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Quarterly Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

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ABSTRACT

Four grenade Aerobees were fired at Ft. Churchill in December, 1957, and January, 1958. Two of these were fired at midnight and noon of the same day to yield a measurement of diurnal variations. SM2.10 carried both the "Grenade" and "falling sphere" experiments for comparison of results. Data reduction of SM1.01 has been finished; cycle counting on SM1.02 has been finished; "spin corrections" are now being made.

Control checks were run on various air sample bottles. The results of these checks are given. University of Michigan sampling results (Argon ratio) are compared with some Russian results reported recently.

Two papers on diffusive separation of gas mixtures in flow fields by V. C. Liu have been accepted for publication: "A Note on Diffusive Separation of Gas Mixtures in Flow Fields", (Journal of Applied Physics), "On the Separation of Gas Mixtures by Suction of the Thermal-Diffusion Boundary Layer", (Quarterly Journal of Mechanics and Applied Mathematics, Oxford).

A series of lectures on geophysics and solar physics was given by Professor Sydney Chapman.

THE UNIVERSITY OF MICHIGAN PROJECT PERSONNEL

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1. INTRODUCTION

This is the eleventh 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 Artic 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 SM1.07, SM1.08, SM1.09 and SM2.10 were fired at Ft. Churchill on December 11 and 14, 1957, and on January 27, 1958. The schedule of operations at Ft. Churchill is given in Table I.

TABLE I

SCHEDULE OF OPERATIONS FOR AEROBEES SM1.07, SM1.08, SM1.09 AND SM2.10

	SM1.07	SM1.08	SM1.09	SM2.10
Horizontal Test	Dec. 6, 1957	Dec. 5, 1957	Jan. 23, 1958	Jan. 23, 1958
Vertical Test	Dec. 11, 1957	Dec. 13, 1957	Jan. 26, 1958	Jan. 27, 1958
Firing	2159:45 CST Dec. 11, 1957	1500:10 CST Dec. 14, 1957	0004:25 CST Jan. 27, 1958	1248:34 CST Jan. 27, 1958

TABLE II

UNIVERSITY OF MICHIGAN-SEL GRENADE AEROBEES AT FT. CHURCHILL

Flight No.	Hour CST	Date	B.O. Time sec	B.O. Vel. ft/sec	B.O. Alt. 10^3 ft	Peak Time sec	Peak Alt. miles	Grenades not Exploded no.	Arrivals Recorded	Altitude Range of Experiment km	DOVAP	Balis. Camera	Supporting Met. Data.
SM 1.01	0551 (Night)	11/12/56	36	3250	64	136	42	8, 18	1-7 9-17	25-60	X	X	X
1.02	2216 (Twilight)	7/21/57	36	4110	77	158	58	14	1-18	26-87	X	X	X
1.03	2330 (Twilight)	7/23/57	35	4050	68	151	55	9	1-8 10-19	25-82	X	X	X
1.04	1000 (Day)	8/12/57	33	3500	61	140	46	1, 7	2-6 8-19	22-70	X		X
1.05	2030 (Twilight)	8/19/57	36	4000	73	157	58	14	1-13 15-16	26-76	X	X	X
2.06	0808 (Day)	8/25/57	44	4800	95	200	85	16	1-13	30-90	X		X
1.07	2159 (Night)	12/11/57	44	3500	80-85	154-159	50-53	1	2-19	24-82	X		X
1.08	1500 (Day)	12/14/57	36	4100	77	158	58-60	---	1-15	26-72	X		X
1.09	0004 (Night)	1/27/58	33	4250	71	161	59	6	1-5 7-19	26-90	X		X
2.10	1248 (Day)	1/27/58	43.5	5000	92.5	203	90	4, 16	1-3 5-15 17-18	30-Δ90	X		X

Aerobee SM1.07 performance was below normal. The estimated peak altitude for this flight is 48 miles (radar-tabulated data) instead of the predicted 58 miles. Maximum velocity was 3750 ft/sec instead of the predicted 4100 ft/sec and burnout time was 44.8 seconds instead of the predicted 33 seconds. Although rocket performance was not monitored, it is suspected that the regulator did not function properly.

The performance of the other three rockets was excellent; indeed, SM2.10 with peak altitude of about 90 miles seems to have exceeded it's expected performance.

All of the grenade experiments on these rockets were successful. The percentage of grenades not detonated was about the same as on previous flights: grenade number 1 on SM1.07, grenade number 6 on SM1.09, grenades number 4 and 16 on SM2.10. All grenades were detonated successfully on SM1.08.

Sound ranging, ground flash detector, and DOVAP records were excellent for all flights. It appears that the arrival from the last grenade on SM2.10 was obtained successfully. It is estimated that this grenade may have been exploded as high as 92 km.

Each of the Aerobees SM1.07 and SM1.08 carried two grenades made of a high-explosive mixture not containing aluminum powder. This was done in an attempt to obtain some additional information on the nature of the mechanism of the explosion-induced modulation of the DOVAP cycle-count record. Three of these four grenades were detonated successfully. A preliminary examination of the modulation did not reveal any effect different from that previously obtained.

