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Quarterly Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

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F. L. Bartman
V. C. Liu
E. A. Wenzel

Approved: L. M. Jones

Department of Aeronautical Engineering

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ABSTRACT

DOVAP data reduction has been completed for SM1.03 and SM1.04 and preliminary data have been obtained for SM1.05 and SM2.10.

The instrumentation required for the Guam rocket-grenade program was assembled, tested, and shipped to Guam.

The study of spherical shock propagation indicates that only the theory of shocks from a "point source" is suitable for scaling to low-density atmosphere. Additional theoretical and experimental data are needed for a spherical shock due to a chemical explosion.

A paper by V. C. Liu, entitled "On the Drag of a Flat Plate at Zero Incidence in Almost-Free-Molecule Flow," was submitted to, and accepted for publication in, the Journal of Fluid Mechanics.

THE UNIVERSITY OF MICHIGAN PROJECT PERSONNEL
(Both Part-Time and Full-Time)

Allen, Harold F., Ph.D., Research Engineer
Barhydt, Peter W., Electronic Technician
Bartman, Frederick L., M.S., Research Engineer
Billmeier, William G., Assistant in Research
Conboy, Thomas J., Assistant in Research
Edman, Marshall W., Assistant in Research
Hansen, William H., B.S., B. Arch., Research Engineer
Harrison, Lillian M., Secretary
Henry, Harold F., Electronic Technician
Jew, Howard, M.A., Research Assistant
Jones, Leslie M., B.S., Project Supervisor
Kakli, G. Murtaza, B.A., Assistant in Research
Kakli, M. Sulaiman, M.S., Assistant in Research
Lay, Manchiu D. S., Assistant in Research
Liu, Vi-Cheng, Ph.D., Research Engineer
Loh, Leslie T., M.S., Research Associate
McKenna, Keith J., Assistant in Research
Millard, Wayne A., Assistant in Research
Nelson, Wilbur C., M.S.E., Prof. of Aero. Eng.
Nichols, Myron H., Ph.D., Prof. of Aero. Eng.
Otterman, Joseph, Ph.D., Research Associate
Pattinson, Theodore R., Electronic Technician
Rock, Allan L., B.S.E., Research Assistant
Schumacher, Robert E., B.S., Assistant in Research
Taylor, Robert N., Assistant in Research
Thayer, Carl A., Assistant in Research
Thornton, Charles H., Assistant in Research
Titus, Paul A., B.S., Research Associate
Wenk, Norman J., Research Engineer
Wenzel, Elton A., Research Associate
Whybra, Melvin G., M.A., Technician
Wilkie, Wallace J., M.S.E., Research Engineer
Wurster, John R., Assistant in Research
Zeeb, Marvin B., Research Technician

1. INTRODUCTION

This is the thirteenth in a series of quarterly reports on Contract No. DA-36-039-SC-64659. The purposes of the contract are:

a. to adapt the rocket-grenade experiment for use in the Arctic during the International Geophysical Year;

b. to participate in the preparation and firing of the IGY rocket-grenade experiments;

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

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

2. FT. CHURCHILL GRENADE EXPERIMENTS

The Ft. Churchill DOVAP data-reduction work was approximately 50% complete as of the end of this work period. The status of the work on each rocket-grenade experiment is summarized below.

SM1.01	Complete.
SM1.02	Complete.
SM1.03	Complete.
SM1.04	Complete.
SM1.05	Preliminary coordinate data have been obtained.
SM2.06	Spin corrections are being made.
SM1.07	Spin corrections are being made.
SM1.08	Counting is 80% complete.
SM1.09	Counting is 75% complete.
SM2.10	Preliminary coordinate data have been obtained.

The data for SM1.05 and SM2.10 are preliminary because of rather large scatter in the 4 independent solutions obtained. The data, DOVAP missile antenna position at time of grenade explosions, with respect to the center microphone at Twin Lakes, for SM1.03, SM1.04, SM1.05, and SM2.10, are shown in Tables I, II, III, and IV, respectively. The quality of the data can be judged from the value of σ_u to be attached to each data point. The calculation of σ_u for selected points from these four sets of data is shown in Table V. The criteria, outlined by W. Dean of BRL, for judging Ft. Churchill DOVAP data are:

TABLE I

SM1.03 DOVAP MISSILE POSITION AT TIME OF GRENADE EXPLOSIONS

Grenade No.	Range Time, second	X(+N), feet	σ_x, feet	Y(+W), feet	σ_y, feet	Z(+up), feet	σ_z, feet
1	38.3680	29802.48	2.38	- 4805.64	2.62	85096.66	0.55
2-1		- 2308.36	4.02	- 800.17	4.40	10996.39	0.85
2	41.3773	27494.12	6.40	- 5605.81	7.03	96093.05	1.39
3-2		- 2318.62	0.64	- 791.13	0.70	10751.40	0.21
3	44.4335	25175.50	5.76	- 6396.94	6.33	106844.45	1.22
4-3		- 2487.27	0.20	- 838.29	0.22	11205.52	0.11
4	47.7373	22688.23	5.95	- 7235.23	6.55	118049.96	1.24
5-4		- 2449.92	3.09	- 830.20	3.38	10674.89	0.64
5	51.0017	20238.31	2.86	- 8065.43	3.16	128724.85	0.59
6-5		- 2600.64	4.23	- 866.99	4.65	10920.16	0.87
6	54.4666	17637.68	1.37	- 8932.42	1.48	139645.01	0.28
7-6		- 2680.99	1.17	- 891.70	1.27	10853.85	0.25
7	58.0455	14956.69	2.54	- 9824.12	2.76	150498.86	0.53
8-7		- 2677.42	0.04	- 884.87	0.05	10486.99	0.03
8	61.6446	12279.27	2.50	-10708.99	2.71	160985.85	0.52
10-8		- 5806.93	0.28	- 1896.43	0.31	21265.35	0.06
10	69.4405	6472.34	2.21	-12605.42	2.40	182251.19	0.48
11-10		- 3188.01	1.13	- 1023.74	1.25	10841.13	0.24
11	73.7207	3284.33	1.09	-13629.16	1.16	193092.32	0.24
12-11		- 3286.62	1.63	- 1067.68	1.78	10553.79	0.37
12	78.1320	- 2.28	2.72	-14696.84	2.94	203646.11	0.61
13-12		- 3410.79	0.91	- 1088.20	1.00	10332.06	0.22
13	82.7256	- 3413.07	3.63	-15785.04	3.94	213978.17	0.83
14-13		- 3783.80	0.26	- 1200.96	0.29	10681.39	0.04
14	87.8266	- 7196.87	3.36	-16986.00	3.65	224659.56	0.80
15-14		- 4045.91	0.36	- 1269.87	0.41	10544.33	0.12
15	93.3013	-11242.79	3.72	-18255.87	4.06	235203.89	0.91
16-15		- 4443.10	1.74	- 1413.63	1.96	10447.82	0.41
16	99.3007	-15685.88	1.99	-19669.50	2.11	245651.71	0.50
17-16		- 4933.33	8.31	- 1532.31	9.15	10266.33	2.23
17	105.9615	-20619.21	10.29	-21201.71	11.26	255918.04	2.73
18-17		- 5784.16	1.36	- 1767.20	1.51	10260.49	0.52
18	113.7832	-26403.37	11.66	-22968.90	12.76	266178.53	3.24
19-18		- 7045.13	11.39	- 2093.12	12.50	9827.16	3.19
19	123.2545	-33448.50	0.31	-25062.02	0.41	276005.69	0.07

Note: Data are given with respect to center microphone at Twin Lakes.

TABLE II

SM1.04 DOVAP MISSILE POSITION AT TIME OF GRENADE EXPLOSIONS

Grenade No.	Range Time, second	X(+N), feet	σ_x, feet	Y(+W), feet	σ_y, feet	Z(+up), feet	σ_z, feet
2	41.6866	18742.33	3.50	- 7804.59	3.88	90819.86	1.05
3-2		- 2760.97	0.33	- 995.39	0.37	8839.55	0.12
3	44.7869	15981.36	3.83	- 8799.98	4.24	99659.41	1.15
4-3		- 2860.31	2.38	- 1021.91	2.63	8821.86	0.72
4	48.0243	13121.05	6.21	- 9821.89	6.88	108481.27	1.86
5-4		- 2930.59	0.42	- 1046.39	0.47	8709.13	0.17
5	51.3701	10190.47	6.63	-10868.28	7.34	117190.40	2.01
6-5		- 3006.37		- 1073.73		8562.40	
6	54.8197	7196.90		-11930.07		125758.52	
8-6		- 6268.30		- 2195.94		16610.95	
8	62.0382	928.60		-14126.01		142369.47	
9-8		- 3303.45		- 1147.41		8097.63	
9	65.8629	- 2374.85		-15273.42		150467.10	
10-9		- 3450.83		- 1203.51		7946.40	
10	69.8587	- 5825.68		-16476.93		158413.50	
11-10		- 3612.84		- 1268.95		7796.03	
11	74.0596	- 9438.52		-17745.88		166209.53	
12-11		- 3833.18		- 1315.67		7648.94	
12	78.5164	-13271.70		-19061.55		173858.47	
13-12		- 3955.33		- 1369.80		7241.76	
13	83.1269	-17227.03		-20431.35		181100.23	
14-13		- 4329.63		- 1490.96		7230.82	
14	88.2319	-21556.66		-21922 31		188331.05	
15-14		- 4788.97		- 1705.82		7003.70	
15	93.8814	-26345.63		-23628.13		195334.75	
16-15		- 5181.80		- 1773.42		6397.27	
16	99.9588	-31519.85	3.88	-25394.63	4.29	201736.03	1.55
17-16		- 5857.34	4.98	- 2001.60	5.51	5823.53	2.02
17	106.8451	-37377.18	1.10	-27396.23	1.22	207559.56	0.47
18-17		- 6786.97	11.22	- 2322.82	12.39	4879.72	5.03
18	114.8679	-44164.15	12.33	-29719.05	13.61	212439.28	5.50
19-18		- 8378.21	10.61	- 2835.04	11.67	3288.92	5.56
19	124.8824	-52542.37	22.94	-32554.09	25.29	215728.20	11.06

Note: Data are given with respect to center microphone at Twin Lakes.

