.54	20,400.86	+58.69	180,654.23	-10.59
		Avg	-45,525.12	±54.6	20,342.17	±54.7	180,664.82	±10.6
14	86.999	1	-47,787.82	+94.77	21,417.99	-104.59	186,328.22	+31.15
		2	-47,792.21	+90.38	21,654.97	+132.39	186,300.18	+ 3.11
		3	-47,989.84	-107.25	21,432.67	-89.91	186,275.06	-22.01
		4	-47,960.50	-77.91	21,584.67	+62.09	186,284.82	-12.24
		Avg	-47,882.59	±53.8	21,522.58	±58.0	186,297.07	±11.6
15	90.499	1	-50,141.88	+96.66	22,606.03	-106.66	191,563.05	+32.75
		2	-50,146.35	+92.19	22,847.83	+135.14	191,533.65	+ 3.35
		3	-50,348.01	-109.47	22,621.01	-91.68	191,507.66	-22.64
		4	-50,317.91	-79.37	22,775.89	+63.20	191,516.82	-13.48
		Avg	-50,238.54	±54.9	22,712.69	±59.2	191,530.30	±12.2
16	93.963	1	-52,463.99	+97.55	23,770.58	-107.63	196,353.57	+34.03
		2	-52,468.51	+93.03	24,014.69	+136.48	196,323.12	+ 3.58
		3	-52,672.11	-110.57	23,785.70	-92.51	196,296.47	-23.07
		4	-52,641.57	-80.03	23,941.87	+63.66	196,304.98	-14.56
		Avg	-52,561.54	±55.4	23,878.21	±59.7	196,319.54	±12.6
17	97.476	1	-54,799.73	+106.17	24,945.45	-117.14	200,820.52	+38.16
		2	-54,804.65	+101.25	25,211.23	+148.64	200,786.48	+ 4.12
		3	-55,026.31	-120.41	24,961.91	-100.68	200,756.98	-25.38
		4	-54,992.92	-87.02	25,131.76	+69.17	200,765.48	-16.88
		Avg	-54,905.90	±58.0	25,062.59	±65.8	200,782.36	±14.1

TABLE VI

STANDARD DEVIATIONS FOR SM1:01 DOVAP DATA

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)	Avg σ_n (cycles)
3	103,207	±21.1	2.1	±22.7	2.3	±3.5	0.55	6.3	0.65
9	154,514	±43.2	2.9	±46.6	2.3	±8.1	0.60	13.5	1.06

TABLE VII

COMPARISON OF STANDARD DEVIATIONS FOR SM1:01 AND AM2:21

Grenade	Altitude	σ_x, ft		σ_y, ft		σ_z, ft	
		SM1:01	AM2:21	SM1:01	AM2:21	SM1:01	AM2:21
1	82,739	±11.4	±12.5	±12.3	±13	± 1.9	±3.5
9	154,514	±43.2	±14	±46.6	±15	± 8.1	±3
17	200,782	±58.0	±22	±65.8	±23	±14.1	±5

Since SM1:01 flew almost directly over the center of the range whereas AM2:21 flew to one side of the range, standard deviations for SM1:01 should be smaller than those for AM2:21.

Although the standard deviations for the individual grenade positions are too large, the solutions for the difference in grenade positions have much less scatter. The four solutions for the differences between successive grenade positions, the average solution for these differences and the standard deviation of these averages are shown in Table VIII. It can be seen that all standard deviations for differences in grenade positions are less than 13.3 ft. Indeed, the maximum standard deviation for a horizontal coordinate difference between two grenades is 13 ft and the maximum standard deviation for a difference in altitude between two grenades is 2 ft. These values are well within the 10-meter accuracy required for the measurement of relative grenade positions, and so it is felt that the data of Table VIII are sufficiently accurate for the calculation of temperature and winds.

TABLE VIII

INITIAL RELATIVE GRENADE-POSITION DATA FOR AEROBEE SM1:01

Grenades	Solution	x, ft		y, ft		z, ft	
1-2	1	-2,424.23	+12.70	1,178.70	-14.06	10,487.20	+2.79
	2	-2,424.81	+12.12	1,210.17	+17.44	10,484.45	+0.04
	3	-2,451.05	-14.12	1,180.65	-12.11	10,481.41	-3.00
	4	-2,447.61	-10.68	1,201.51	+ 8.75	10,484.58	+0.17
	Avg	-2,436.93	± 7.2	1,192.76	± 7.8	10,484.41	±1.2
2-3	1	-2,403.66	+ 4.39	1,180.24	- 4.83	9,988.84	+1.48
	2	-2,403.86	+ 4.19	1,191.42	+ 6.35	9,987.56	+0.20
	3	-2,413.19	- 5.14	1,180.93	- 4.14	9,986.53	-0.83
	4	-2,412.50	- 3.45	1,187.68	+ 2.61	9,986.49	-0.87
	Avg	-2,408.05	± 2.5	1,185.07	± 2.7	9,987.36	±0.6
3-4	1	-2,426.18	+ 8.17	1,189.51	- 9.01	9,718.13	+2.37
	2	-2,426.56	+ 7.79	1,210.02	+11.50	9,715.99	+0.23
	3	-2,443.66	- 9.31	1,190.78	- 7.74	9,714.02	-1.74
	4	-2,441.01	- 6.66	1,203.79	+ 5.27	9,714.89	-0.87
	Avg	-2,434.35	± 4.6	1,198.52	± 5.0	9,715.76	±0.9
4-5	1	-2,390.76	+ 2.16	1,168.73	-14.15	9,113.67	+0.98
	2	-2,390.84	- 2.08	1,222.76	+39.88	9,112.92	+0.23
	3	-2,394.22	- 1.30	1,168.98	-13.90	9,112.52	-0.17
	4	-2,393.34	+ 0.42	1,171.03	+11.85	9,111.65	-0.04
	Avg	-2,392.92	± 1.0	1,182.88	±13.30	9,112.69	±0.3
5-6	1	-2,339.57	+ 8.19	1,146.98	+ 3.46	8,624.69	+2.58
	2	-2,339.94	+ 7.82	1,117.56	-25.96	8,622.39	+0.28
	3	-2,357.10	- 9.34	1,148.26	+ 4.74	8,620.34	-1.77
	4	-2,354.44	- 6.68	1,161.28	+17.76	8,621.00	-1.11
	Avg	-2,347.76	± 4.7	1,143.52	+ 9.2	8,622.11	±1.0
6-7	1	-2,370.00	+ 6.58	1,167.05	- 7.26	8,346.69	+2.34
	2	-2,370.30	+ 6.28	1,183.64	+ 9.33	8,344.64	+0.29
	3	-2,384.14	- 7.56	1,168.08	- 6.23	8,342.95	-1.40
	4	-2,381.90	- 5.32	1,178.45	+ 4.14	8,343.12	-1.23
	Avg	-2,376.58	± 3.7	1,174.31	± 4.0	8,344.35	±0.9