SM1.09 and SM2.10 each carried one 1-lb grenade. On SM1.09 this grenade was exploded at about 45 km, on SM2.10, at about 65 km. Sound arrivals were recorded successfully for each of these explosions. It is possible that on future experiments 1-lb grenades could be used to altitudes up to 70 or 75 km. The payload weight of the grenade experiment rockets could be reduced considerably over the present design.

SM1.09 and SM2.10 were flown at approximately midnight and noon respectively of the same day. Thus the data from these two rockets will yield a measurement of diurnal upper-air-temperature variations. Figure 1 shows the launching of SM2.10.

SM2.10 contained both the grenade experiment for upper-air-temperature and winds and the sphere experiment for upper-air density. The comparison of data from the two experiments will give valuable information regarding

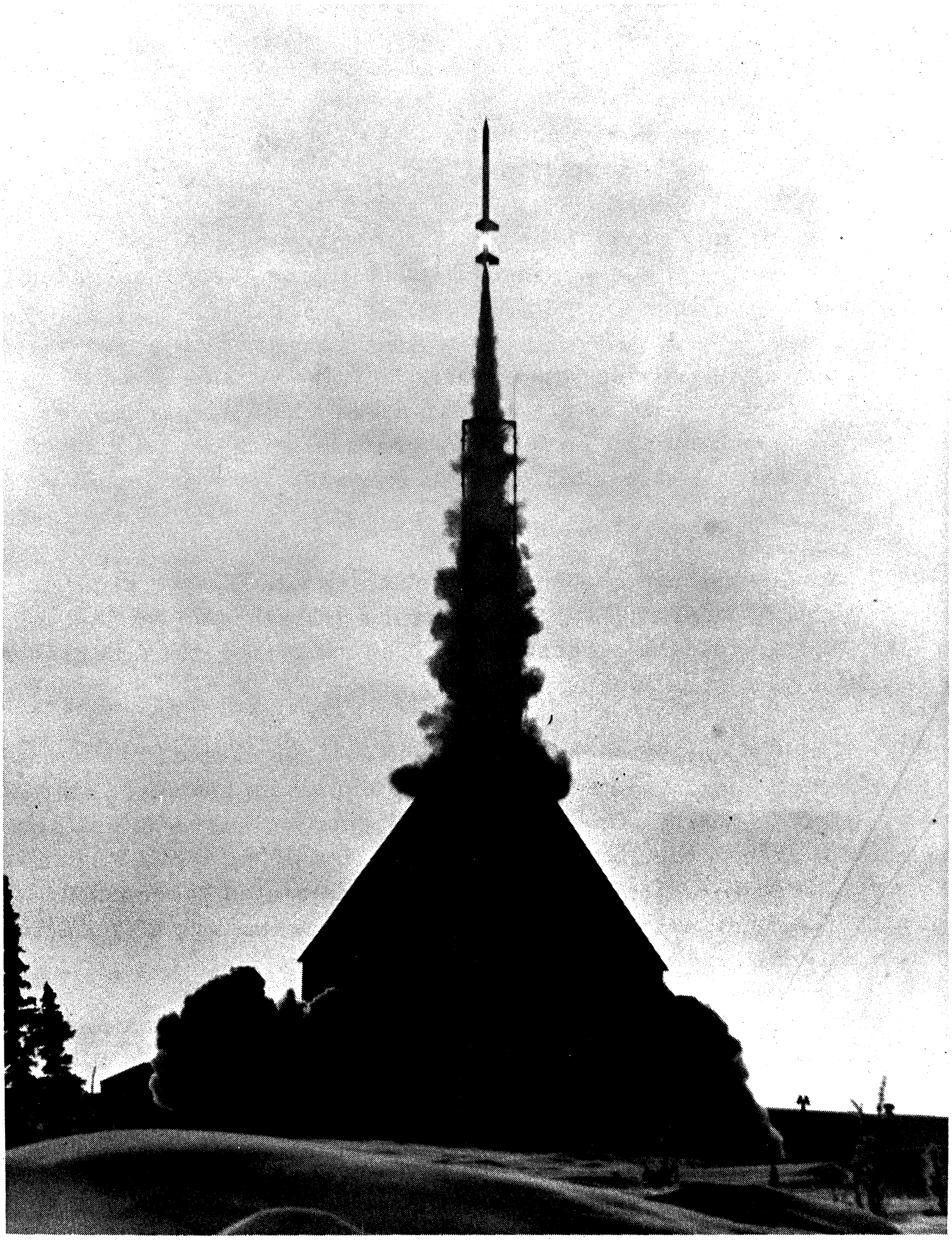

Fig. 1. Launching of Aerobee SM2.10, Carrying Both "Grenade" and "Falling-Sphere" Experiments.

their accuracy. A third comparison will be possible from the results of Niki-Cajun AM6.36. This rocket carried alphatron gauges for the determination of upper-air pressure, density, and temperature by means of the measurement of imact and cone-wall pressures. This rocket was flown about 30 minutes after SM2.10.

These firings completed the series of IGY series of Grenade Aerobee rockets. Table II is a summary of the performance of the ten rockets in these series. Each experiment was flown successfully.