TABLE III

PRELIMINARY SM1.05 DOVAP MISSILE POSITION AT TIME OF GRENADE EXPLOSIONS

Grenade No.	Range Time, second	X(+N), feet	σ_x, feet	Y(+W), feet	σ_y, feet	Z(+up), feet	σ_z, feet
1	38.7668	36417.77	9.79	85.27	10.61	86679.10	1.76
2-1		- 729.16	2.38	- 119.44	2.58	11318.53	0.58
2	41.7730	35688.61	7.41	- 34.17	8.03	97997.63	1.18
3-2		- 739.16	2.18	- 124.36	2.35	11304.92	0.43
3	44.8858	34949.45	5.24	- 158.53	5.68	109302.54	0.75
4-3		- 797.08	1.76	- 131.73	1.91	11664.35	0.17
4	48.2113	34152.37	6.99	- 290.26	7.60	120966.89	0.92
5-4		- 787.02	0.89	- 122.44	0.97	11122.40	0.06
5	51.4937	33365.34	7.88	- 412.70	8.57	132089.29	0.95
6-5		- 831.04	3.57	- 114.83	3.89	11577.82	0.34
6	55.0334	32534.31	11.45	- 527.53	12.46	143667.11	1.28
7-6		- 863.76	5.08	- 120.43	5.52	11396.06	0.45
7	58.6500	31670.55	16.53	- 647.95	17.98	155063.17	1.73
8-7		- 879.57	2.01	- 128.52	2.19	11067.41	0.15
8	62.3009	30790.98	18.54	- 776.48	20.17	166130.58	1.84
9-8		- 907.43	0.70	- 130.37	0.75	11257.33	0.17
9	66.1715	29883.56	17.84	- 906.85	19.42	177387.91	1.69
10-9		- 954.68	2.34	- 127.60	2.56	11161.39	0.17
10	70.1842	28928.88	20.18	-1034.44	21.98	188549.30	1.83
11-10		- 1004.29	1.27	- 170.18	1.39	11414.71	0.19
11	74.4957	27924.59	18.91	-1204.62	20.58	199964.01	1.66
12-11		- 1087.66	10.36	- 144.15	11.29	11196.74	0.85
12	78.9640	26836.93	29.27	-1348.77	31.87	211160.74	2.50
13-12		- 1128.70	2.72	- 139.89	2.97	11264.09	0.23
13	83.7406	25708.23	31.99	-1488.66	34.84	222424.83	2.68
15-13		- 2572.01	22.62	- 364.46	24.70	22764.25	1.86
15	94.5359	23136.23	54.62	-1853.12	59.54	245189.08	4.50
16-15		- 1440.41	0.30	- 262.59	0.32	10949.39	0.25
16	100.4845	21695.81	54.33	-2115.71	59.22	256138.47	4.50
17-16		- 1532.60	18.30	- 145.75	19.81	11082.63	1.48
17	107.2339	20163.22	36.03	-2261.46	39.41	267221.10	3.03
18-17		- 1884.84	26.66	- 205.71	29.02	11197.85	2.32
18	115.1867	18278.38	62.69	-2467.17	68.43	278418.95	5.33
19-18		- 2162.37	105.43	- 140.45	114.80	10918.72	9.01
19	124.8305	16116.01	42.74	-2607.62	46.37	289337.66	3.67

Note: Date are given with respect to center microphone at Twin Lakes.

TABLE IV

PRELIMINARY SM2.10 DOVAP MISSILE POSITION AT TIME OF GRENADE EXPLOSIONS

Grenade No.	Range Time, second	X(+N), feet	σ_x, feet	Y(+W), feet	σ_y, feet	Z(+up), feet	σ_z, feet
1	43.9582	34057.47	5.76	- 208.68	6.25	101924.75	0.88
2-1		- 1086.10	0.10	- 219.24	0.11	11783.41	0.11
2	46.3774	32971.37	5.66	- 427.92	6.16	113708.16	0.79
3-2		- 1124.22	1.04	- 221.30	1.13	12108.19	0.20
3	48.9072	31847.16	4.62	- 649.22	5.03	125816.35	0.59
5-3		- 2289.96	0.79	- 454.73	0.86	23999.77	0.18
5	54.0599	29557.20	3.83	-1103.95	4.17	149816.11	0.43
6-5		- 1186.71	2.71	- 228.75	2.95	12105.42	0.28
6	56.7322	28370.49	6.54	-1332.70	7.12	161921.53	0.70
7-6		- 1232.94	7.31	- 258.64	7.96	12250.39	0.73
7	59.4905	27137.55	13.85	-1591.34	15.08	174171.92	1.43
8-7		- 1254.62	6.33	- 229.20	6.88	12387.29	0.68
8	62.3377	25882.93	7.52	-1820.53	8.19	186559.21	0.76
9-8		- 1311.20	2.04	- 241.66	2.23	12560.02	0.23
9	65.2878	24571.73	5.47	-2062.19	5.96	199119.23	0.53
10-9		- 1303.43	0.47	- 235.28	0.50	12296.22	0.06
10	68.2419	23268.30	5.00	-2297.47	5.46	211415.45	0.48
11-10		- 1319.69	5.15	- 245.61	5.61	12065.18	0.48
11	71.2078	21948.62	10.15	-2543.08	11.07	223480.63	0.96
12-11		- 1346.39	3.71	- 259.11	4.02	12045.71	0.36
12	74.2415	20602.22	6.45	-2802.19	7.05	235526.34	0.61
13-12		- 1379.56	4.12	- 265.81	4.44	12153.12	0.39
13	77.3793	19222.66	2.32	-3068.00	2.61	247679.46	0.22
14-13		- 1422.65	10.47	- 266.72	11.38	12327.31	0.98
14	80.6485	17800.02	8.15	-3334.71	8.77	260006.78	0.76
15-14		- 1495.58	0.47	- 231.12	0.61	12491.26	0.06
15	84.0572	16304.44	8.62	-3565.84	9.38	272498.04	0.81
17-15		- 3098.78	7.39	- 523.47	7.99	24737.36	0.69
17	91.1299	13205.67	1.24	-4089.30	1.39	297235.40	0.13
18-17		- 1533.52	40.27	- 174.97	43.84	12039.65	3.85
18	94.7446	11672.15	39.04	-4264.27	42.45	309275.05	3.72

Note: Data are given with respect to center microphone at Twin Lakes.

TABLE V

CALCULATION OF $\bar{\sigma}_u$ FOR DOVAP DATA

Rocket No.	Grenade No.	σ_x, feet	$\frac{\sigma_x}{\sigma_u}$	σ_u, feet	σ_y, feet	$\frac{\sigma_y}{\sigma_u}$	σ_u, feet	σ_z, feet	$\frac{\sigma_z}{\sigma_u}$	σ_u, feet	$\bar{\sigma}_u$, feet
SM1.03	3	5.8	2.2	2.6	6.3	2.35	2.7	1.2	0.75	1.6	2.3
	8	2.5	3.0	0.8	2.7	3.5	0.8	0.5	0.8	0.6	0.7
	18	11.7	5.8	2.0	12.8	6.25	2.0	3.2	1.4	2.3	2.1
SM1.04	3	3.8	2.2	1.7	4.2	2.45	1.7	1.2	0.75	1.6	1.7
	19	23.0	5.9	3.9	25.3	6.4	4.0	11.1	2.0	5.6	4.5
SM1.05	3	5.2	2.2	2.4	5.7	2.4	2.4	0.8	0.75	1.1	2.0
(Preliminary	7	16.5	3.0	5.5	18.0	3.5	5.1	1.7	0.65	2.6	4.4
Data)	19	42.8	5.7	7.5	46.4	6.15	7.5	3.7	0.7	5.3	6.7
SM2.10	1	5.8	2.2	2.6	6.3	2.4	2.6	0.9	0.75	1.2	2.8
(Preliminary	6	6.5	3.0	2.2	7.1	3.45	2.1	0.7	0.65	1.1	1.8
Data)	18	39.0	5.7	6.8	42.5	6.15	6.9	3.7	1.0	3.7	5.8

Note: Values 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.

σ_u = 5 ft; "good" (normal)
σ_u = 8 ft; "probably OK"
σ_u = 15 ft; "something wrong"

From Table V, it can be seen that on SM1.03 and SM1.04, for all points shown $\bar{\sigma}_u$ is less than 5 ft, and therefore the data are "good"; however, for grenades 19 of SM1.05 and 18 of SM2.10, the $\bar{\sigma}_u$ is greater than 5 ft. The data for these two grenades are "probably OK." SM1.05 and SM2.10 data are therefore called preliminary data, as more work will be done to improve the $\bar{\sigma}_u$ for these points.

Note that, in Table II, there are no entries for σ_x, σ_y, and σ_z in the time interval of 54-94 seconds. On this flight (SM1.04) because of a temporary power failure, DOVAP data were not obtained at the Twin Lakes station during this time interval. Thus the DOVAP data for this interval had only one solution, based on Metro, Launch, and Digges stations and values of σ_x, σ_y, and σ_z could not be calculated.

During the next work period, work on the data reduction of the Ft. Churchill firings will continue as follows. Counting will be completed for SM1.08 and SM1.09. Preliminary computations of position will be made for SM2.06, SM1.07, SM1.08, and SM1.09, and final computations will be made for at least two of the six uncompleted sets of data.

3. THE GUAM PROGRAM

3.1 GENERAL COMMENTS

This report describes all the operations up to the date of shipping equipment to Guam, and thus, for the sake of continuity, covers the work of a few weeks following the end of the quarterly report work period.

The description of the work of this period is divided into several parts, each of which concerns a main unit of equipment and its associated component parts and instruments.

3.2 THE TRANSMITTER VAN

This van was the first unit of Guam equipment to arrive at the University. It contained two motors to be used with the air-contitioning system. These motors were checked out and installed. The entire air-conditioning system was then checked out. The van was painted with two coats of aluminum paint in accordance with instructions furnished by the Signal Corps.