TABLE VIII (Continued)

Grenades	Solution	x, ft		y, ft		z, ft	
7-9	1	-4,732.36	+14.45	2,333.76	-15.90	15,517.26	+5.36
	2	-4,733.04	+13.77	2,370.08	+20.42	15,512.59	+0.69
	3	-4,763.33	-16.52	2,336.00	-13.66	15,508.73	-3.17
	4	-4,758.49	-11.68	2,358.79	+ 9.13	15,509.03	-2.87
	Avg	-4,746.81	± 8.2	2,349.66	± 8.9	15,511.90	±2.0
9-10	1	-2,322.88	+ 1.94	1,157.40	- 2.12	7,034.49	+1.33
	2	-2,322.97	+ 1.82	1,162.39	+ 2.87	7,033.41	+0.25
	3	-2,327.13	- 2.31	1,157.71	- 1.81	7,032.73	-0.43
	4	-2,326.29	- 1.47	1,160.58	+ 1.06	7,032.01	-1.15
	Avg	-2,324.82	± 1.1	1,159.52	± 1.2	7,033.16	±0.5
10-11	1	-2,374.79	+ 6.32	1,180.18	- 6.95	6,845.53	+2.68
	2	-2,375.08	+ 6.03	1,196.07	+ 8.94	6,843.20	+0.35
	3	-2,388.35	- 7.24	1,181.16	- 5.97	6,841.38	-1.47
	4	-2,386.20	- 5.09	1,191.10	+ 3.97	6,841.27	-1.58
	Avg	-2,381.11	+ 3.6	1,187.13	± 3.9	6,842.85	+1.0
11-12	1	-2,362.10	+ 2.83	1,178.58	- 3.12	6,400.20	+1.72
	2	-2,362.23	+ 2.70	1,185.79	+ 4.09	6,398.76	+0.28
	3	-2,368.24	- 3.31	1,179.03	- 2.67	6,397.75	-0.73
	4	-2,367.16	- 2.23	1,183.38	+ 1.68	6,397.20	-1.28
	Avg	-2,364.93	± 1.6	1,181.70	± 1.7	6,398.48	±0.7
12-13	1	-2,306.60	+ 2.15	1,156.66	- 2.35	5,877.67	+1.53
	2	-2,306.71	+ 2.04	1,162.12	+ 3.11	5,876.39	+0.25
	3	-2,311.26	- 2.51	1,156.99	- 2.02	5,875.54	-0.60
	4	-2,310.42	- 1.67	1,160.25	+ 1.24	5,874.94	-1.20
	Avg	-2,308.75	± 1.2	1,159.01	± 1.3	5,876.14	±0.6
13-14	1	-2,352.05	+ 5.42	1,174.43	- 5.98	5,634.92	+2.67
	2	-2,352.30	+ 5.17	1,188.10	+ 7.69	5,632.62	+0.37
	3	-2,363.70	- 6.23	1,175.28	- 5.13	5,630.85	-1.40
	4	-2,361.84	- 4.37	1,183.81	+ 3.40	5,630.60	-1.65
	Avg	-2,357.47	± 3.1	1,180.41	± 3.3	5,632.25	±1.0
14-15	1	-2,354.06	+ 1.89	1,188.04	- 2.08	5,234.83	+1.61
	2	-2,354.14	+ 1.81	1,192.86	+ 2.74	5,233.47	+0.25
	3	-2,358.17	- 2.22	1,188.34	- 1.78	5,232.60	-0.62
	4	-2,357.41	- 1.46	1,191.22	+ 1.10	5,231.99	-1.23
	Avg	-2,355.95	± 1.1	1,190.12	± 1.2	5,233.22	±0.6

TABLE VIII (Concluded)

Grenades	Solution	x, ft		y, ft		z, ft	
15-16	1	-2,322.11	+ 0.90	1,164.55	- 0.97	4,790.52	+1.28
	2	-2,322.16	+ 0.85	1,166.86	+ 1.34	4,789.47	+0.23
	3	-2,324.10	- 1.09	1,164.69	- 0.83	4,788.81	-0.43
	4	-2,323.66	- 0.65	1,165.98	+ 0.46	4,788.16	-1.08
	Avg	-2,323.01	± 0.5	1,165.52	± 0.5	4,789.24	±0.5
16-17	1	-2,335.74	+ 8.62	1,174.87	- 9.51	4,466.95	+4.12
	2	-2,336.14	+ 8.22	1,196.54	+12.16	4,463.36	+0.53
	3	-2,354.20	- 9.84	1,176.21	- 8.17	4,460.51	-2.32
	4	-2,351.35	- 6.99	1,189.89	+ 5.51	4,460.50	-2.33
	Avg	-2,344.36	± 4.9	1,184.38	± 5.3	4,462.83	±1.5

2.7.2 The second calculation of SM1:01 DOVAP trajectory data.—Although the initial SM1:01 DOVAP trajectory calculation gave satisfactory results for the relative grenade positions, the absolute grenade-position data had standard deviations larger than should be obtained on a good DOVAP data reduction. Accordingly it was felt desirable to examine critically the entire data-reduction procedure. When this was done, the following four sets of changes were made:

1. The raw cycle-count data were changed.
    a. A correction of +0.1 cycle was made to all stations in the interval 2.5 to 3.0 sec because of a previously unnoticed imperfection.
    b. The cycle counts in the region up to 6 sec were counted to the nearest 0.01 cycle instead of to the nearest 0.05 cycle since the low frequency permitted this.
    c. A correction of -0.5 cycle was applied to the data from the Twin Lakes station in the interval 19 to 19.5 sec due to a different interpretation of an irregular spot on the record.
    d. An irregularity in the series of counts in the interval 42 to 44.5 sec at Digges station was smoothed out while keeping the total count in the interval constant.