2.2 DATA REDUCTION

The third and final calculation of SM1.01 DOVAP data was completed. The position at half-second intervals with respect to the Aerobee launcher was computed up to 148 seconds. Position—vs.—time data are given as follows:

a) at 0.5-second intervals from 1—100 seconds, and from 129.5—148 seconds.

b) at 5-second intervals from 100—129.5 seconds.

Peak time has been determined as 132.0 seconds, peak altitude at 223,886 feet (42.41 miles, 68.24 km).

Grenade-position data were computed with respect to the Aerobee launcher, and with respect to the center microphone at Twin Lakes. The grenade-explosion coordinate data and the layers between grenades, referred to the center microphone at Twin Lakes, are given in Table III. Standard deviations are also given. This data reduction appears to give very good results, using the criterion for results outlined by W. Dean at one of the past SGIGY meetings, i.e.:

for Ft. Churchill DOVAP data reduction,

σ_u = 5 feet - "good" (normal)
σ_u = 8 feet - "probably O.K."
σ_u = 15 feet - "something wrong".

Taking the data from Table II for grenades 3 and 10 at altitudes of 20 and 30 miles, respectively, we have:

	σ_x	σ_y	σ_z	σ_u
Grenade 3	3 ft.	3 ft.	3 ft.	1-1.5 ft.
Grenade 10	2 ft.	2 ft.	2 ft.	1 ft.

where ratios of $\frac{\sigma_x}{\sigma_u}$ $\frac{\sigma_y}{\sigma_u}$ $\frac{\sigma_z}{\sigma_u}$ were taken from graphs prepared by W. Dean for the Ft. Churchill range.

TABLE III

GRENADE AEROBEE POSITION DATA FROM THIRD DOVAP DATA REDUCTION ON SM1.01*

Grenade No.	Range Time	X(+N)	σ_x	y(+w)	σ_y	z(msl)	σ_z
	sec	ft	ft	ft	ft	ft	ft
1	41.774	25332.78	6.69	7103.35	7.29	82607.41	1.14
2-1		-2455.05	4.23	1110.86	4.61	10489.17	0.74
2	45.204	22877.73	2.46	8214.21	2.68	93096.58	0.41
3-2		-2426.95	0.38	1104.08	0.42	9992.03	0.08
3	48.663	20450.78	2.85	9318.29	3.10	103088.61	0.47
4-3		-2454.30	1.75	1116.51	1.91	9720.50	0.29
4	52.188	17996.48	1.09	10434.79	1.18	112809.10	0.18
5-4		-2412.56	1.87	1089.60	2.05	9117.35	0.32
5	55.650	15583.92	2.97	11524.39	3.23	121926.45	0.49
6-5		-2368.65	1.99	1076.61	2.18	8626.68	0.33
6	59.080	13215.27	0.98	12601.00	1.05	130553.13	0.16
7-6		-2398.69	1.12	1093.70	1.22	8348.99	0.19
7	62.560	10816.58	0.14	13694.69	0.17	138902.12	0.03
9-7		-4793.70	3.18	2188.06	3.48	15521.14	0.60
9	69.527	6022.87	3.32	15882.75	3.64	154423.26	0.63
10-9		-2349.36	1.22	1080.05	1.33	7037.67	0.21
10	72.945	3673.51	2.11	16962.80	2.32	161460.93	0.41
11-10		-2407.02	1.28	1105.51	1.38	6847.48	0.26
11	76.462	1266.49	3.38	18068.31	3.70	168308.40	0.68
12-11		-2391.66	0.60	1100.41	0.64	6403.07	0.10
12	79.955	-1125.17	2.78	19168.72	3.05	174711.47	0.58
13-12		-2335.87	0.84	1079.42	0.91	5880.60	0.16
13	83.371	-3461.04	1.95	20248.14	2.14	180592.07	0.42
14-13		-2385.91	1.02	1098.92	1.11	5636.82	0.23
14	86.873	-5846.95	2.96	21347.05	3.25	186228.89	0.64
15-14		-2385.62	0.87	1108.41	0.95	5237.76	0.17
15	90.373	-8232.57	2.09	22455.46	2.30	191466.65	0.47
16-15		-2352.81	1.32	1084.73	1.44	4793.72	0.29
16	93.837	-10585.38	0.77	23540.19	0.86	196260.37	0.18
17-16		-2375.56	3.09	1102.62	3.38	4467.37	0.73
17	97.350	-12960.94	3.85	24642.81	4.24	200727.74	0.91

* Referred to a right cartesian coordinate system having its origin at sea level at the center microphone at Twin Lakes and having its x-y plane tangent to Clark Spheroid at that point.

The data reduction on SM1.02 is coming along very well. The initial cycle counting of all eight channels (each by two different persons) has been completed. The "spin" corrections are now being made.

2.3 COMPARISON OF SM1.01 DOVAP DATA WITH SM1.01 BALLISTIC CAMERA DATA

The Ballistic Camera data reduction for Aerobee SM1.01 has been completed. The results are contained in a technical note issued by BRL.[1] The comparison of the DOVAP and Ballistic Camera data for SM1.01 grenade bursts is very interesting.

The DOVAP position data refers to the position of a point on the longitudinal axis of the missile corresponding to the center-line of the DOVAP missile antenna system. However the grenades are exploded at a point forward of the nose cone. The DOVAP data must be corrected for this difference of position before they are compared with the Ballistic Camera coordinates of the grenade bursts.