The 2-kw Gates DOVAP transmitter was set up in the laboratory and was given a preliminary check-out. The various stages tuned approximately as specified in the operations manual. However, the unit was extremely unstable. After several weeks of operation, during which time personnel were becoming familiar with the unit, the instability remained. Analyses indicated that improper "grounds" and the existence of "ground loops" were the primary cause of the instability. Severe modification of the unit was felt necessary to insure reliable operation at Guam. A list of the modifications is given below.

a. Radiofrequency shielding was improved by removing paint from the joining panel, chassis, and sections of the transmitter frame; by placing brass weather stripping on the transmitter doors and frame; by using aluminum side panels instead of the panel supplied with the unit; and by fastening together the top and rear covers of the oscillator with aluminum. These modifications also improved conductivity for ground circuits.

b. The oscillator was retuned.

c. Parasitic oscillations of the driver unit were eliminated by paint removal, installation of a shield around the 6146 buffer grid coil, installation of 18-ohm resistors in the grid leads of each of the 6146 driver tubes, and installation of a parasitic choke in the screen grid lead of the 6146 driver tube.

d. The tuning condenser, C218, of the driver unit was replaced by a 50-μμf variable condenser to achieve a wider tuning range.

e. A 74-Mc parallel tuned plate trap was inserted into the output plate circuit.

f. The rf plate choke L210 was replaced by a type Z-28 choke to eliminate rf overheating during periods when the driver is not loaded.

g. A low-pass filter was inserted between the driver and final stage to help improve second harmonic attenuation

h. To improve screen-voltage regulation (screen voltage varied from 500-900 volts with load changes), a 15,000-ohm bleeder resistor was connected from the load side of R602 to ground. This change was beneficial also in that now the final-amplifier plate current drops to zero during key-up conditions The better screen-voltage regulation also reduces self-oscillation.

i. Aluminum foil was wrapped around the crystal to give better temperature regulation for the crystal

j. The Micromatch VSWR bridge was mounted between the base of the transmitter and the bottom of the cage of the final stage with the output flange on the coupler bolted to the base of the transmitter

k. The Gates low-pass filter was mounted on the bottom of the van beneath the transmitter. Andrews RG17/U coaxial cable was used to connect the low-pass filter to the antenna.

l. The filament transformer rack, located beneath the final-stage cage, was moved about an inch further into the transmitter to prevent arcing and shorting between the aluminum side panels and the wiring beneath the rack.

m. The plate tuning condenser was moved to a point at the center of the chassis, between the final tubes and slightly toward the left wall, with the shaft pointed downward; a right-angle drive was added.

n. The coupling coil to the final grid was series-tuned with a 35-μμf variable for easier impedance matching.

o. The grid coil was changed, and the grid-tuning variable capacitor was changed to a single section of 35-μμf capacity. An aluminum shield was placed around the grid-tuning section.

p. The sockets for the finals were rotated 90° so that the common ground point for each tube could be at the center of the chassis between each tube. The purpose of this change was to balance the rf current in the two tubes for stabilization of the amplifier.

q. The shield separating the final rf chokes and by-pass capacitors from the tube base connections was extended to the side of the chassis walls to improve the rf shielding.

r. The grid suppressor chokes were rewound (3 turns on 47-ohm 2-watt carbon). Screen suppressor chokes were inserted (3 turns on 3900-ohm 2-watt carbon).

s. The large by-pass capacitors were removed and replaced with smaller high-voltage ceramic capacitors (Centralab 850S 1000 μμf) which were mounted directly on the sockets for shorter rf return paths and lower inductance.

t. The final-amplifier plate coil was lowered to provide shorter leads.

u. A neutralizing condenser of the coaxial design was constructed and mounted between the final tubes and toward the right wall.

v. The ceramic trimmer condenser in the neutralizing circuit was mounted on the side wall behind the pressure switch.

w. The counter stops on the vacuum capacitors were changed so as to decrease the minimum capacitance.

The rf pickup coil for test purposes was moved to the left wall of the final cage so that it would clear the final tank coil adequately.

After the above modifications were made, the transmitter proved to be completely stable working into either a 52-ohm dummy antenna or the helical antenna. During tuning of the final through its complete range, without excitation, and with 4500 volts on the plates of the tubes of the final stage, the unit showed no tendency to oscillate.

The overall stability of the transmitter also proved good. After a suitable warmup period, the frequency of the transmitter varied only 3 cycles in a period of 10 minutes. Frequency measurements were made with a Hewlett-Packard frequency counter. This stability is considered adequate for our purposes.

A helical transmitting antenna was constructed. It was made of 3/4-in. copper tubing fastened to 2-in. stand-off insulators by means of copper straps. The frame was varnished.

The electrical feed-in to the antenna is at the center of the coil near the axis. Initially, the VSWR of the antenna was measured to be 2.5/1. The addition of a 19-1/2-in. stub and a 33-1/2-in. line stretcher enabled a VSWR of less than 1.1/1 to be obtained.

The VSWR indicated by the directional coupler, with the transmitter operating into a 50-ohm dummy antenna with the Gates low-pass in the line, was about 1.5/1. With the low-pass filter removed, it differed from 1/1 by a negligible amount. Pinching together the turns of the output coil of the low-pass filter enabled a VSWR reading of almost 1/1 to be obtained with the low-pass filter in the line.

Figure 1 is a schematic diagram of the modified portion of the transmitter circuit.

After all modifications had been made, the transmitter was operated at 3-kw output into its helical antenna at 36.94 Mc. The high-frequency channel of the DOVAP receiver was attached to a 73.88-Mc helical receiving antenna located about 30 ft from the transmitting antenna. Under these conditions, the receiver AVC meter read "15" on the "50" scale. The second harmonic content indicated is thus very low (of the order of a few microvolts). Since the transmitting and receiving antennas will be about 1/2 mile apart at Guam, with a resulting decrease in second harmonic at the receiving antennas of a factor of approximately 10^4, this measured second harmonic content is satisfactory. The Hewlett-Packard frequency counter for monitoring the stability of the transmitter will be included in the transmitting van. This unit was shock-mounted at the end of the bench in the aft portion of the van.

An amateur transmitter and receiver will be installed in the van for providing contact with home for the members of the party. The receiver will double as a frequency monitor of WWVH to provide a means of calibrating the frequency counter.

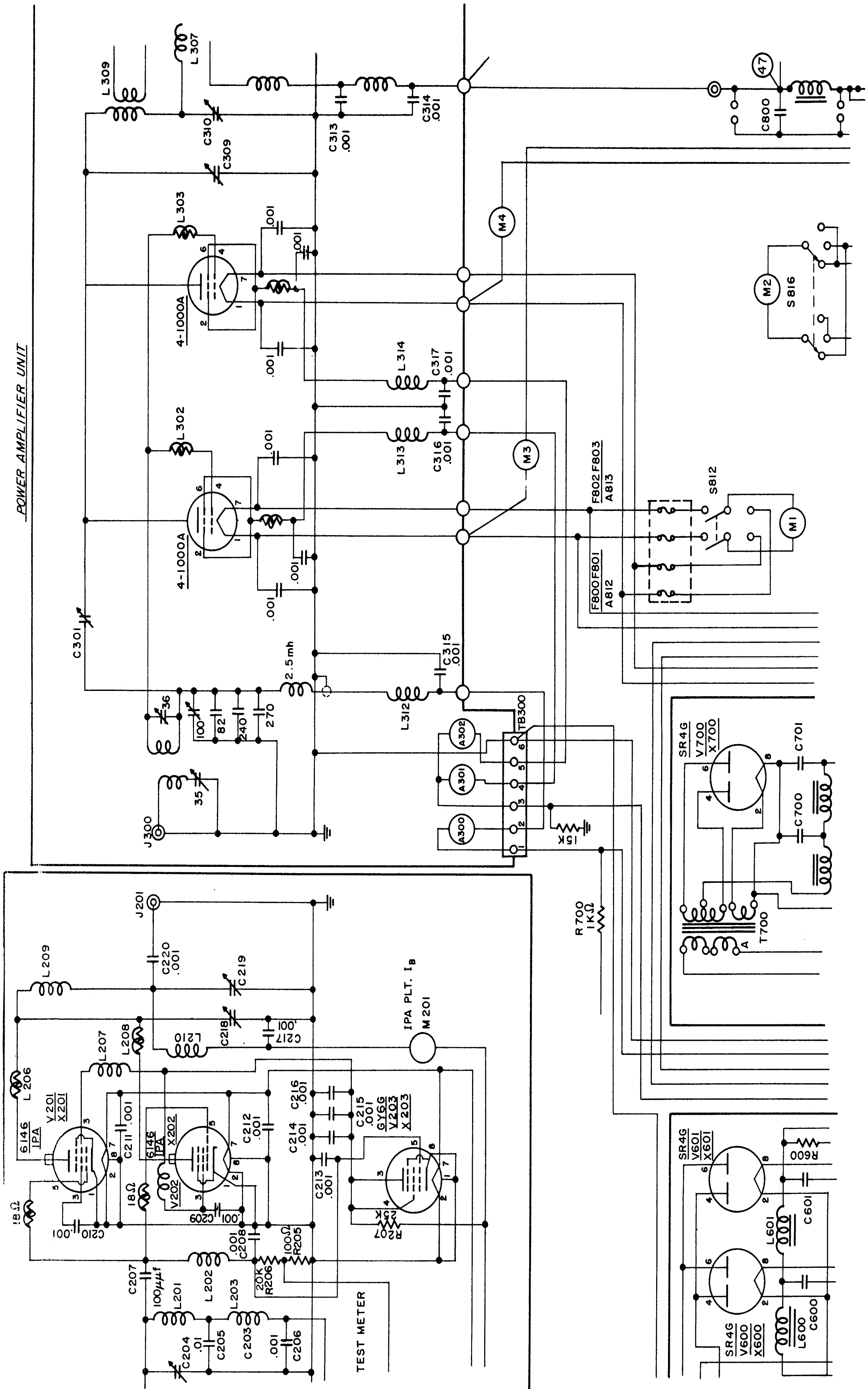

Fig. 1. Final stages of modified DOVAP transmitter.

Coaxial outlets were provided in the side of the van for the amateur band-transmitting antenna and for the WWVH antenna. In addition, connections were provided for attaching an intercom system and telephone, if required.

3.3 THE RECEIVER VAN

This van was received with air-conditioning unit completely installed. Replenishing the fluid in one of the two compressor units was the only work that had to be done on the air-conditioning system. The van was painted with two coats of aluminum paint to match the transmitter van. The controls of the motor-generator set were rewired and the unit was tested under operating conditions.

Conferences were held with personnel of USASRDL and BRL to determine DOVAP data requirements. Training sessions at BRL enabled University of Michigan personnel to become familiar with the art of testing and adjusting the equipment.

The initial effort on equipment for this van was expended in carrying out a complete check-out of the two DOVAP receivers. After the usual familiarization period, the receivers were found to be functioning improperly. On one receiver, peaking of the rf section could not be accomplished without replacement of a shunt capacitor. In general, solder joints were poor on both receivers and had to be re-heated. One i-f can contained a resistor with one side disconnected. Although the receivers were new on arrival, apparently they had never been subjected to an adequate final inspection.

Upon completion of the preliminary inspection and testing, a complete check-out was made for stability, sensitivity, noise figure, and calibration. Both units performed within specified limits. A graph of AVC meter readings vs. input voltage is shown in Fig. 2.

The Bendix TDA-9 sub-carrier discriminator showed signs of wear at the time of arrival. During the initial inspection, a malfunction was discovered in the output balancing circuit. This was caused by an open line in the "printed circuitry." A similar malfunction at a later date was caused by a faulty tube. In general, the discriminator was found to be in good condition and operated according to specifications. The tuning unit (30 kc ± 40%) was replaced by a new unit (30 kc ± 15%) at the request of USASRDL.

The Nems-Clarke Model 1502 receiver was in perfect working order when received, as shown by noise-figure and sensitivity tests. The only work done on this unit was for purposes of operator familiarization.