2. The spin correction was modified. Because the two antennas at the launch station are in different locations separated by about 31 ft, they receive a different doppler cycle count even if the missile is not spinning. This fact was overlooked in the initial spin correction process and all the difference in cycle count was attributed to spin. For the trajectory of SM1:01 a difference of two cycles in count between these two stations is obtained in

the first 5 sec for a nonspinning missile. This produces a change in the total spin correction during this interval of 1 cycle. After this time this effect is very small, i.e., it is valid to assume that the difference in cycle count is entirely due to spin.

3. The initial point of the trajectory was taken at the time of wire break (0.654-sec range time) rather than at 1-sec range time. When the initial cycle count was made, it was felt that the cycles in the region from wire break to 1-sec range time were too difficult to interpret, and so the initial position was taken at 1-sec range time at a point calculated as described in the last quarterly report. However, after a discussion with W. Dean at the Ballistic Research Laboratories, it was decided to use these data. Accordingly the initial position was taken at wire break and the cycle counts in the interval 0.654 to 1 sec were counted.

4. The coordinates used for the launch antenna were corrected. In the initial calculation the coordinates of the launch-station antenna were taken as the mean of the coordinates of the left-hand and right-hand antennas. This was incorrect and was changed to the coordinates of the right-hand antenna since data for all right-hand antennas (corrected for spin) were used in the trajectory calculations.

The net effect in the SM1:01 trajectory data should be as follows:

a. Absolute positions at any time should be changed slightly; relative positions between any two grenade positions should be affected by a negligible amount.
b. The scatter in absolute and relative positions should be decreased.

Because the MIDAC was shut down, calculations are being made by hand. As of the end of this work period, some grenade positions had been calculated. Standard deviations were smaller than on the initial calculations. This will be reported on in full in the next quarterly report.

2.7.3 The IBM 650 program for the DOVAP trajectory.—The programming of the DOVAP trajectory calculations for the IBM 650 computer was begun. Several runs had been made; however, as of the end of this work period, the program was not yet working.

2.7.4 Cycle counting.—The cycle counting of the remainder of the SM1:01 flight, 100 to 279 sec, has been completed. The count was read off and recorded at 5-sec intervals except for the region around the peak of the trajectory, where it was read off and recorded at 0.5-sec intervals.

Two operators, working independently took two weeks to perform this counting. The improved training of the operators demonstrated itself in the fact that the checking of the count by the supervisor (not including the time spent on studying the irregularities in the record) took less than one day.

2.7.5 Noisy spots in the SM1:01 DOVAP cycle-count record.—A considerable amount of time has been devoted to the study of noisy spots and other irregularities in the DOVAP cycle-count record. The times of the irregularities have been tabulated along with a short description of the nature of the irregularity.

It appears that most of the irregularities can be connected with the null of the missile transmitting antenna. This antenna has approximately the field strength pattern of a loop antenna with null axis at right angles to the missile's longitudinal axis. When the orientation of the missile is such that this axis is directed at, or close to, one of the receiving antennas, the signal received at the station is weak and noise predominates. In the case of a spinning missile, then, as the null of the missile transmitting antenna sweeps by one of the receiving antennas, it produces a noisy section on the DOVAP cycle-count records. At the same time a rather sudden phase shift is produced in the record. This sudden phase shift can be as large as $\pm \pi$. Its magnitude depends on how close to the receiving antenna, in terms of the angle, the null axis actually is. This phase shift is corrected for on the average by the spin correction; however, it is important to identify these noisy spots as definitely being due to spin. If a noisy spot is not due to spin, then a different kind of correction may have to be applied.

Consideration of the known spin rate of the missile as determined from the launch-signal-strength record together with the known geometry of the receiving stations and the observed periodicity of the noisy spots leads to the identification of those noisy spots which are due to this cause.

Some irregularities on the SM1:01 DOVAP cycle-count record still remain unexplained; however, the study will be continued on this and the other grenade Aerobee DOVAP records.

2.8 VELOCITY OF PROPAGATION OF ELECTROMAGNETIC RADIATION AND DOVAP TRAJECTORY CALCULATIONS

The velocity of propagation of electromagnetic radiation transmitted through the atmosphere varies with the air density. Thus the wavelength of the DOVAP carrier varies as it travels from the ground up through the air to the missile and then back down to the ground. In the DOVAP data reduction, the wavelength λ_{av} is assumed to be constant at an average between its computed wavelength at the surface of the earth and the generally accepted vacuum wavelength. It is known that this assumption may introduce error in the absolute position data obtained from DOVAP.

The average carrier wavelength λ enters the DOVAP trajectory calculations in the calculation of transmitter-missile-receiver distances

$$u_i = u_{i-1} + \lambda_{av} \cdot \Delta n_i \quad , \tag{1}$$

each of which determines an ellipsoid of revolution in space having the transmitter and receiver as foci. The intersection of three such ellipsoids of revolution determines the position of the missile in space. If more than three u_c are known at a given time, a least-squares solution for the missile position is obtained.

The exact equation for the u_i, incorporating the variation of λ as a function of air density, appears to be difficult to write down; however, a method of calculating the u_i has been worked out which considers in an approximate manner the variation of λ as a function of air density. This method has been used to calculate the u_i for Aerobee SM1:01 at the time of grenade 17 explosion. These u_i are larger than those calculated from Eq. (1). The largest differences are: 47 ft in the case of Launch station, and 62 ft in the case of Digges station.

The difference in missile position between a data reduction using constant λ and one using the method incorporating a correction for variable λ has not been completely evaluated as yet. It is expected that there will be a difference in absolute grenade positions but that relative grenade positions will be affected only slightly.

It is hoped that the consideration of the variable velocity of propagation of electromagnetic radiation in the DOVAP data reduction may be of some value in comparing DOVAP position points for grenade explosions with explosion-position data obtained from Ballistic Cameras.

2.9 FINITE AMPLITUDE PROPAGATION

The finite amplitude propagation effect, that is to say, the distance that a shock wave covers in traveling from the explosion to the ground minus the distance that a sound wave would cover in the same interval of time, has been computed for explosions of 4-pound grenades at different altitudes. The results are plotted in Fig. 9. The method of calculation has been outlined in the Quarterly Report 2387-6-P of November 15, 1955. As stated there, the calculations are largely based on a dimensionless solution for spherical blast waves by H. L. Brode.[2] In the recent calculations the ARDC model atmosphere, 1956, has been used.