Although the grenades were designed to be detonated when the lanyard was fully unwound, movies of ground test firings of the grenades show that the grenades do not always travel to a distance corresponding to a complete unwinding of the lanyard before exploding. DOVAP telemetry on SM1.01 confirms this fact for the grenade explosions on SM1.01. The time interval between actual ejection, monitored by a microswitch, and the actual explosion, monitored by a missile-borne flash detector, varies from grenade to grenade.

Assuming that the ejection velocity is the same for each grenade and that the maximum time interval corresponds to a full unwinding of the lanyard, the relative distance between the DOVAP antenna system centerline and the explosion can be computed approximately.

An additional complication arises from the fact that the missile is probably precessing, and so the vector representing the relative position is also precessing in space. On SM1.01, the correction was made under the assumption that the correction vector was in the direction of the tangent to

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[1] Laura Ewalt, "Photogrammetrically Determined Spatial Coordinates for Aerobee SM1.01 Grenade Bursts During IGY Firings at Fort Churchill, Canada", BRL. TN 1157, December 1957.

TABLE IV

ESTIMATED POSITION OF GRENADE BURSTS RELATIVE TO DOVAP ANTENNA SYSTEM ON SM1.01

Grenade No.	δx (+N)	δy(+N)	δz(+up)
1	-4.02	1.80	17.35
2	-4.76	2.12	19.83
3	-4.46	1.99	17.84
4	-5.83	2.60	22.41
5	-6.03	2.74	22.34
6	-6.12	2.73	21.69
7	-6.48	2.89	21.77
9	-6.35	2.86	19.91
10	-6.24	2.83	18.05
11	-7.76	3.57	21.25
12	-7.72	3.61	20.06
13	-5.17	2.36	12.57
14	-8.60	4.00	19.52
15	-9.76	4.49	20.56
16	-7.49	3.45	14.52
17	-10.59	4.88	18.77

TABLE V

COMPARISON OF DOVAP AND BALLISTIC CAMERA GRENADE-BURST-POSITION DATA FOR SM1.01*

	x(+N)			y(+W)			z(MSL)		
	DOVAP	BC	Δx DOV-BC	DOVAP	BC	Δy DOV-BC	DOVAP	BC	Δz DOV-BC
1	-17211.23	-17276.87	65.64	5647.95	5711.93	-63.98	82754.69	82726.21	28.48
2	-19688.36	-19757.18	68.82	6758.11	6830.69	-72.58	93241.61	93231.44	10.17
3	-22135.36	-22211.24	75.88	7861.09	7939.62	-78.53	103226.60	103211.73	14.87
4	-24609.82	-24691.55	81.73	8977.26	9061.66	-84.40	112946.76	112926.28	20.48
5	-27042.15	-27119.37	77.22	10066.09	10160.74	-94.63	122059.21	122040.44	18.77
6	-29428.46	-29514.38	85.92	11141.82	11240.13	-98.31	130680.51	130672.31	8.20
7	-31844.53	-31945.47	100.94	12234.83	12332.65	-97.82	139024.77	139012.19	12.68
9	-36669.75	-36787.98	118.23	14421.24	14524.25	-103.01	154534.47	154543.65	-9.18
10	-39033.35	-39146.90	113.55	15500.50	15600.36	-99.86	161565.59	161571.20	-5.61
11	-41455.88	-41581.28	125.40	16606.00	16715.85	-109.85	168411.46	168421.58	-10.12
12	-43860.59	-43979.57	118.98	17705.74	17808.36	-102.62	174808.55	174815.92	-7.37
13	-46205.92	-46331.93	126.01	18783.22	18897.60	-114.38	180677.01	180668.93	8.08
14	-48606.78	-48730.22	123.44	19883.12	20006.52	-123.40	186316.01	186289.00	27.01
15	-51004.29	-51141.63	137.34	20991.38	21108.88	-117.50	191550.05	191525.21	24.84
16	-53364.64	-53497.27	132.63	22074.48	22198.12	-123.64	196333.04	196288.98	44.06
17	-55752.47	-55895.56	143.09	23177.94	23307.04	-129.10	200799.91	200777.16	22.75

* With reference to a right cartesian coordinate system having its origin at sea level at the Aerobee launcher and its x-y plane tangent to the Clark spheroid at that point.