The Ampex FR-107A tape recorder required a great amount of study, as the staff was completely unfamiliar with its operation. At the time of arrival, the "head" cable was found to be defective. A replacement was supplied by the Ampex Corporation. The unit was modified to allow panel meter monitoring of the "Direct Record" Amplifier inputs and the "Direct Reproduce" Amplifier outputs. An

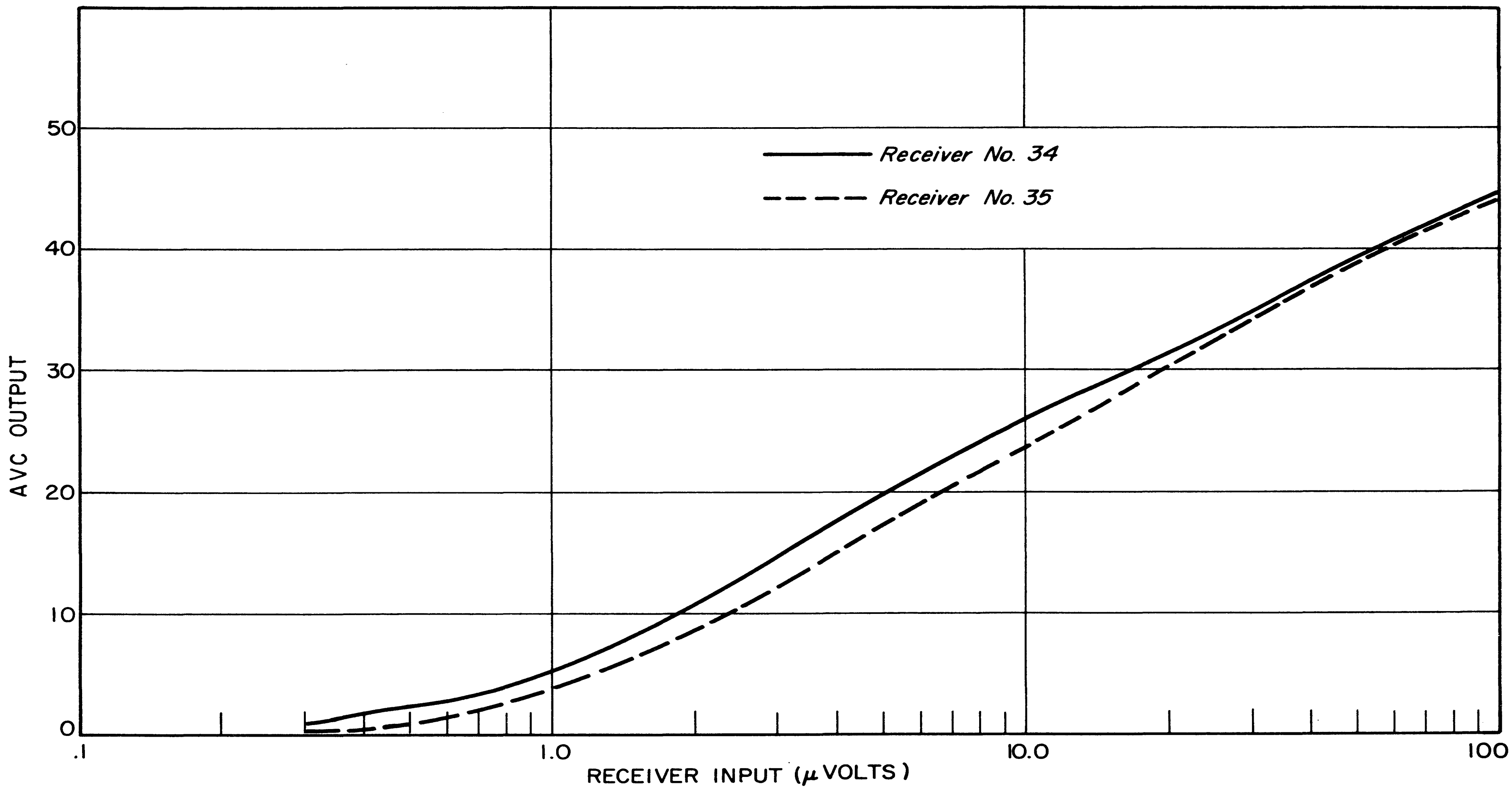

Fig. 2. Dynamic response of 73.88-Mc DOVAP receiver.

additional panel was installed to allow all signal connections to be made from the front of the chassis. A complete check-out was made following the procedure recommended in the Operations Manual supplied with the unit.

After the necessary rack mountings and fittings were completed, all equipment was shock-mounted in the van. Appropriate switching panels were built to permit oscilloscope monitoring of the various signals. Necessary interconnections were installed, and the equipment was tested as a complete system. Operationally, the receiver system performed satisfactorily. The only major problem that developed was excessive generation of heat by the discriminator; this was sufficient to overheat adjacent equipment. Blowers were mounted at the rear of the rack to dissipate the heat.

The only modifications made in the van itself were the installation of additional line strips and the installation of a connection panel for external cabling.

Necessary spare parts were stocked for all test and operational gear.

Helical antennas were constructed for the DOVAP receivers, one of "right-hand" and the other of "left-hand" polarization. A third helical antenna was constructed for use with the telemeter receiver. Each antenna was provided with a stub and stretcher to match the RG8U coaxial cable to the antenna with a VSWR of less than 1.1. A dipole antenna was constructed and arrangements were made for mounting it on the receiving van. This antenna will be used with the "spin" receiver.

Coaxial, phone, intercom, remote-transponder-power, and remote-transponder-control outlets were mounted in the side of the van.

3.4 THE RANGE-TIMER ASSEMBLY

Drift and noise in the WWVH amplifier caused very unstable operation. To correct this condition, an 82K grid leak was added to the grid of the second stage.

The input to the final stage was modified as indicated in Fig. 3. Following these changes, the operation proved entirely satisfactory.

The gain control in the pulse amplifier was modified in the same way and passed tests satisfactorily.

Operating instructions or circuit diagrams of the Range-Timer "Pip" Generator were not included in the shipment containing this unit. As a result, the voltages assumed for the various circuits were incorrect and unsatisfactory operation resulted. Operating instructions were obtained later and the unit then operated according to specifications.

Still later, trouble which developed was traced to a bad resistor in the

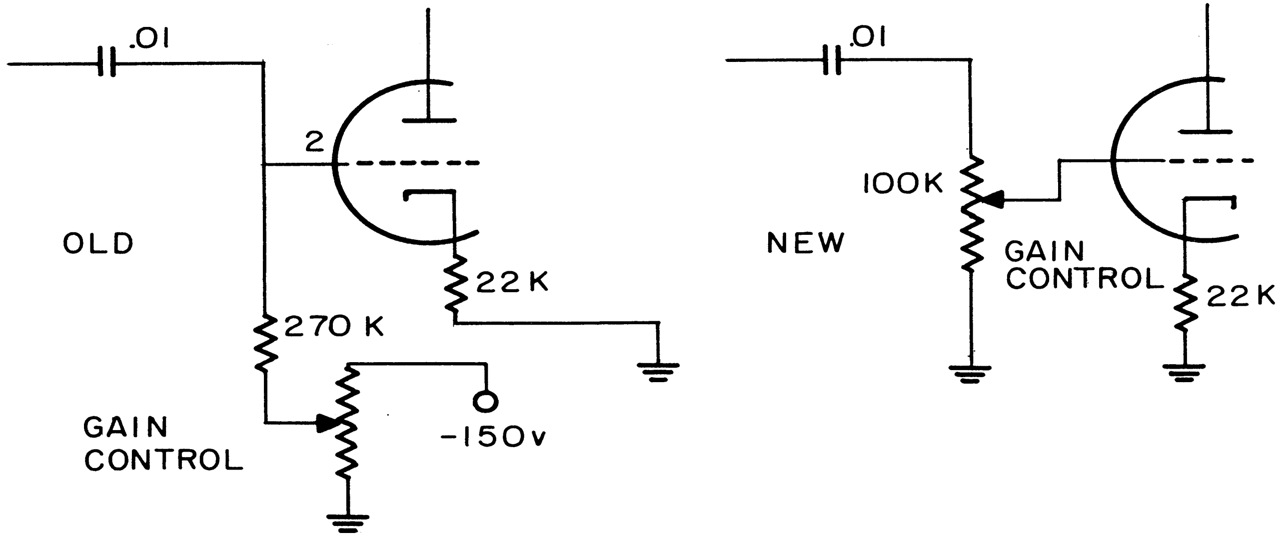

Fig. 3. Final stage of WWVH amplifier, showing modifications.

pulse amplifier. This was replaced. Sixty-cycle a-c noise was noted on the recorder. This was traced to a dirty contact in the pulse amplifier "output to Brush Recorder" plug.

All tubes in the unit were checked and three tubes in the pulse amplifier were replaced.

The Brush Recorder tends to jam at high speeds. There was insufficient time to correct this fault before shipping. However, all necessary data were taken on the Ampex recorder and a spare recorder was included in the shipment as a backup for the faulty unit.

A small pulse network, which would superpose a pulse on the range-time signal, was built. This unit will provide missile-lift data for the camera and all records.

An audio limiter was constructed to provide a constant output from the WWVH receiver. This will reduce the loss of record due to "fading" and "blasting" of the signal. The circuit diagram is shown in Fig. 4. This circuit provides an output pulse which varies no more than ± 1 db for inputs varying from 0.17 to 10 volts. Figure 5 is a graph of the output-input characteristic. The frequency-response curve of this unit was found to be "flat" from 50-50,000 cps.