The interval Δt, by which the travel time from the explosion to the ground is shortened because of the finite amplitude propagation, is plotted as the function of the altitude of the explosion in Fig. 10. It should be pointed out that the curve in Fig. 10 is much more dependent on the assumed temperature profile than the plot in Fig. 9. A correction for finite amplitude propagation effect can be introduced into the data reduction if the measured time of travel from the explosion to the geophone array is increased by this amount Δt before the computation of winds and temperatures. Such a correction would be especially important in the layer between the explosion of a 2-pound grenade and the explosion of a 4-pound grenade.

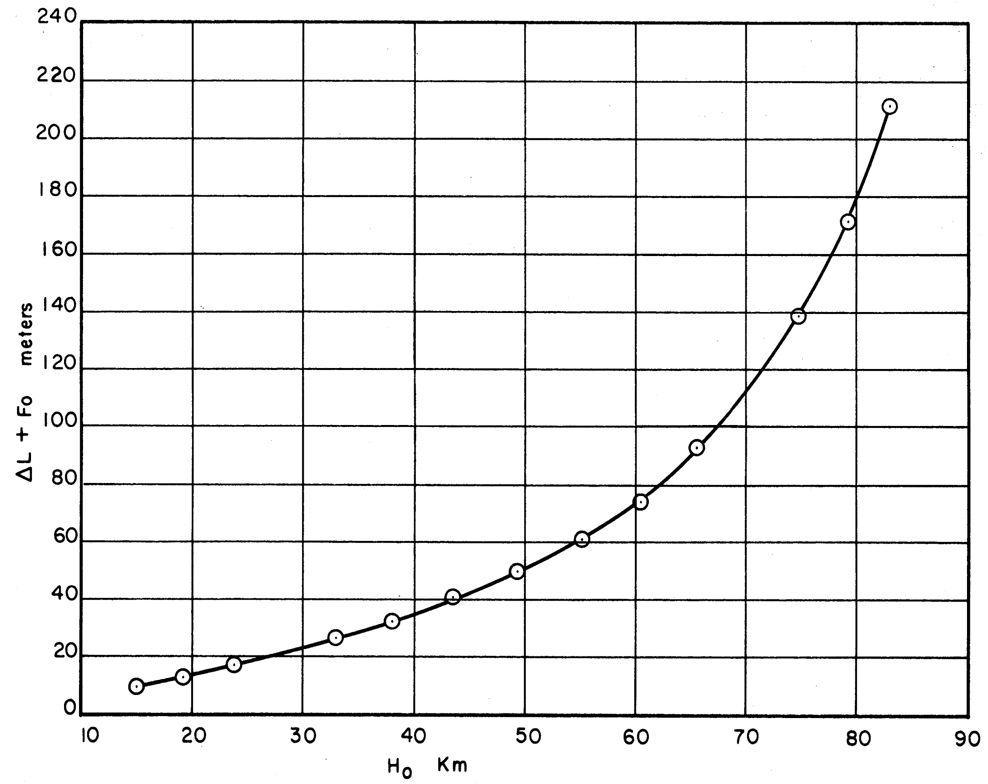

Fig. 9. Finite amplitude propagation effect.

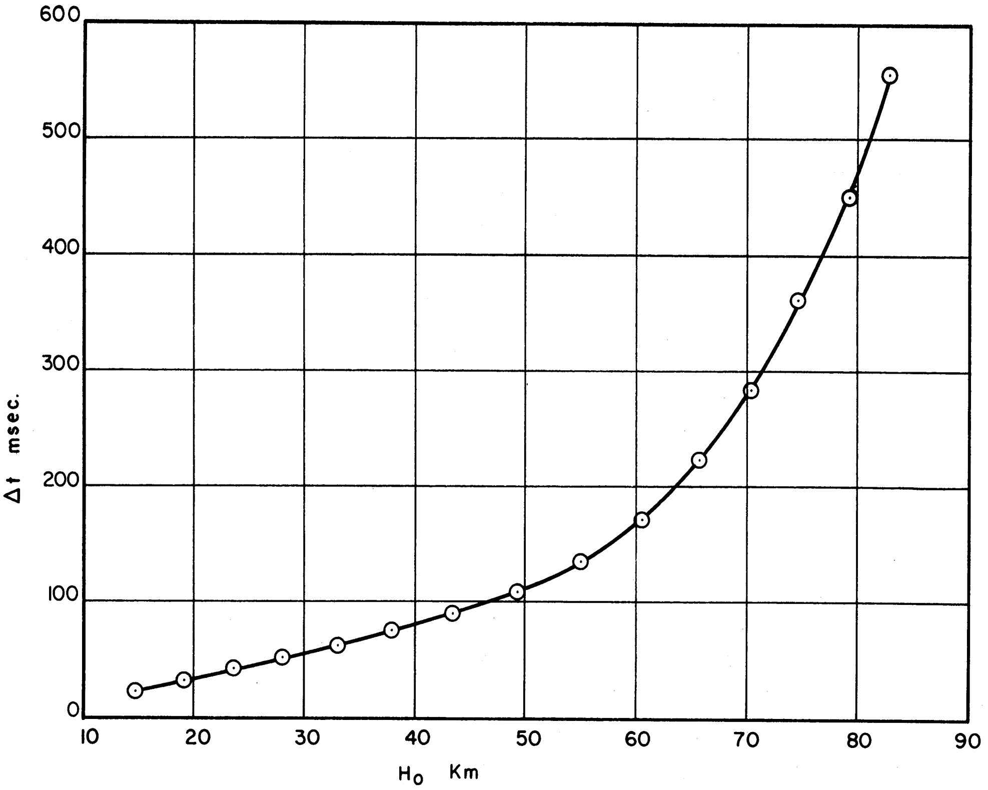

Fig. 10. Finite amplitude of propagation corrections to travel times.

After the calculations for 4-pound grenades had been carried out, it was discovered that a very large difference exists between the numerical results of Brode and the data of Bethe.[3] According to an interpretation of Brode's results, the ratio E_W/E of the energy of the shock wave E_W to the total energy of the explosion E is about 0.06 at the point where the relative overpressure π is 0.07. According to Bethe, this ratio is from 0.2 to 0.3. If figures by Bethe are accepted, the finite amplitude propagation effect will be larger by about a factor of 2. Further calculations have been postponed until this discrepancy has been clarified.