TABLE VI

COMPARISON OF DOVAP AND BALLISTIC CAMERA DATA FOR LAYERS BETWEEN GRENADES ON SM1.01

	x(+N)			y(+W)			z(MSL)		
	DOVAP	BC	Δx DOV-BC	DOVAP	BC	Δy DOV-BC	DOVAP	BC	Δz DOV-BC
1									
	-2477.13	-2480.31	3.18	1111.16	1118.76	-7.60	10486.92	10505.23	-18.31
2									
	-2447.00	-2454.06	7.06	1102.98	1108.93	-5.95	9984.99	9980.29	4.70
3									
	-2474.46	-2480.31	5.85	1116.17	1122.04	-5.87	9720.16	9714.55	5.51
4									
	-2432.33	-2427.82	-5.51	1088.83	1099.08	-10.25	9112.45	9114.16	-1.71
5									
	-2386.31	-2395.01	8.70	1075.73	1079.39	-3.66	8621.30	8631.87	-10.57
6									
	-2416.07	-2431.09	15.02	1093.01	1092.52	0.49	8344.26	8339.88	4.38
7									
	-4825.22	-4842.51	17.29	2186.41	2191.60	-5.19	15509.70	15531.46	-21.76
9									
	-2363.60	-2358.92	-4.68	1079.26	1076.11	3.15	7031.12	7027.55	3.57
10									
	-2422.53	-2434.38	11.85	1105.50	1115.49	-9.99	6845.87	6850.38	-4.51
11									
	-2404.71	-2398.29	-6.43	1099.74	1092.51	7.23	6397.09	6394.34	2.75
12									
	-2345.33	-2352.36	7.03	1077.48	1089.24	-11.76	5868.46	5853.01	15.45
13									
	-2400.86	-2398.29	-2.57	1099.90	1108.92	0.98	5639.00	5620.07	18.97
14									
	-2397.51	-2411.41	13.90	1108.26	1102.36	5.90	5234.04	5236.21	2.17
15									
	-2360.35	-2355.64	-4.71	1083.10	1089.24	-6.14	4782.99	4763.77	19.22
16									
	-2387.83	-2398.29	10.46	1103.46	1108.92	-5.46	4466.87	4488.18	21.31
17									

the trajectory. The actual corrections applied to the DOVAP data on SM1.01 are shown in Tables IV, V, and VI and compare the corrected DOVAP and Ballistic Camera data. The difference in absolute position (DOVAP - BC) can be summarized as follows:

In the x-coordinate, between 65 and 143 feet.
In the y-coordinate, between 64 and 129 feet.
In the z-coordinate, between -10 and 44 feet.

The comparison of data for the layers between grenades shows differences (DOVAP - BC) of

Between -6.4 and 17.3 feet in x
Between -11.8 and 7.2 feet in y
Between -21.8 and 21.3 feet in z.

The differences in both absolute position and layers are slightly larger than what might be expected from the index of precision σ_x, σ_y, and σ_z for the DOVAP data, and the estimated systematic error of the Ballistic Camera data as noted in BRL TN 1157 (referred to above), which states that the unknown systematic error for the Ballistic Camera grenade-burst data varies from "± 4 meters at the lower altitudes to better than ± 10 meters at the higher altitudes". (The "better" is to be interpreted as less than).

Thus, although the data reductions for SM1.01 agree well enough for purposes of the grenade experiment, they do not agree as well as they might, theoretically. It is hoped that BRL will make an independent DOVAP data reduction for SM1.01 to check the U of M results. When the data reduction for SM1.02 through SM2.10 have been finished, it is planned to re-examine the SM1.01 data reduction to see if any errors can be found.

3. AIR-SAMPLING EXPERIMENT

3.1 SCOPE OF THE WORK

The quarter was devoted largely to performing control checks on various bottles. The contents of bottles E-2 and C-21-B were analyzed. These two bottles were prepared for flight on Aerobee rockets SC 34 and 35 but were not flown. The helium leak detector was used to determine the leak rates of bottles B-15, B-10, C-23-B, B-25, and E-2.

3.2 ANALYSIS OF CONTENTS OF BLANK BOTTLES

The results of the analysis of the accumulation in E-2 and C-21-B are recorded in Table VII, with calibration runs and entrance-tubing checks.

TABLE VII

CONTROL CHECKS ON SAMPLE BOTTLES

						% Condensable Material			
						Before Oxidation		After Oxidation	
Sample	$CCNTP^5$ Gas in Bottle CCNTP	10^{-3} CCNTP After oxidation with dry-ice trap	He Ratio	Ne Ratio	% Loss on hot copper filament.	Vol. lost Liq. N_2	Vol. lost Dry Ice	Vol. lost Liq. N_2	Vol. lost Dry Ice
(1) 19-1		4.73	1.00	1.00	18.7	----	----	----	0.95
(1) 19-2		3.85	1.00	1.00	19.2	----	----	----	0.90
(2) 1-E-2B-E		(3)0.017	382.	4.19	93.3	11.1	0.9	68.5	2.0
(2) 2-E-2BE		(3)0.014	212.	2.27	91.5	8.4	0.6	67.5	0.6
E-2-1	2.16×10^{-2}	4.86	3.48	1.42	46.7	2.7	1.1	14.6	12.7
(1) 20-1		11.17	1.00	1.00	20.0	----	----	----	0.84
(2) C-21-BE		(3)0.00106	78.4	1.27	97.7	36.6	4.9	98	16.4
(2) C-21-1	8.6×10^{-4}	(3)0.0529	13.6	1.76	88.8	17.9	1.2	62.5	10.7
(4) $\frac{xx}{\text{C-21-B-1}}$	8.15×10^{-3}	5.7	0.95	0.966	0.0	5.6	2.0	5.4	1.8

(1) Ground-air control.

(2) Accumulation in Entrance tubing.

(3) Liquid N_2 Cold Trap. He and Ne Ratios based on CCNTP found with Liquid N_2 on cold trap.

(4) Ground air introduced into C-21.