3.5 TRANSPONDERS AND ASSOCIATED EQUIPMENT

Several modifications of the transponders were necessary. They are listed below:

a. A hole was drilled, tapped, and an 8-32 screw was inserted through the end plate of each transponder for pressure relief when installing and removing the transponders from their cans. After final closure, Glyptol will be applied to the screw for permanent sealing.

b. Radiofrequency by-pass capacitors were added to all pins on the power plug of each transponder. A brass ring was then mounted around the by-pass capacitors and the plug was potted with heat-setting "Scotchcast" No. 3. It was decided that Scotchcast No. 4 would be used for further potting applications because it eliminates the need for external heat while setting.

c. For greater reliability, the selenium rectifiers in the power supplies were replaced by silicon diodes. Two silicon diodes in series were necessary (400-volt inverse-voltage rating each) to meet the 500-volt inverse-voltage-rating minimum called for in the specifications.

d. Several malfunctions of the transponder power supplies occurred. They are as follows:

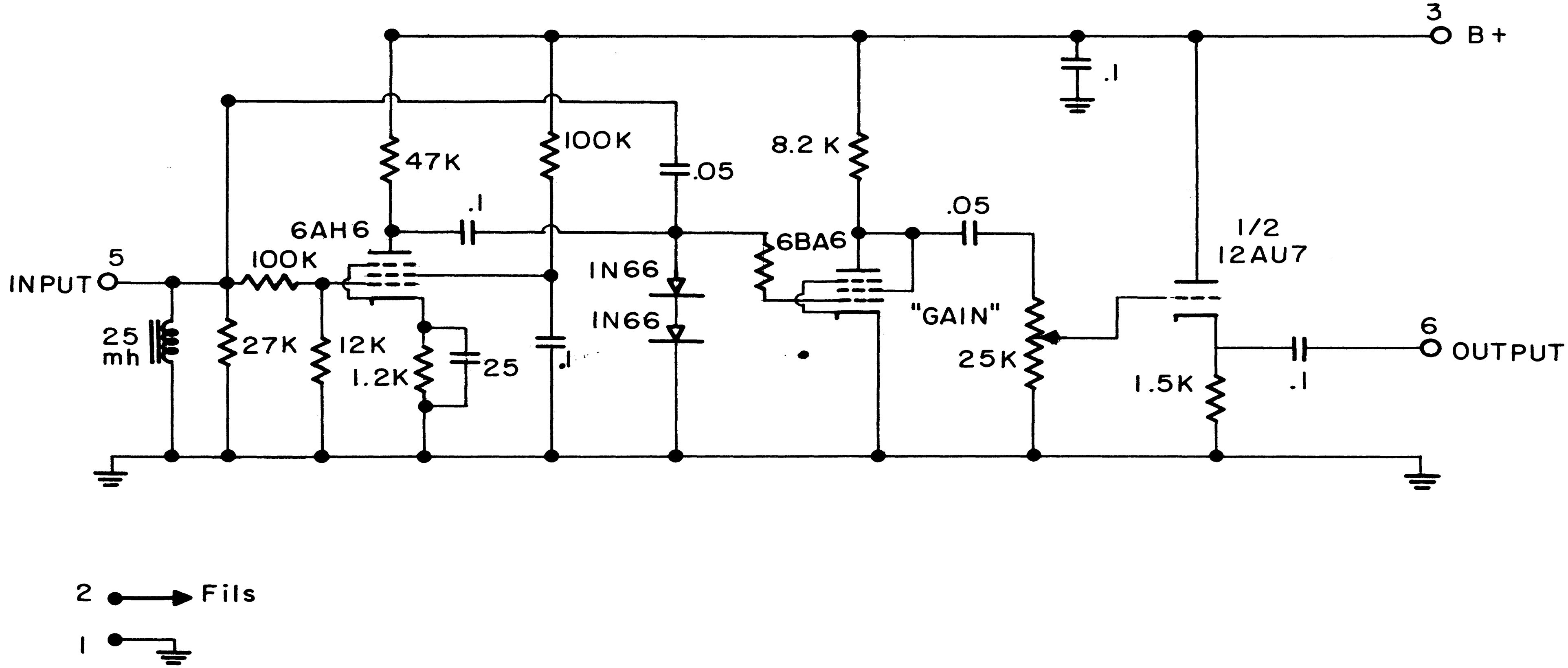

Fig. 4. Audio limiter for WWVH receiver.

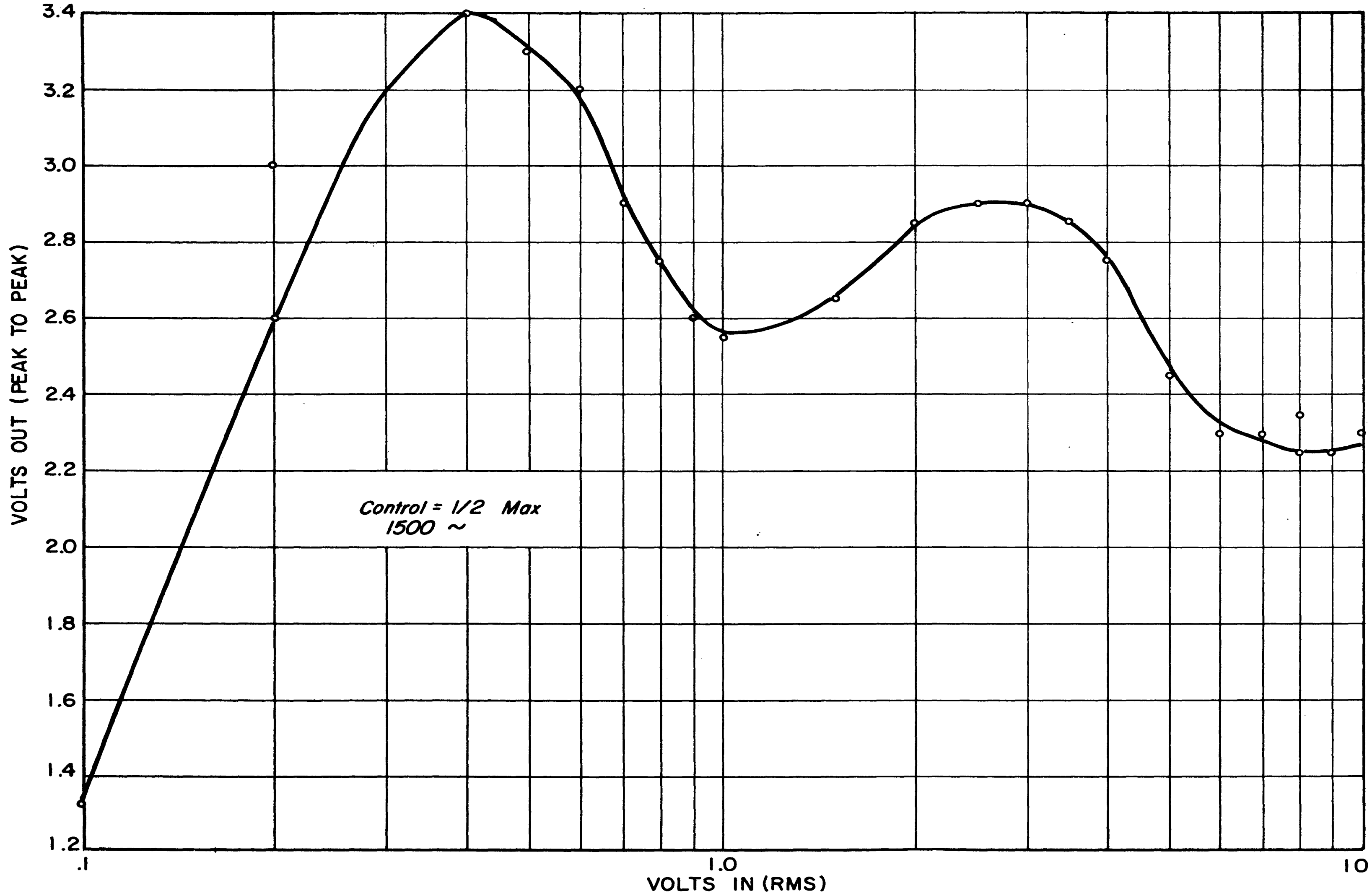

Fig. 5. Output-input characteristic of audio limiter.

Unit SN 114 - low B^+, with fluctuations. A loose diode was discovered and its mounting clips were tightened. The trouble disappeared.

Unit SN 111 - Vibrator refused to start. The vibrator was replaced and the unit resealed. Upon test, a direct short across the B^+ was discovered. It was found that during the resealing process, solder had flowed internally onto the B^+ terminal, shorting it to ground. The solder was removed and the unit resealed.

Five spare vibrators were ordered for replacement purposes. Under bench check, four of the vibrators failed to start. The trouble appeared to be due to dirty contacts. After cleaning the contacts, the vibrators started and appeared to function properly.

e. A decoupling circuit, R14 (1K) and C8 (20 μf), was added to the input of the sub-carrier oscillators.

f. The sub-carrier oscillator deviation was changed from 40% to 15% as per request of the Signal Corps. Changes are as follows:

R4 changed from 4.0K to 3.0K.
R5 changed from 100K to 36K.
C3 and C4 changed from 24 μμf to 39 μμf.

g. A crystal filter was added to the input of each transponder to minimize outside interference. The resulting bandwidth was about 2.5 kc with 3-db insertion loss.

h. Several troubles were discovered in other individual units, ranging from a solenoid switch wired backwards to a broken resistor. In several instances, unsoldered and cold-soldered joints were discovered and repaired.

The check-out procedures were the same for all transponders. First, the transponders were tuned for maximum power output. Limiting levels were observed and were generally between 30 and 50 μv. Power requirements were noted for both no-input and limiting-input conditions. Receiver sensitivity and bandwidth were checked without crystal filters and curves were run (see Fig. 6). The sub-carrier oscillator was checked for center frequency and stability and curves were run for from 0.0-v to 5.5-v input (see Fig. 7). A crystal filter was added to transponder SN 1 and a sample curve was run (see Fig. 6). The internal power supplies were added to each unit and bench checked. The units were then sealed in their cans and given a 1/2-hr warmup on internal power. Sub-carrier oscillator curves were re-run and the units checked for stability (see Fig. 8). Six of the nine units were acceptable while three were either unstable or had too great a shift of center frequency.