2.10 MODULATION OF THE DOVAP RECORD BY THE GRENADE EXPLOSIONS

The last quarterly report contains a qualitative description of the disturbance produced on the DOVAP record by the grenade explosions. In this report, the modulation of the DOVAP record was described qualitatively as consisting of three phases:

1. An initial phase starting within 1 millisecond of the grenade explosion time, indicated by missile and ground flash detectors, during which several "secondary" doppler cycles appear to be superimposed upon the regular doppler frequency.
2. The second phase, starting 5 milliseconds or less after the time of grenade explosion. During this phase noise often completely dominates the signal. This phase may last for as long as 8 milliseconds or may not appear at all.
3. A third phase in which secondary doppler cycles again are superimposed upon the regular doppler frequency.

The possible explanation of this modulation as being due to effects produced by the expanding shock front was also discussed in the last quarterly report, i.e.:

1. During phase one the secondary doppler cycles could be due to multiple paths of propagation. The secondary doppler cycles would, in this case, be a measure of the relative velocity of the shock wave with respect to the missile.
2. Phase two could be due to effects produced when the shock wave arrives at the DOVAP antennas.
3. Phase three would be due to multiple propagation effects occurring after the shock wave has passed the DOVAP antennas.

The additional paths of propagation could be due to reflection from the surface of the shock wave or from some point inside the shock wave. It is possible that there might be enough ionization persisting for a long enough period of time to enable this reflection to take place. Another possibility is that these effects are caused by the aluminum powder contained in the grenade's high-explosive mixture.

A program of study of this modulation effect has been begun. The primary objective of this study is to determine whether or not the effect can be used to make measurements of one of the upper-atmosphere parameters. It appears that the shock-wave propagation is a function of the ambient air density. Measurement of its propagation characteristics should yield information on upper-air ambient density.

The attempt to reproduce the modulation effect during the ground tests at Aberdeen Proving Ground Section 2.5) has not been completely evaluated yet, because of the urgency of the summer's rocket firings. The data from SM1:01 and the data from the ground tests will be analyzed shortly.

2.11 FUTURE PROGRAM

During the next quarter, work on the grenade experiment will include:

1. The pre-flight tests and firing of grenade Aerobees SM1:04, 1:05, and 2:06 at Ft. Churchill.
2. Construction of grenades and instrumentation section for grenade Aerobees SM1:07, 1:08, 1:09, and 2:10 to be fired at Ft. Churchill in December, 1957, and January, 1958.
3. Data reduction on grenade Aerobees SM1:01 through SM2:06.
4. Programming of DOVAP trajectory calculations for the IBM 650.
5. Analysis of data already available on the modulation of DOVAP by the grenade explosions, and the formulation of plans for further tests to be made in studying this effect.
6. Analytical studies of:
    a. Finite amplitude of propagation
    b. The variable velocity of propagation of electromagnetic radiation and DOVAP

3. AIR SAMPLING

3.1 INTRODUCTION

During this quarter the analysis of stratospheric sample in bottle C-23-B was completed. Dr. Paneth reported the results of analysis of stratospheric sample in bottle B-25. A re-examination of all data was started. A trip to Germany was made to discuss the results of the analysis of bottle B-25. In addition, separate discussions were held with Drs. Paneth, Wänke, Howe, Nichols, and Ebert regarding the interpretation of the results to date.

3.2 ANALYSIS OF BOTTLE C-23-B AT ANN ARBOR

Upper-atmosphere bottle C-23-B was found to contain 0.0206 cc N.T.P. of air. With this sample, three analyses were made in this laboratory. The results include: loss of gas on a hot copper filament, helium ratio and neon ratio with respect to ground air, condensables removed with a dry-ice trap, and condensables removed with a liquid nitrogen trap. These condensable checks were made both before and after operation of the copper filament.

The overall procedures for analysis of C-23-B followed closely our two previous analyses on bottles B-10 and B-15. The sequence of operations was as follows:

1. Calibration runs on the new ionization gage with ground-air sample No. 18 for O_2, He. Runs 1, 2, 3, and 4.
2. Analysis of gas accumulated in the connecting tubing between the unopened bottle and the extraction töpler pump for O_2, He, Ne, and condensables. One run.
3. Analysis of upper-atmosphere sample in C-23-B for O_2, He, Ne, and condensables. Runs 1 and 2.
4. Analysis of ground-air sample No. 18, 5th run.
5. The glass vial containing a portion of the upper-atmosphere sample was sealed off the system (sample later analyzed in Germany). Analysis of bottle sample remaining in the analyzer after seal-off of the vial, 3rd run. This check gave assurance that no composition change took place during seal-off. The analysis was for He, Ne, O_2, and condensables.
6. Analysis of the residual gas remaining in the sample bottle after previous töplering, plus leakage and outgassing through connecting tubing. One run for O_2, He, Ne, and condensables.
7. Analysis of gas baked from the walls of the bottle after last analysis. One run for condensables. Another run for He, Ne, O_2, and condensables.
8. Analysis of ground-air sample No. 18 admitted to C-23-B after a brief baking and pumping. One run for He, Ne, O_2, and condensables.
9. Analysis of ground-air sample No. 18, 6th run for He, Ne, O_2, and condensables.

The results of these runs are tabulated in Table IX.

3.3 ANALYSIS OF C-23-B IN GERMANY

On August 26, an analysis of a sample of C-23-B was made at the Max Planck Institute at Mainz. The techniques and procedures were observed by a representative of this laboratory.