(5) Total Quantity as computed from system McLeod Reading.

Bottle E-2 was believed to have a small leak because a change in pressure was noted on the Pirani gage. This was verified by the quantity of air found in the bottle and subsequent helium leak checks.

C-21-B was of an earlier vintage and prepared for the 1956 flights only by fabricating special adaptor rings. It was evacuated about five years previous to the analysis. This bottle was believed to be as vacuum-tight as C-23-B. It was monitored briefly by operation of its Philipps gage and was found to have accumulated very little gas.

3.3 BOTTLE LEAK TESTING

The results of helium-leak checks on the various bottles are shown in Table VIII.

TABLE VIII

HELIUM-LEAK CHECKS ON VARIOUS BOTTLES

Bottle No.	CC NTP/Sec to account for extra He found on analysis	CC NTP/Sec found using leak detector	% Extra He accounted for by obsereed leak
B-10	7.9×10^{-15}	2.1×10^{-15}	26%
B-15	17×10^{-15}	46×10^{-15}	270%
C-23-B	1.5×10^{-15}	0.028×10^{-15}	2%
E-2	5.8×10^{-15}	2.8×10^{-15}	48%
(1)B-25	$33. \times 10^{-15}$	$109. \times 10^{-15}$	330%
(2)B-25	66×10^{-15}	109×10^{-15}	165%

(1) Upper-Atmosphere Sample

(2) Ground Air introduced into Bottle.

Up to this time no complete evaluation of the accuracy of the bottle helium-leak rates found with the helium leak detector has been made. However, the results appear to be good and repeated checks of one bottle, using several different collection times, agree very well.

The contents of C-23-B flight bottle appear to be the most likely to be a true sample of the atmosphere.

Associated bottles B-10 and B-15 from the same flight and opened at the same time showed small leaks.

Gas from C-23-B contained 24% more helium than the same quantity of ground-air. Gas from B-10 contained 48% more helium than the same quantity of ground air. Correcting B-10 for the helium leak of 26% of the excess helium as indicated in Table II, the gas in B-10 would contain only 35% more helium than ground air. This correction brings the helium ratio of B-10 quite close to that of C-23-B.

This reasoning breaks down when B-10 leak rates are studied. The helium leakage rate is observed to be twice the leakage rate required to account for the extra helium found by analysis in the bottle. Since this is one of the earliest leak tests done on the analyzer, the technique may have been faulty. It may be possible to re-check this bottle later. The other possibility presented is that the leak size changed during preparation of the bottle for the leak check. It is hoped this question can be resolved.

No comments will be made on B-25 except to say that the leak predicted by Wanke and Paneth in this bottle was present. Data have not been received indicating the total quantity of gas in the bottle after oxygen removal and the time from sampling to analysis. Therefore, only rough estimates of the actual leakage can be made until the data are available.

A comparison of the argon-nitrogen ratio in the upper atmosphere with that of ground air was made using the results reported by Paneth on our samples and the results reported by the Russians. Figure 2 shows the result.

It was noted that all points, with one exception lie between the two roughly parallel lines A andB, and the general slope of the lines would seem to indicate increasing separation with altitudes. It is also noted that the Russian results appear to indicate slightly less separation than shown in the American samples.

4. THEORETICAL WORK ON DIFFUSIVE SEPARATION OF GAS MIXTURES IN FLOW FIELDS

During this quarter, the analysis of the problem of diffusive separation of gas mixtures in flow fields that is involved in the upper-air sampling experiment has been completed. The results of this research are reported by V.C. Liu in two scientific papers. The first paper, "A Note on Diffusive Separation of Gas Mixtures in Flow Fields" has been accepted for publication