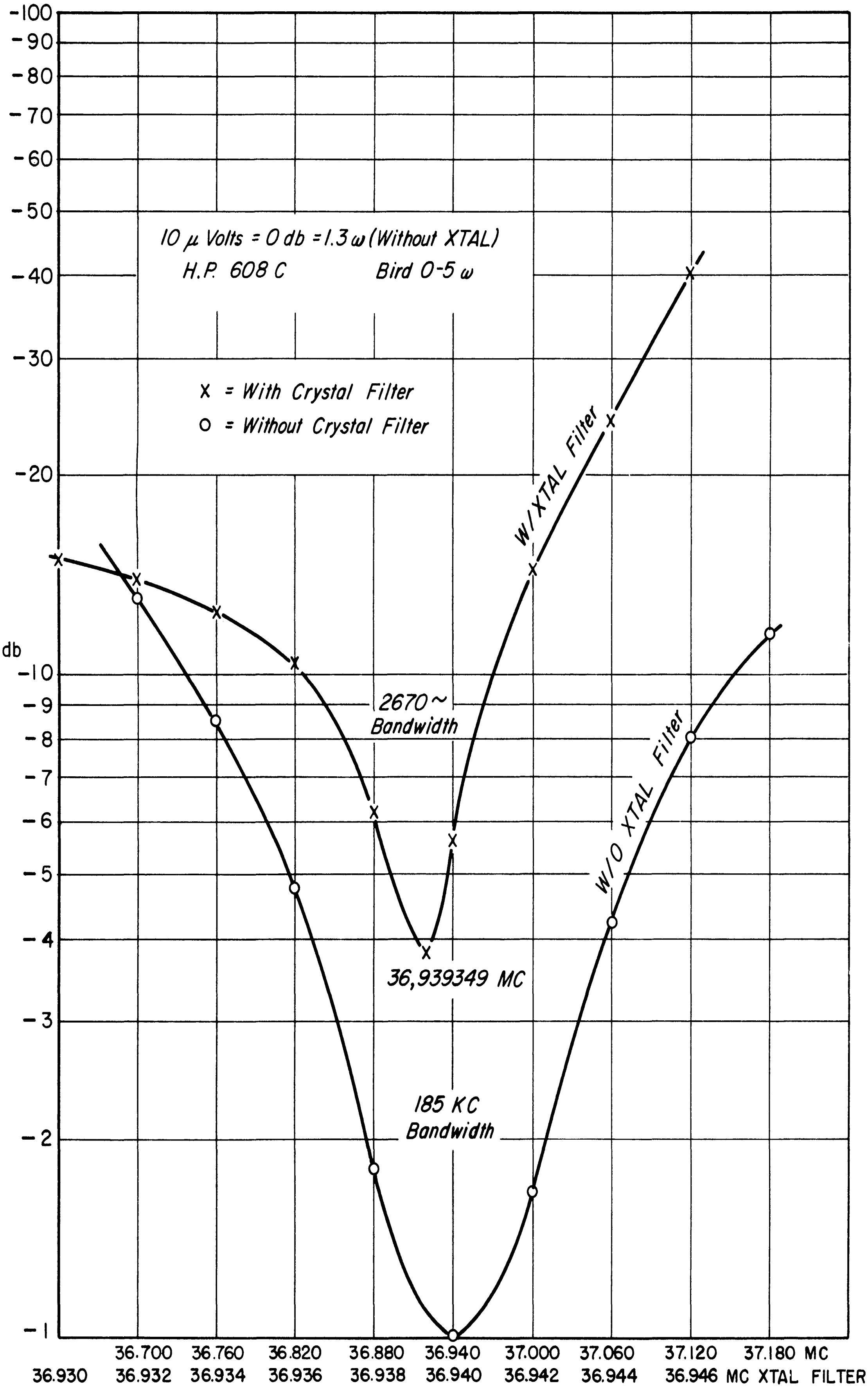

Fig. 6. Sensitivity and selectivity curve for transponder No. 1.

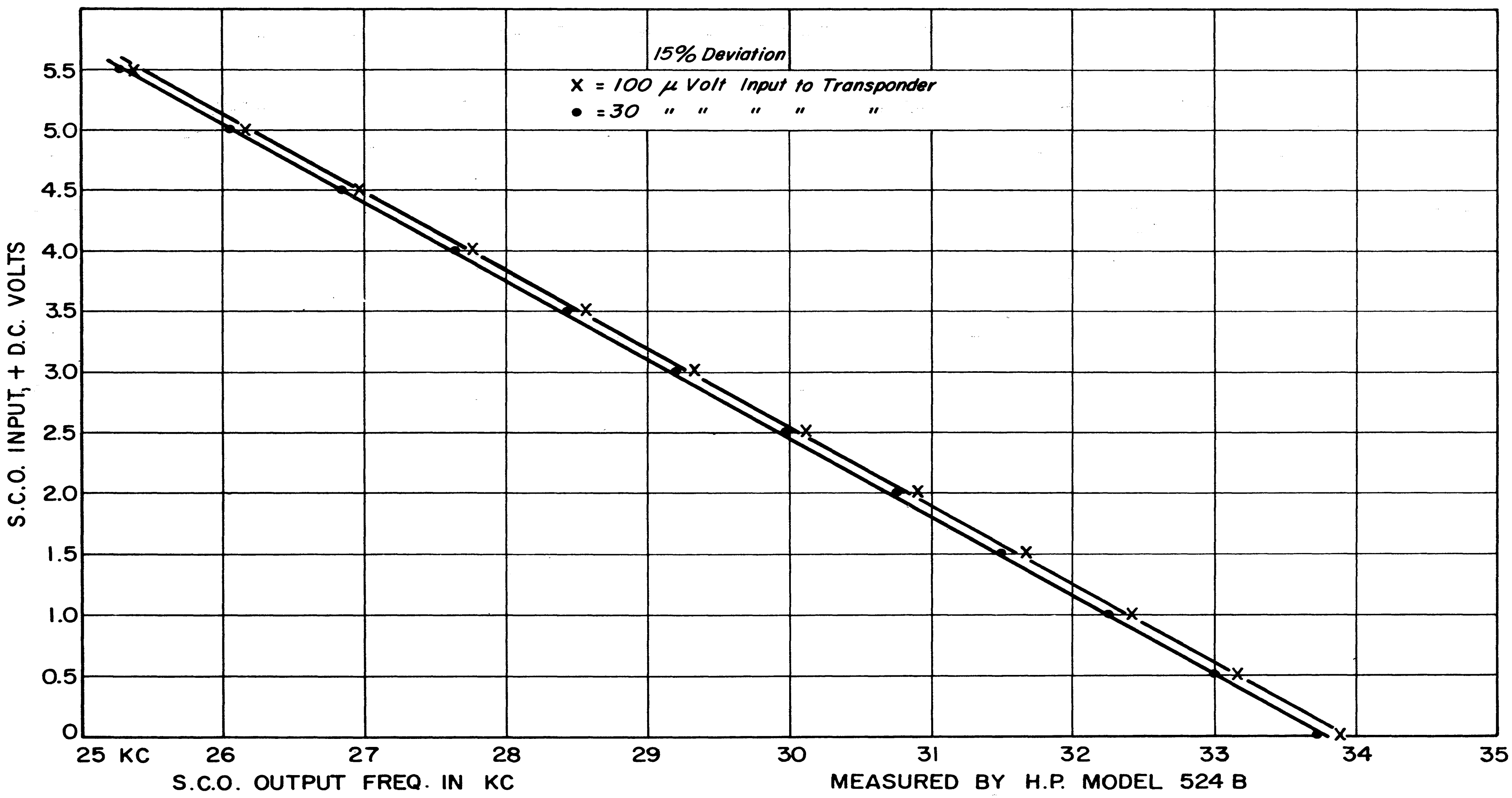

Fig. 7. S.C.O. calibration curve, transponder No. 2, preliminary calibration.

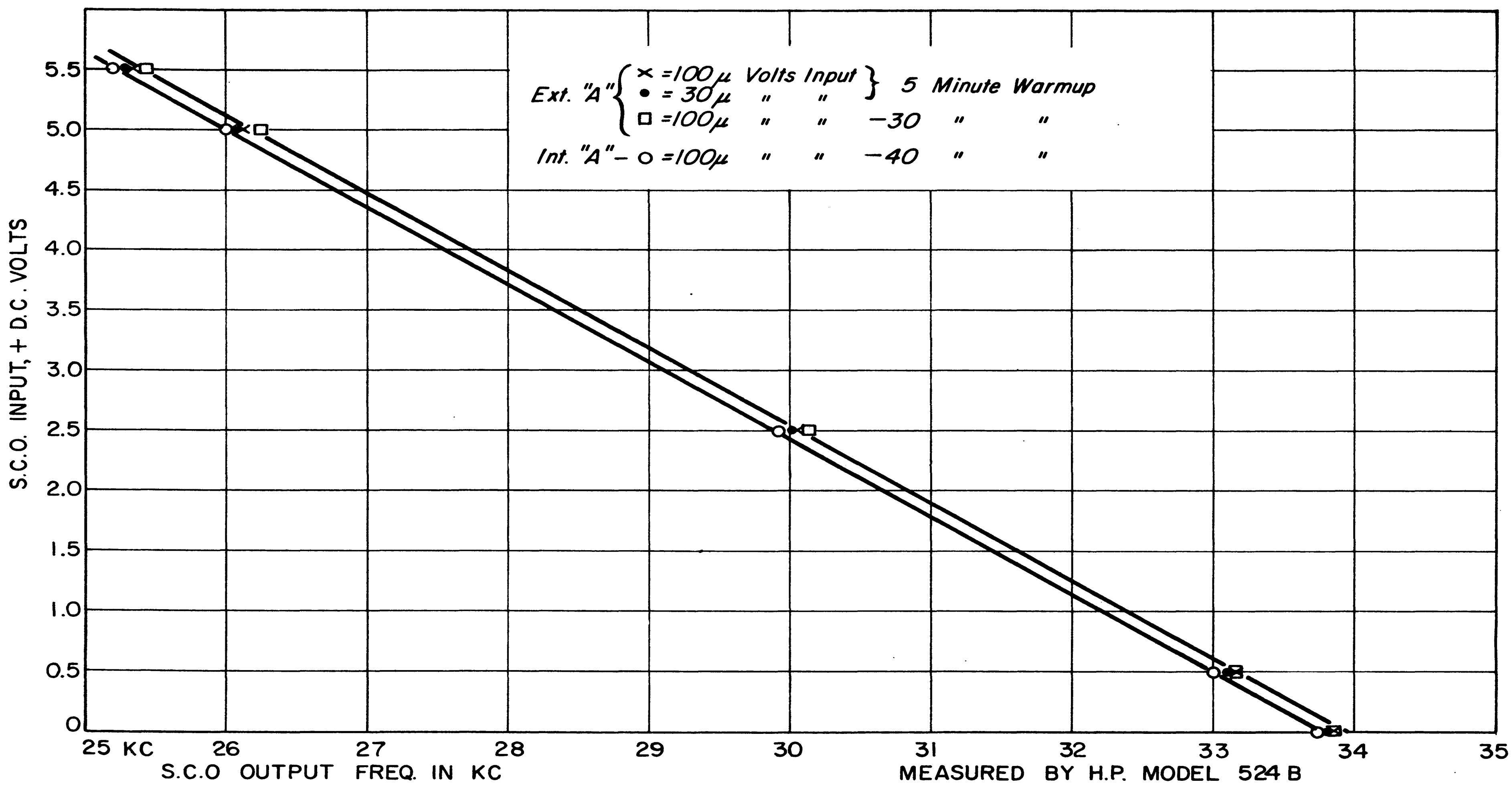

Fig. 8. S.C.O. calibration curve, transponder No. 2, unit sealed in can.

In preparation for tuning and adjusting the missile DOVAP antennas, two "E" probes, two phase meters and a 36.94- and a 73.88-Mc signal generator were constructed. This equipment was made at the suggestion of BRL and most of the units followed their designs. The slightly modified 36.94-Mc signal generator circuit is shown in Fig. 9 and the 73.88-Mc signal generator circuit, in Fig. 10.

The missile antenna systems and tuning procedure are described below.

(a) Aerobee Missile Antenna System

One-half of the center mounting strips on these antennas were found to be facing in the wrong direction for proper mounting on the missile. New mounting strips were built and mounted on the antennas.

The tie-down bands for the antennas were too long. A section approximately 4-1/2 in. long was removed and the band spot welded.

A dummy Aerobee body was constructed from sheet metal for use in antenna tuning. Generally, the Aerobee antennas tuned satisfactorily, coming within specifications.