TABLE IX

ANALYSIS OF BOTTLE C-23-B

Sample	Run	cc N.T.P. of Gas After Oxidation, with Dry-Ice Trap	He Ratio*	Ne Ratio	% Gas Lost on Hot Filament	Condensable Matter			
						Before Oxidation		After Oxidation	
						Vol.** Lost Liq. N_2 %	Vol. Lost Dry Ice %	Vol. Lost Liq. N_2 %	Vol. Lost Dry Ice %
Ground Air									
18	1	0.00853	1.00		18.1	--	--	--	0.81
18	2	0.00564	1.00	1.00	18.8	--	--	--	0.67
18	3	0.00365	1.00	1.00	18.7	--	--	--	0.61
18	4	0.00769	1.00	1.00	19.0	--	--	--	0.81
18	5	0.00424	1.00	1.00	18.3	--	--	--	0.82
18	6	0.00585	1.00	1.00	17.9	--	--	1.96	0.35
Leaked in or Outgassed Material									
Before C-23-B Opening	1	0.000694	4.56	0.117	7.41	83.5	46.7	92.5	50.0
Upper-Atmosphere Bottle C-23-B									
C-23-B	1	0.00544	1.256	1.037	0.13	3.3	0.76	4.1	1.33
C-23-B	2	0.00445	1.222	1.016	0.23	--	--	--	1.17
C-23-B	3	0.00348	1.248	0.010	0.36	--	--	--	0.69
Upper-Atmosphere Bottle C-23-B, Analyzed in Germany									
C-23-B	7	0.0057	1.11 ± 10%	1.04 ± 2%	--	--	--	--	--
Residue in Upper Atmosphere Bottle C-23-B									
C-23-B	4'	0.00094	2.695	0.588	3.1	31.0	0.92	34.4	1.42
Hot Residue from Upper-Atmosphere Bottle C-23-B									
C-23-B	5"	0.00422	----	----	3.5	85.7	25.0	--	--
C-23-B	6"	0.00392	0.0325	0.00425	~3.9	85.9	25.8	89.4	26
Ground Air No. 18 Introduced into Bottle C-23-B									
18 in C-23-B	1	0.00792	0.952	0.958	~0.0	3.4	0.4	3.5	0.44

---

*Ratio of He to N_2 + A in unknown sample divided by the same ratio in ground air. The same applies to neon ratio.

**Measured with McLeod gage.

The soft glass vial was attached to the system and the joints were checked for leaks. This section was then allowed to pump overnight and was again checked. It proved satisfactory. The vial was then opened and analysis proceeded. One run was made using the entire sample of 0.0057 cc N.T.P. (The quantity of gas checked closely with the amount computed to be in the vial.) The results of the run are shown in Table IX. No ground-air runs were made either before or after the analysis. However, calibration checks of the Pirani gage were made using pure helium and neon immediately after each determination. Due to some instability of the gage, the accuracy of the helium determination was estimated to be ±10% and the accuracy of the neon ± 2%.

These results check reasonably well with our analysis of C-23-B.

3.4 ANALYSIS OF UPPER-ATMOSPHERE BOTTLE B-25

In December an analysis was made at the Max Planck Institute at Mainz of stratospheric sample B-25 from SC-34 Aerobee fired August 9, 1956. The results of this analysis are reported here for the first time.

The German laboratory reported that all work was done under the most favorable conditions. All Pirani readings were made late at night when variation of fields due to electrical equipment was at a minimum and there was little movement in the building to affect the galvanometers.

Only one run was made. It was felt that one run with a moderately large sample with high accuracy was superior to several runs of less accuracy. No data were taken on oxygen content, condensables, or argon content. The data reported are as follows:

Helium ratio = 3.14 Neon ratio = 1.34

Following this analysis, a small quantity of ground air, about the size of the upper-air sample was introduced into the bottle and allowed to remain for 11 weeks. At that time it was analyzed as above. The results are:

Helium ratio = 2.12 Neon ratio = 1.15

On the basis of these data Dr. Paneth has expressed the opinion that the separation shown was due to a small leak in the bottle structure. Bottle C-22-B from SC-34 was found to have been damaged on impact and contained gas at atmospheric pressure; therefore no analysis could be made on this bottle.

3.5 EXAMINATION OF DATA

Now that most of the data from the flights of SC-34 and SC-35 are in, the data may be summarized as follows.

SC-34

Altitude 85.5 km

B-25 (the only good bottle)

Helium Ratio	Neon Ratio
3.14	1.34

SC-35

Altitude 86.0 km

B-10	1.49	1.10	Avg 3 runs
B-15	1.65	1.13	Avg 4 runs
C-23-B	1.24	1.02	Avg 3 runs

From these data it is very apparent that some factor other than diffusive separation in the upper atmosphere is operative. It is not immediately clear from a study of the bottle and sampling conditions what this effect is.

A study of the various effects that may be involved in bottle sampling was undertaken by a re-examination of all data. The factors involved include:

- helium ratio
- neon ratio
- argon ratio
- percentage of oxygen
- altitude of sampling
- velocity at sampling
- diameter of intake tube on bottle
- size of sample collected
- presence of Philips gage in bottle
- operation of Philips gage in bottle
- presence of Pirani gage in bottle
- time between preparation of bottle and sampling
- time between sampling and analysis
- ambient pressure during sampling
- ambient temperature during sampling
- ram pressure during sampling
- control test of bottle with built-in ground-air sample
- adsorption test of nitrogen in sample bottle
- helium leak detection of sample bottle
- pressure change in bottle after sealing
- pressure change in bottle after sampling
- condensable matters in liquid nitrogen or in dry ice in air sample
- behavior toward heated oxide-covered copper filament

An attempt was made to compare each variable with each of the others. In several cases there is insufficient data to draw any conclusions. In other cases the data showed no diffinite trend. There appeared to be a few cases which showed an indication that they might influence the result of the sampling. It is hoped that these can be resolved by further laboratory experiments. No conclusions will be drawn at this time.

3.6 DISCUSSIONS

During the quarter, discussions were held with Drs. Paneth, Wänke, and Ebert in Germany, and with Drs. Nichols and Howe here at this laboratory. In these discussions the overall results were considered as carefully as possible. A plan was then set up for further operation.

3.7 FUTURE WORK

The following is our plan of operation for the next quarter:

1. The bottle B-25 will be returned to our laboratory for examination. Leaks in the bottle of the size indicated in their ground-air aging check should be readily detectable on our helium leak detector. This check should show that the leakage did not take place in their analyzer.
2. A sample of upper-atmosphere gas from B-25 was returned to this laboratory for analysis. This will further correlate the results of the two types of analyzer.
3. A series of checks will be made on sample bottles prepared for flight in August, 1956. The leakage of these bottles, if any, and the analysis of the gas contained in the bottles would be an indication of what might be expected in upper-atmosphere bottles fabricated during the same period.
4. A mass spectrometric analysis of samples remaining from B-10 and B-15 will be made to determine argon/nitrogen ratio. A complete analysis of the gas in the vials will also be attempted.
5. With these data, a further evaluation of the results will be made, and, if possible, conclusions will be drawn as to the validity of the results of our sampling.