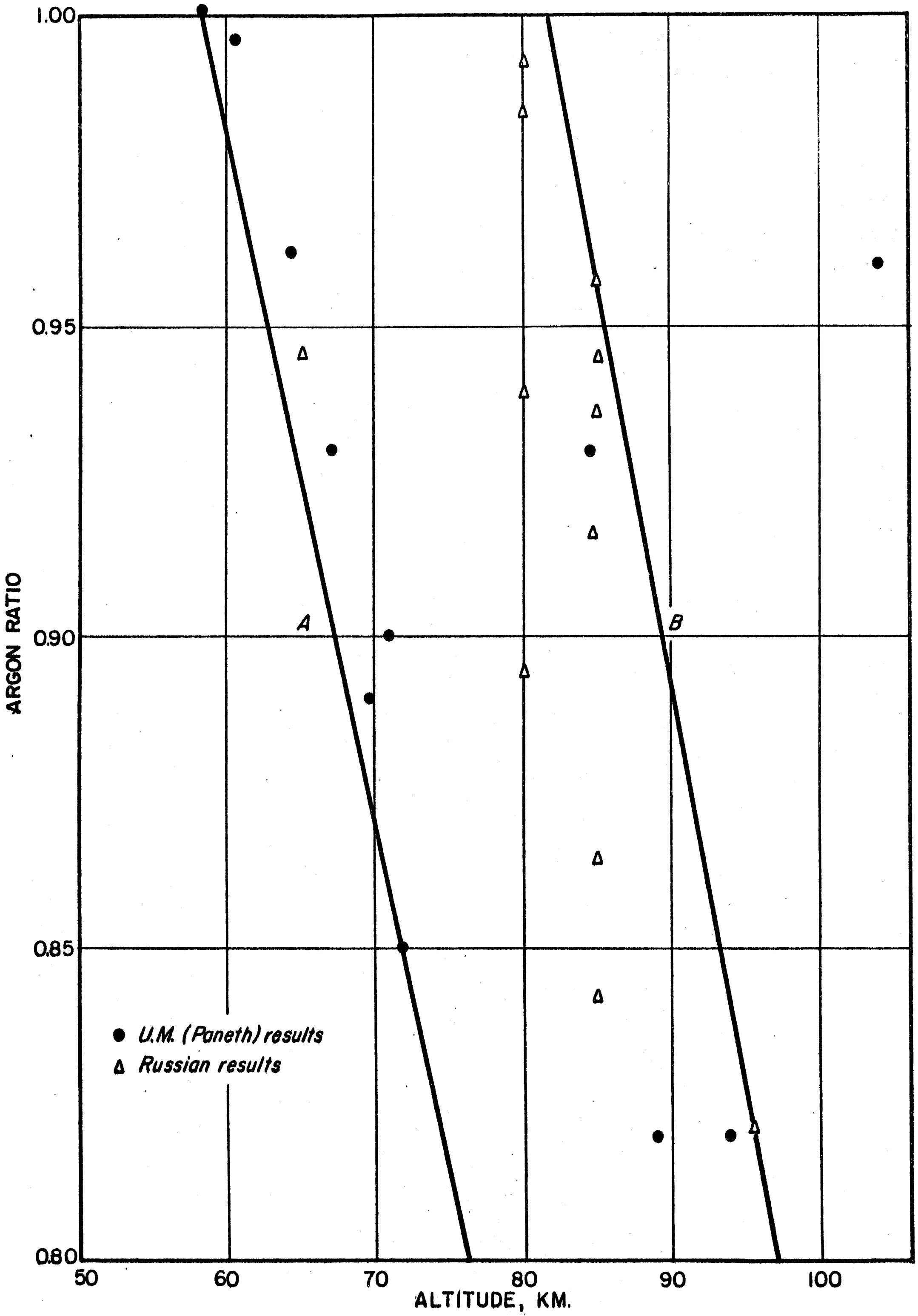

Fig. 2. Comparison of the University of Michigan (Paneth) and the Russian Sampling Results.

by the Journal of Applied Physics. The abstract of this paper is quoted in the following paragraphs.

"This paper discusses the effect of pressure-diffusion flux upon the concentration distribution of gas mixtures in flow fields. The equation of concentration is formulated for a binary gas mixture in which the mass ratio is large and the concentration of the lighter gas is very small. An asymptotic solution to the steady-state equation of concentration is given for an irrotational and is incompressible flow.

"As an illustration, the diffusive separation (i.e. deviation from the original homogeneous state) of a mixture of helium and nitrogen along streamlines at the entrance to a long straight channel is calculated. It is assumed that the pressure inside the channel is 90% of that in the free stream; and that the diffusion coefficient of the mixture corresponds with the atmospheric conditions at 80 km altitude."

The second paper, "On the Separation of Gas Mixtures by Suction of the Thermal-Diffusion Boundary Layer" reports an accidental discovery of a special diffusion phenomenon which could conceivably lead to a new and more effective (compared to the one which based on Clusius' thermal-diffusion column) method of separating gas isotopes. Last summer, the preliminary manuscript of this paper was sent to Professor Sydney Chapman who since then has announced and reviewed this new result in his lecture at the Gas-Dynamics Symposium of the American Rocket Society held at Northwestern University in August, 1957. This manuscript was then communicated by Professor Chapman for the author to the Quarterly Journal of Mechanics and Applied Mathematics (Oxford) for publication. The abstract of the second paper is given below:

"This paper discusses the formation and characteristics of the boundary layer of thermal diffusion that exists along the surface of a heated wall over which a mixture of gases of unequal molecular weights flows. A thermal-diffusion flux is set up in the boundary layer, due to the existence of a temperature gradient, such that the lighter gas tends to move to the hot region and the heavier gas to the cold region. When the temperature of the surface is maintained much higher than that of the free stream, the concentration of the lighter gas increases monotonically from its free-stream value at the outer edge of the boundary layer to a maximum value at the plate.

"The existence of an extremely high temperature gradient makes it possible to obtain significant diffusive separation of gas mixtures in the boundary layer of a laminar flow; it is from this consideration that the idea of a new method of separating gas mixtures by suction of the thermal-diffusion boundary layer is conceived. An analysis of the thermal-diffusion boundary layer is made, using a flat plate with constant suction as a model and assuming that the concentration of the lighter gas is much smaller than unity. The strong stabilizing effect of suction on the laminar flow is discussed briefly. A limiting ratio of suction vs free-stream velocity for the maintenance of laminar flow is derived. An estimation of the rate of attaining the equilibrium-concentration profile is also made."

5. LECTURES BY PROFESSOR SYDNEY CHAPMAN

A series of lectures on topics of interest to workers in the field of upper-atmosphere research was given by Professor Sydney Chapman during his stay at the University of Michigan. The following copy of the announcement of these lectures describes their content.