(b) Nike-Cajun Missile Antenna System

The Nike-Cajun antennas posed more of a problem due to improper phasing. Shortening the feed length on the negative-phase antenna approximately 3 in. shifted the phase enough to allow fairly decent tuning of the antennas. As opposed to the Aerobee antennas, the Nike-Cajun antennas seemed to be unmatched sets. On one set of antennas, it was necessary to change the tap points physically to phase them properly. Four sets of these antennas were finally matched within specifications. Two sets were later shipped to us from BRL, giving us a total of six workable sets for the Guam shoots. Several unmatched sets were shipped to Guam for later matching, should the necessity arise.

(c) General Tuning Procedure

The antennas were individually mounted on their respective rockets and tuned for minimum VSWR and maximum E-Probe readings. Sets were then chosen by equal SWR and E-Probe readings. The sets were then mounted on the rockets and then tuned for minimum SWR and 0 phase while still obtaining nearly equal E-Probe readings.

After preliminary tuning of the antennas in sets, the antennas were packed and shipped to Guam where final tuning will be done with the antennas mounted upon their individual rockets.

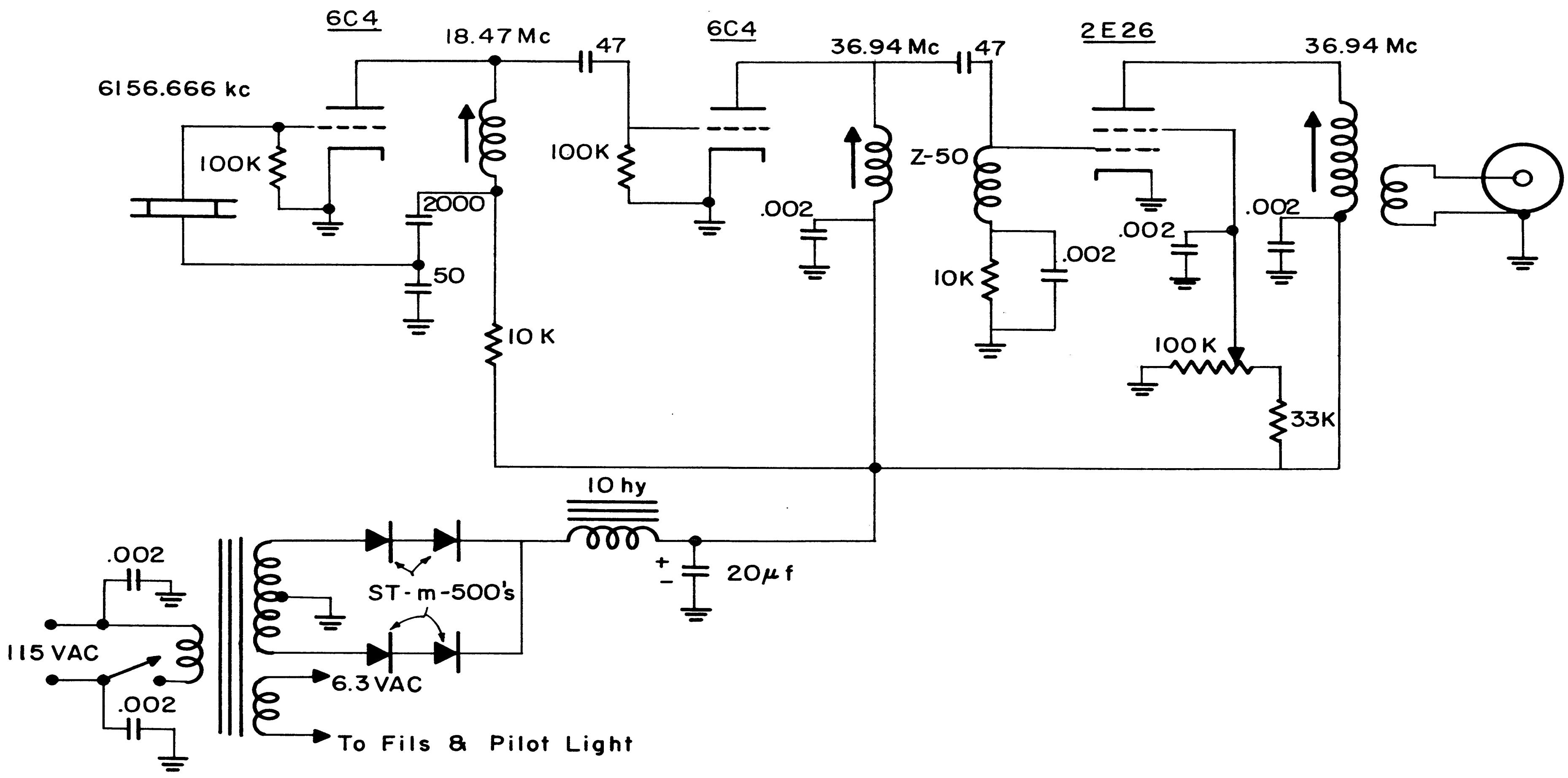

Fig. 9. 36.94-Mc signal generator.

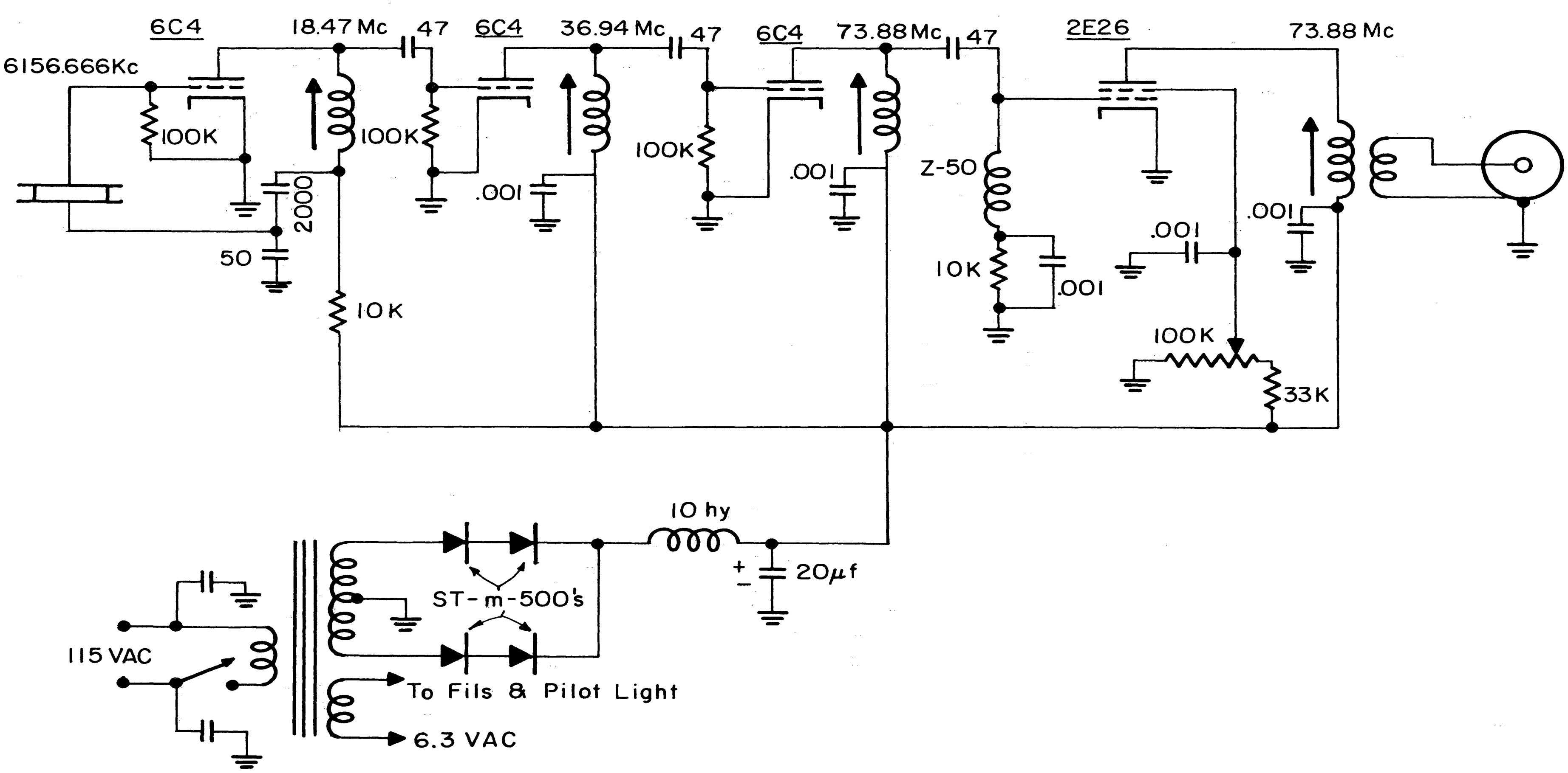

Fig. 10. 73.88-Mc signal generator

3.6 BALLISTIC CAMERAS

Four ballistic cameras and a dozen 1/16-in. glass plates were received from Ft. Monmouth at the end of May. The emulsion on these plates was old, and when the first pictures taken were fogged, it was attributed to the age of the emulsions. A camera mount was designed, and drawings were carried to Guam during the coordinating visit in June. Two mounts were erected at the University's station on Peach Mountain, at an elevation of approximately 1100 ft above sea level, near Dexter, Michigan.

The first of the 1/8-in. plates arrived in June, but due to weather difficulties, no pictures were taken prior to the Guam coordinating trip. The refrigeration unit failed at an unknown date during this interval, so the plates were stored for an undetermined period of time at room temperature.

The solenoid-operated shutters were received in July, and were modified by additional bracing of the solenoid which was eccentrically mounted and subject to considerable deflection. A microswitch was added to give a circuit indication when the shutter is open. The leads from the solenoid and microswitch were brought out to a four-prong AN-type connector. One shutter operated in all positions, and two others in nearly all positions. These three shutters were shipped to Guam along with a battery box and the necessary cables. The other shutter was retained at The University of Michigan for further tests.

The first star-trail photographs taken with the 1/8-in. plates were fogged by light coming through leaks in the plateholders. These were repaired, but the design of the plate holders is such that freedom from leaks cannot be guaranteed. Consequently, loaded plateholders must be handled in darkness, and transported inside of a light-proof "changing" bag. Weather difficulties prevented completion of the planned series of star-trail photographs. The first shipment of plates was used up by this time, except for those retained for grenade-exposure tests. Two cameras were shipped to Guam at the end of July.