4. MEASUREMENTS WITH ION GAGES AT HIGH ALTITUDES

The validity of existing density or pressure measurements, by direct methods such as by ionization gages, above about 100 miles, is questionable because of outgassing of the rockets carrying the instrument.[4] We are exploring the feasibility of incorporating an ion gage and telemeter in a small ejectable unit which is previously outgassed on the ground and sealed in a capsule until after ejection. Some of the phenomena which must be considered with this approach are: the effect of ionization present due to solar radiation, photoelectrons emitted from the ion collector by solar radiation, the effect of motion of the ejected unit on ion collection, the effect of dissociation on the calibration of the gage, etc. It already appears that difficulties arising from these phenomena can be overcome, but more detailed study is required before an adequate proposal can be made.

5. RAREFIED-GAS-FLOW RESEARCH

The theoretical analysis of pitot-tube pressure in a rarefied gas stream is made within the same framework of approximations as described in the previous progress reports (2387-22-P; 2387-25-P). The motive of this analysis can be briefly discussed. The present method of treating a rarefied gas flow is based on some plausible physical concept; namely, starting from the free-molecule-flow theory in which the frequency of collisions between the molecules in the neighborhood of the body is negligible compared to that between the molecules and the body, and the effect of molecular collisions is gradually taken into account in successive approximations. It would be very desirable to check the theoretical results concerning a particular model of flow against experimental results. This appears perhaps more likely to materialize with a pitot-tube pressure measurement than with a drag-force (on a flat plate, say) measurement which would involve precise force determination in a wind tunnel. A more valid reason for analyzing pitot-tube pressure in a rarefied gas flow is that the pitot-tube method has been one of the most successful rocket-sounding method of measuring ambient density at an intermediate altitude where Rayleigh's supersonic pitot-tube equation applies.

Although the final result of the present analysis of the pitot-tube pressure in a rarefied gas flow has not yet been obtained, the sketch of the method of approach can be briefly reported. In calculating the free-molecule-pitot-tube pressure in steady state, we equate the number of molecules flowing into the cavity to that passing out of it at the mouth of the pitot tube. The same condition prevails in the present analysis except that in determining the number of molecules transferring at the opening of the tube, we take the molecular collisions into consideration in a restricted manner.

6. LABORATORIES VISITED

The following places were visited during this quarter:

Ballistic Research Laboratories, Aberdeen Proving Ground
U. S. Army Signal Engineering Laboratories
Otis Air Force Base, Massachusetts
Ft. Churchill, Manitoba, Canada
Max Planck Institute for Chemistry, Mainz, Germany

7. ACKNOWLEDGEMENT

We are indebted to the Meteorological Branch of the U. S. Army Signal Engineering Laboratories for continued collaboration and support, and to the Ballistic Research Laboratories, Aberdeen Proving Ground, for their collaboration in conducting the ground tests on grenades.

8. REFERENCES

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2. H. L. Brode, "Numerical Solutions of Spherical Blast Waves," *J. Appl. Phys.*, *26*, 766 (June, 1955).

3. H. A. Bethe *et al.*, "Shock Hydrodynamics and Blast Waves," AEDC-2860, 59 (Oct., 1944).

4. H. E. Newell, Jr., *High Altitude Rocket Research*, Academic Press, Inc., N. Y., 1953.

APPENDIX

NOrmandy 3-1511
Extension 2546

1520 E. Engineering Bldg.
University of Michigan
Ann Arbor, Michigan

May 7, 1957

Mr. Warren W. Berning
Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

Dear Warren:

The following is a summary of my understanding of our plans for testing grenades at Aberdeen Proving Ground during the week of May 13, 1957.

The objectives of these tests are:

1) to obtain light-intensity and spectral-distribution data for the flash from the grenades, and

2) to measure the modulation produced on the DOVAP record by the explosion-produced shock wave and to correlate this modulation with the propagation of the shock wave toward the DOVAP antennas.

The data on light intensity and spectral distribution will be of help to personnel who will operate the Ballistic Cameras at Fort Churchill for grenade Aerobees SM1:02 and SM1:03. The measurement of DOVAP modulation is an attempt to reproduce at sea level an effect which was obtained on the DOVAP records of grenade Aerobee SM1:01 (November 11, 1956). The attempt to correlate this modulation with the shock-wave propagation is made to find out under controlled conditions if this modulation is due to the reflection of the DOVAP RF carrier from the shock-wave surface or from some point within the expanding sphere of gases from the explosion.

A by-product of these tests is the operational training of personnel who will operate Ballistic Camera and DOVAP equipment at Fort Churchill during the IGY.

The tests will be made at the "Perkins" test site on Spesuti Island at Aberdeen Proving Ground. The attached sketch is a plan view indicating the approximate location of equipment at this test site.

The grenades will be exploded at one end of a mound of sand which has dimensions of approximately 30 ft x 20 ft x 3 ft high. The grenades will be electrically detonated by type M-8 "Engineers Special" detonators or equivalent. They will be mounted on a suitable support 2 to 2.5 feet above a 5- or 6-foot diameter 0.5-inch-thick steel plate.

Ballistic Camera photographs of the explosion will be taken from a point about 5 miles distant across Chesapeake Bay. A screen will be placed between the explosion and the Ballistic Cameras to reduce the intensity of the light that reaches the cameras to an amount simulating the magnitude of light intensity that would reach the camera from a grenade exploded at high altitudes. Time intensity and spectral-distribution measurements will be taken from a site on the island close to the "Perkins" location.

DOVAP antennas will be mounted on a simulated Aerobee rocket, complete with nose cone. This "dummy" rocket will be located on the sand bank at a distance of 20 to 25 feet from the explosion. The DOVAP transponder will be mounted inside of or closely adjacent to the "dummy" rocket. The rocket will be mounted 4 or 5 feet above the sand and will be tilted slightly so the nose cone will point directly at the explosion.

An array of six Barium Titanate gages will be located between the explosion and the "dummy" Aerobee to measure the propagation of the shock wave toward the DOVAP antennas. These gages will be located at distances of 3.3, 6.6, 9.9, 13.2, 15.5, and 19.8 feet from the center of the grenade, respectively.

A flash detector consisting of a Kodak Ektron lead-sulphide cell and amplifier will be mounted on a barricade which stands about 200 feet from the mound of sand. Recording and communication equipment will be contained in trailers located behind the barrier. The switch used to apply electrical current to the type M-8 detonators will be located there, also.

Records obtained for each explosion will be as follows:

1) The Grenade Flash.

    a) Ballistic Camera photograph.
    b) Time-intensity curve.
    c) Spectrograph record.

2) DOVAP and Shock Propagation—Oscilloscope Record.

    a) DOVAP signal.
    b) Barium Titanate gage signals.