UNIVERSITY OF MICHIGAN

PROFESSOR SYDNEY CHAPMAN
International President of the Special Committee for the IGY
Visiting Professor of Aeronautical Engineering

WILL PRESENT A SERIES OF LECTURES
(1957-1958)

Nov. 26 – "The Solar Corona and the Interplanetary Gas"

Dec. 3 – "The Earth's Atmosphere in the Satellite Region"

Dec. 10 – "How Eruptions of Solar Gas Influence the Earth"

Dec. 17 – "Thermal Diffusion in the Laboratory and in the Solar Corona"

Jan. 7 – "The Electrical Conductivity of the Ionosphere"

Jan. 23 – "The International Geophysical Year and the Earth Satellites"

First Five Lectures – TUESDAYS, 4:00 PM
Auditorium C, Angell Hall
Sixth Lecture – THURSDAY, 8:00 PM
Rackham Amphitheater

Auspices of
Departments of Aeronautical and Electrical Engineering,
Astronomy, Mathematics, and Physics

LECTURES

by

PROFESSOR SYDNEY CHAPMAN, noted astronomer, geophysicist and mathematician, is International President of the Special Committee for the International Geophysical Year. He has worked at the Royal Observatory, Greenwich; and at the Universities of Cambridge, Manchester, London, and Oxford, in England; Cairo in Egypt; Istanbul in Turkey, and Gottingen in Germany. In this country he has worked at the California Institute of Technology and the Universities of Alaska, Michigan, New York, Iowa, and Colorado. His experience fits him to bring to his listeners a comprehensive description of some of the solar and terrestrial problems that occupy astrophysical and geophysical scientists today.

Nov. 26 – THE SOLAR CORONA AND THE INTERPLANETARY GAS.

The sun's temperature falls from millions of degrees at the center to 6000° at the surface. Above this, the temperature rises again to about a million degrees in the sun's outer atmosphere, called the corona, that becomes visible during a total solar eclipse. The corona extends far outwards from the sun, and it appears likely that it constitutes a hot interplanetary gas through which the earth and other planets move in their orbits.

This lecture will be illustrated by a 10-minute movie showing the motions of prominences and the corona at the edge of the sun. This film is one recently prepared at the Sacramento Peak Observatory of the Air Force Cambridge Research Directorate, at Sunspot, New Mexico.

Dec. 3 – THE EARTH'S ATMOSPHERE IN THE SATELLITE REGION.

Radio physicists can explore the earth's upper atmosphere to about 200 miles height by radio beams, but above that level the nature of our atmosphere is uncertain. One theory is that the temperature rises to about 1500°C and then remains constant at greater heights. An alternative view will be presented: that the temperature rises to 200,000°, and that above the ionosphere we know, there is an immensely extended layer of atomic hydrogen, beyond which our atmosphere changes to a mixture of protons and electrons and merges with the interplanetary gas. The satellites should be able to decide between these alternatives.

Dec. 10 – HOW ERUPTIONS OF SOLAR GAS INFLUENCE THE EARTH.

From time to time the sun projects great clouds or streams of hot gas, mainly consisting of protons and electrons, into the space around it. Often the gas impinges on the earth, and causes the visible phenomenon of the northern lights (or aurora borealis) and the invisible phenomena of magnetic storms and disturbances of the ionosphere; these may greatly hinder radio and telegraphic communications. These and other effects of the solar gas on our atmosphere are being actively studied, bringing new discoveries to light.

Dec. 17 – THERMAL DIFFUSION IN THE LABORATORY AND IN THE SOLAR CORONA.

Whenever a gas consists of more than one constituent, a gradient of temperature will cause a diffusive flow tending to change the composition between different regions. This property, called thermal diffusion, is much used to separate rare iostopes, in chemical laboratories and atomic energy establishments. It can also be disturbing phenomenon in chemical experiments on mixed gases. Moreover it occurs in mixed gases in nature - in our atmosphere and in that of the sun. It seems likely to be of much importance in the solar corona.

Jan. 7 – THE ELECTRICAL CONDUCTIVITY OF THE IONOSPHERE.

Many substances, such as wood and (especially) crystals, have elastic or optical properties that are different in directions. An ionized gas in a magnetic field likewise has this feature, as regards its electrical conductivity. The ionosphere is such a gas. The peculiarities of its electrical conductivity have interesting consequences. One of these was known long before the cause was understood - it is an enhancement of the daily magnetic variation on the magnetic equator.

Jan. 23 – THE INTERNATIONAL GEOPHYSICAL YEAR AND THE EARTH SATELLITES.

(Announcement to follow.)

6. LABORATORIES VISITED

Ft. Churchill, Manitoba, Canada.
U. S. Army Signal Engineering Laboratories

7. ACKNOWLEDGEMENTS

We are indebted to the Meteorological Branch of the U. S. Army Signal Engineering Laboratories for continued collaboration and support. The success of the ten firings of the Aerobee "Grenade" experiment at Ft. Churchill are due to a very large measure to the superb facility for upper-air research which is located there. We are deeply indebted to the work of all of the groups at Ft. Churchill who contributed so much effort to insure the success of our firings.