Initially, grenade-exposure tests were planned to be held at The University of Michigan, but it appeared more convenient to carry these out at Camp Wellfleet, Massachusetts, a National Guard base. During the night of August 7-8, six plates were exposed at various stop openings, and the plates were developed the following day in the base's darkroom. All plates were fogged, and an unexposed plate developed at the same time was also fogged. It was assumed that the emulsion had been fogged by the prior accidental storage at room temperature, and by extremely high-temperature storage at Camp Wellfleet, as well as by difficulties with high developer temperature. However, another unexposed plate which had made the trip to Wellfleet and return was developed at Ann Arbor and found to be reasonably clear of fog, so the darkroom at Camp Wellfleet was considered to be faulty, and a new series of grenade-exposure tests was planned at The University of Michigan.

During August, poor weather conditions still prevailed, but a limited amount of star-trail information was obtained. It was determined that the quality of star images is very poor except in the center of the field at the larger stop openings. At f/11 and f/16, a fair number of star trails are visible when clear weather prevails, and the quality of the images is much improved. There appears to be very little background fog at exposures of up to eight minutes' duration, even with a full moon just out of the field of view. Photographs were taken only on very clear nights.

Grenade-exposure tests were delayed by the fact that the grenades required over a month's shipping time, and tests were finally conducted on 19 September. Two cameras were mounted at the Peach Mountain station, and the grenades were fired at Butler Hill, another elevated point 15 miles distant, with a clear line of sight. The weather was extremely clear, and successful exposures were obtained for exposures of f/22 to f/6.3. Plate measurements have not been carried out as yet, but it is believed that the data are sufficient to establish the camera settings during the Guam firings.

3.7 OVERALL SYSTEM CHECK-OUT

After all equipment was installed in the two vans, a complete operations check was made. The transmitter was checked out as a separate unit, and during the test operation, a 4-watt signal generator was used to simulate the transmitter. The transponder was put into "remote" operation and operated from small input and output antennas.

The test is probably best described by the "X" time instructions below.

Starting with all equipment warmed up.

X-5 min

Public address pickup on.
Ampex recorder transport on.
Range-time Brush Recorder on.
Transponder on external power.

X-4 min

Camera shutters open (pulse on Brush Recorder, indicating lights on).

X-2 min

Camera shutters close (pulse on Brush Recorder, indicating lights off).
Transponder on internal power.
Ampex transport off.
Range Brush Recorder off.

X-30 sec

Ampex transport on.
Esterline Angus Recorders on.
Two Brush Recorders on.

0

Lift - produces lift pulse.

X+10 sec

Telemeter information signal (0.5 volt)

X+20 sec to X+100 sec

Telemeter information signal increases at 10-sec intervals to 5 volts

At X+20 sec the ballistic cameras are opened with resulting pulse.

X+110 sec

Telemeter information signal (0.0 volt)

X+150 sec

Cameras off, with resulting pulse.

X+250 sec

End test - all equipment off.

At the conclusion of the test, the Ampex tape was played back and the signals were inspected for stability, noise, and accuracy. The two channels of Esterline Angus tape and the four channels of Brush Recorder tapes were checked in a similar manner.

This procedure simulated an actual rocket firing as accurately as was possible with our available equipment. It is planned to make similar tests at Guam.

Inspection of Fig. 11 will provide an understanding of the overall operation including the equipment furnished by USASRDL.

By August 4 all equipment was installed and packed to be shipped to the Army for final processing for overseas shipment. The shipment was expected to leave Jersey by boat in transit to Guam on August 20.

3.8 FUTURE WORK

The next work period will be occupied by the installation, testing, and operation of the ground-station equipment at Guam.

4. AIR-SAMPLING EXPERIMENT

During the month three technical papers were prepared. The first, "The Measurement of Diffusive Separation in the Upper Atmosphere," was furnished and published in the book, IGY Rocket Report Series, Number 1, July 30, 1958, "Experimental Results of the U. S. Rocket Program for the International Geophysical Year to 1 July 1958." The second, "A Micro Fractional Adsorption Analyser for Determination of Helium and Neon," and the third, "Measurement of Helium and Neon by

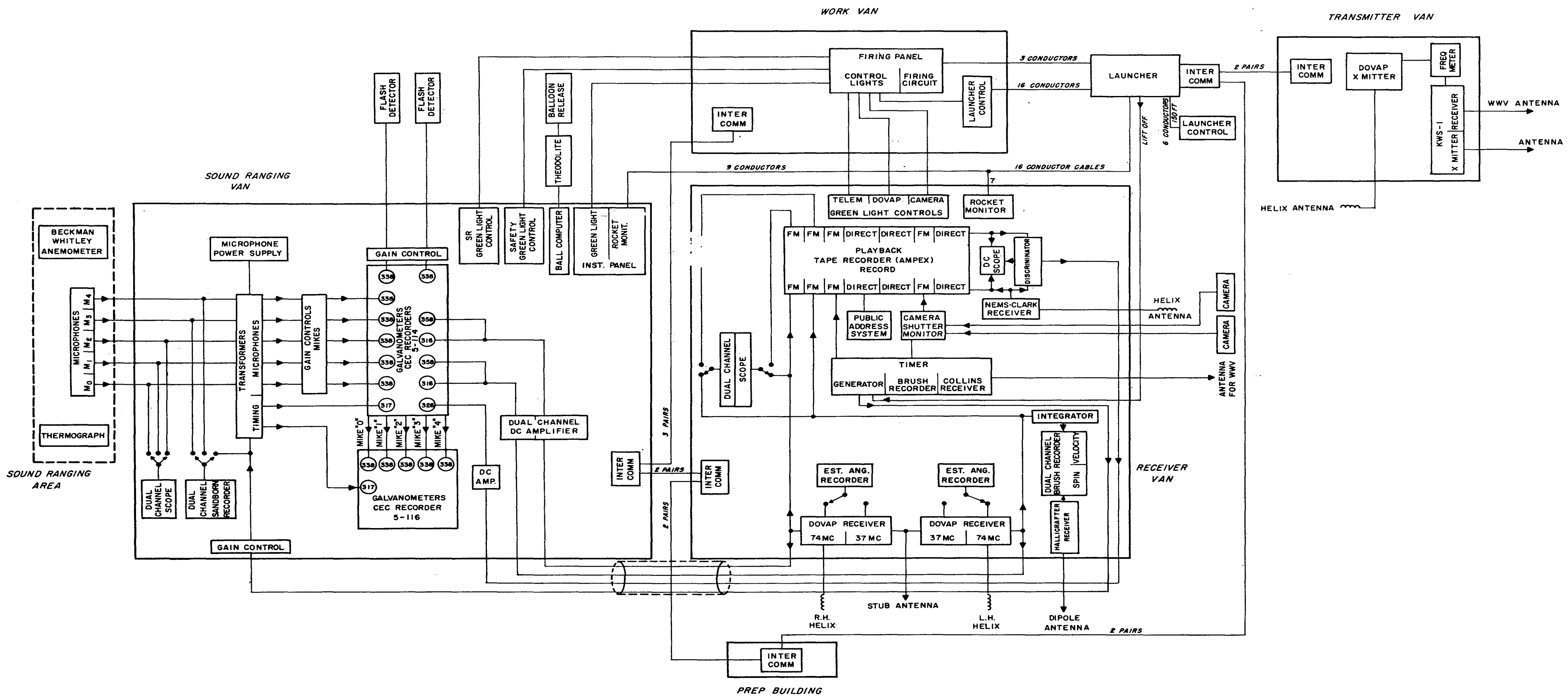

Fig. 11. Diagram of overall instrumentation required for Guam rocket-grenade experiments.

Means of an Ionization Gage," were prepared and are awaiting final approval before publication.

5. SHOCK WAVES FROM EXPLOSIONS

The study of spherical shocks has continued. The status of the existing knowledge in this field of study, as revealed by a search of the literature, is summarized below.

Theoretical studies include mathematical solutions of the nonlinear partial differential equations which describe the propagation of spherical shocks caused by:

a. The idealized case of the "instantaneous release of a point source of energy" in an ideal gas and in air at NTP (normal temperature and pressure).

b. Chemical explosions of spherical charges in air at NTP.

c. The instantaneous release of spheres of high-pressure gas in air at NTP.

Analytical solutions of the equations have been obtained for some regions of the point-source case, and approximate numerical solutions have been obtained for all three cases by the use of a high-speed digital computer.

Experimental data available in the literature include measurements of the propagation of shocks due to:

a. Nuclear explosions in air.

b. Chemical explosions, in air, of charges of various shapes and kinds of explosive.

c. The release of spheres of high-pressure gas in air at NTP.

d. High-energy sparks in air at NTP.

The experimental shock-propagation data for nuclear explosions and for spark sources agree very well, except for the region close in to the source, with the point-source theory; the shock-propagation data for chemical explosions and for the spheres of high-pressure gas agree with their theories within the limitations of the experimental techniques.

The difficulty in applying these theories to the measurement of air density at high altitudes lies in the extrapolation or scaling of the theory to describe the propagation of spherical shocks in atmospheres other than those at NTP. Suitable scaling is possible for the point-source theory. However, for the other sources, scaling is not possible. Thus additional solutions, theoretical and experimental, are required for spherical shocks propagating in low-density media.

The question of the scattering or reflection of electromagnetic radiation from some region of the shock wave has not been completely answered so far by the literature survey. Work on this aspect of the problem will continue during the next work period.

6. RAREFIED GAS DYNAMICS RESEARCH

During this period the first application of the proposed principle of almost-free molecule flows was made. This principle was applied to the calculation of skin friction of a flat plate. A paper, entitled "On the Drag of a Flat Plate at Zero Incidence in Almost-Free-Molecule Flow," was submitted to, and accepted for publication in, the Journal of Fluid Mechanics. A summary of this paper is given below.

A physical theory is proposed for the skin friction on a flat plate of zero incidence in the transition flow regime, i.e., in the flow of a moderately rarefied gas. The ratio of the molecular mean free path to the characteristic size of the plate is assumed of the order unity or larger. A general formula for the perturbation to the well-known skin friction of the free-molecule theory is given. This perturbation is attributed to the intermolecular collisions which are neglected on the basis of the free-molecule hypothesis. The expected rate of collisions is calculated for rigid spheres, using the classical kinetic theory.

Although this is intended as an approximate theory, the theoretical results check surprisingly well with the limited experimental data that are available. The present theory shows that the ratio of the Reynolds number to the Mach number squared is the governing parameter for determining the intermolecular collision effect on skin friction in the transition flow regime.

7. LABORATORIES VISITED

U. S. Army Signal Research and Development Laboratories
Aberdeen Proving Ground
White Sands Proving Ground
The RAND Corporation
New Mexico College of Agriculture and Mechanic Arts
Centre Universitaire Mediterraneen in Nice, France
(Symposium on Rarefied Gas Dynamics)

8. ACKNOWLEDGMENT

We are indebted to the Meteorological Branch of the U. S. Army Signal Research and Development Laboratories for continued collaboration and support.

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