- c) Timing (1 kc or 10 kc).
- d) Flash time (R1130B flash tube operated by Kodak Ektron flash detector).

3) Auxiliary DOVAP Measurements—Oscillograph Record.

- a) 74-mc receiver AGC (Ground Station).
- b) 74-mc antenna front and back power (transponder).
- c) Timing (as above).
- d) Flash time—output of flash detector.

General meteorological data will aid the interpretation of test results. For this purpose the following data should be recorded:

1) Barometric pressure.
2) Temperature.
3) Wind speed and direction.
4) Visibility.
5) Relative humidity.

The schedule of firings is as follows:

May 13 — Overall equipment check-out and inspection.

May 14 — (Night) — Explode and take data for one 2-lb and one 4-lb grenade.

May 15 — (Night) — a) If previous night's data are good and proper settings of camera equipment are known, fire remainder of grenades (three 2-lb and three 4-lb grenades).
b) If cameras' settings are doubtful, fire one 2-lb and one 4-lb grenade.

May 16 — (Night) — Fire remaining grenades, if any.

The grenades are being shipped from the National Northern Company early this week.

The scheduled arrival of personnel at APG to assist in and witness the tests is as follows:

May 13 — Fred. L. Bartman - Univ. of Mich.

May 14 — Robt. L. Woodburn - Natl. Northern.

May 15 — Capt. W. Bandeen - USASEL.

I will bring the nose cone for the "dummy" rocket and the Kodak Ektron flash-detector circuit to APG when I come next week.

There is one aspect of these plans of which I am uncertain. We are planning to fire the grenades from a point 2 to 2.5 feet above ground. This 2 or 2.5 feet corresponds to the estimated maximum radius of the fireball. The shock wave which propagates toward the "dummy" rocket and DOVAP antenna system consists of the direct (or incident) wave plus a reflected wave joined together at the top of the Mach stem increases with distance from the explosion. It is possible that there may be reflection of the DOVAP RF carrier from each of the waves, with some difficulty in interpreting the results. If after the first two explosions it should become apparent that this is the case, it would be desirable to explode the grenade much higher in the air or down at the surface of the ground.

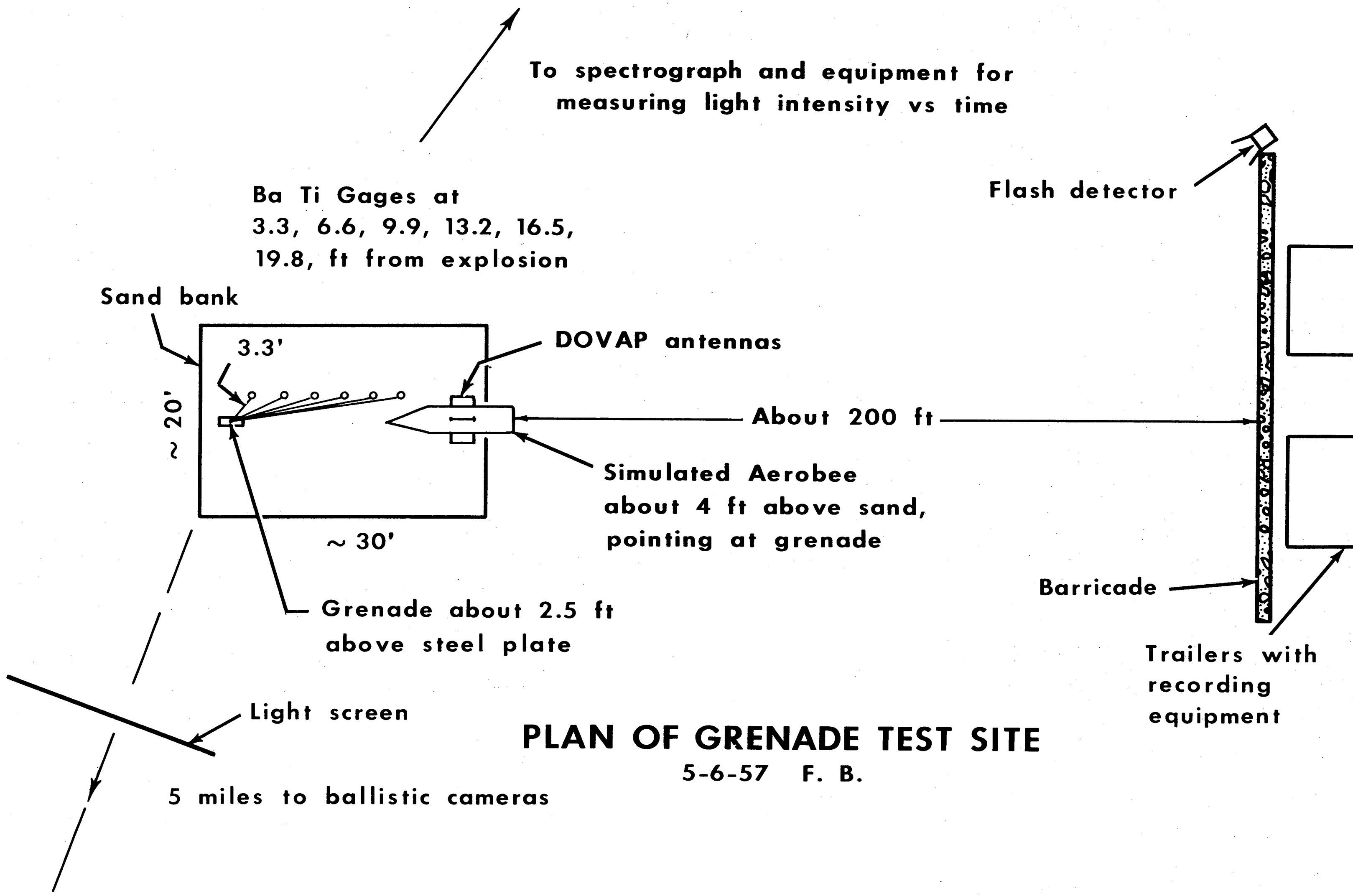
I would like very much to thank everyone at Aberdeen for help in these tests. Things are in good shape as of this date. See you next week.

Sincerely yours,

Fred. L. Bartman
High Altitude Engineering Lab.

FLB/lh
Att: sketch

cc: L. G. deBey, BRL
W. G. Stroud, USASEL



PLAN OF GRENADE TEST SITE

5-6-57 F. B.