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THE UNIVERSITY OF MICHIGAN
ANN ARBOR

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

Quarterly Report

for the period

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by

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F. L. Bartman

L. T. Loh

J. Otterman

Approved: L. M. Jones

Department of Aeronautical Engineering

Project 2387

DEPARTMENT OF THE ARMY PROJECT NO. 3-17-02-001
METEOROLOGICAL BRANCH, SIGNAL CORPS PROJECT NO. 1052A
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

Tests of the various components of a grenade leading to the design of a grenade were accomplished. Calculations of the magnitude of pressures to be expected at the ground from explosions of 4-pound charges were made. The process of DOVAP spin corrections was programmed for MIDAC. Further hand counting of DOVAP cycles of previous Aerobee firings was carried out. An economic comparison of machine and hand counting of DOVAP cycles was made. Work was continued on the preparation of flight upper-air sample bottles. Four air samples (control and residual upper air) were analyzed on the new Michigan analyzer.

THE UNIVERSITY OF MICHIGAN PROJECT PERSONNEL
Both Part Time and Full Time

Bartman, Frederick L., M.S., Research Engineer
Battenburg, Joseph R., B.S., Assistant in Research
Cameron, James L., Assistant in Research
Fischbach, Frederick, B.S., Assistant in Research
Gleason, Kermit L., Instrument Maker
Hansen, William H., B.S., Associate Research Engineer
Harrison, Lillian M., Secretary
Jew, Howard, M.A., Research Assistant
Jones, Leslie M., B.S., Project Supervisor
Kaul, M. M., M.A., Research Assistant
Liu, Vi-Cheng, Ph.D., Research Engineer
Loh, Leslie T., M.S., Research Associate
Nelson, Wilbur C., M.S.E., Prof. of Aero. Eng.
Otterman, Joseph, Ph.D., Research Associate
Reddy, Gopal K., M.A., Assistant in Research
Samborski, Cassimere, Machinist
Schaefer, Edward J., M.A., Research Engineer
Schumacher, Robert E., B.S., Assistant in Research
Titus, Paul A.,Research Associate
Wenk, Norman J., B.S., Research Engineer
Wenzel, Elton A., Research Associate
Whybra, Melvin G., M.A., Technician
Wilkie, Wallace J., M.S., Research Engineer

1. INTRODUCTION

This is the fourth 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 collect and analyze upper-air samples, and

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

The title of the first three reports was _The Rocket-Grenade Experiment For Upper-Atmosphere Temperature and Winds._ In view of the fact that item (b) above has been added to the tasks of the contract, the title of the reports reverts to that used in previous Michigan—Signal Corps upper-air work, namely, _Atmospheric Phenomena at High Altitudes._ The sampling work was previously supported by Contract DA-36-039 SC-56737 and others.

2. THE GRENADE METHOD FOR UPPER-AIR TEMPERATURE AND WINDS

2.1 GRENADE EJECTION AND LANYARD OPERATION

At the end of the last report period, test firings of a preliminary design of the flash-and-sound unit (sometimes called grenade) were made at National Northern. The tests were not satisfactory, and it was decided that two more basic tests should be made before the design could proceed properly. The tests were to determine the proper amount of black powder to be used for the ejection and to check experimentally the operation of the lanyard device.

The black-powder mortar and simulated grenade shown in Figs. 1 and 2 were built for these tests. The mortar shown in Fig. 1 consists of an aluminum cylinder mounted on a heavy base plate. Black powder in cellophane bags is placed at the base of the aluminum tube and ignited by two squibs which are fired by a 22.5-volt battery to eject the simulated grenade. The simulated

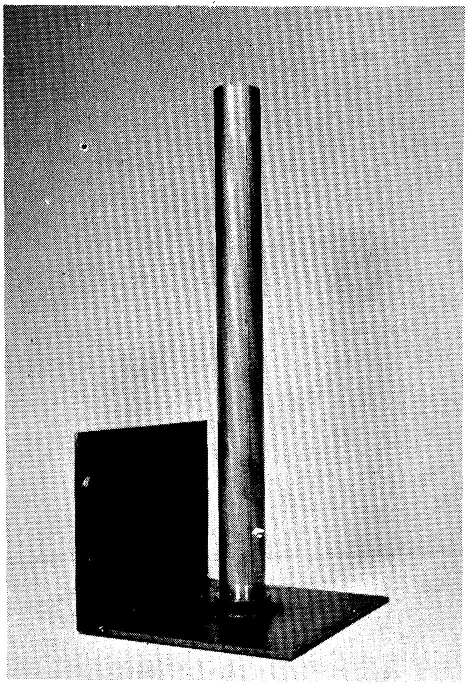


Fig. 1. Mortar for test firing of simulated grenade.

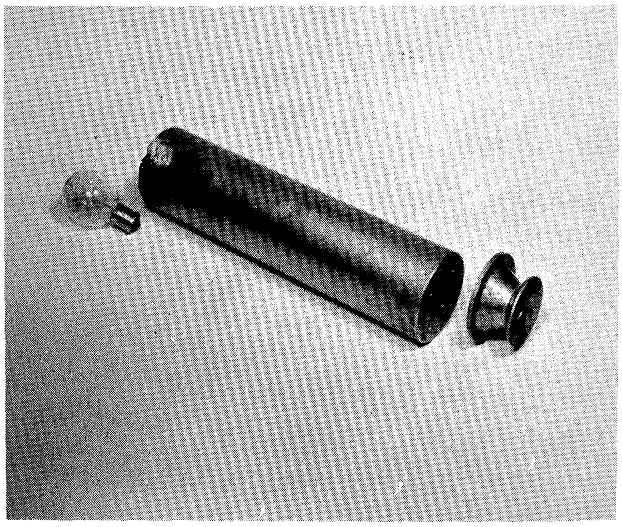


Fig. 2. Simulated grenade.

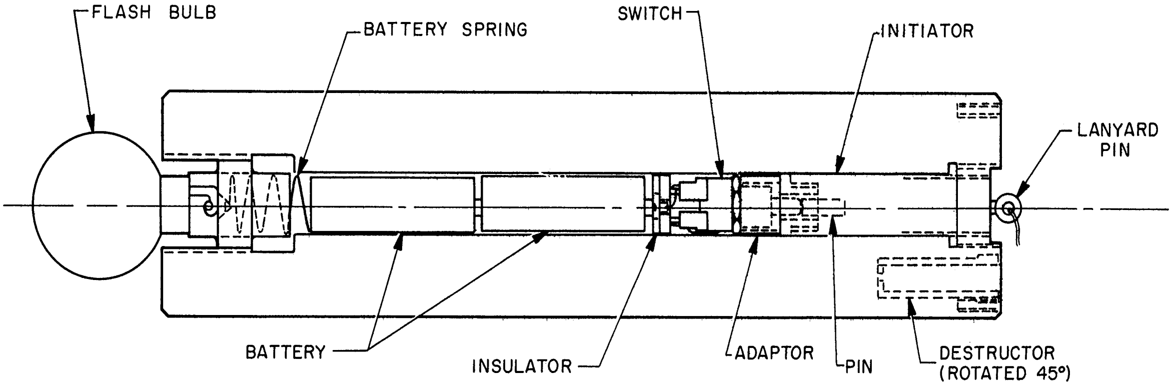


Fig. 3. Grenade-assembly drawing.

grenade shown in Fig. 2 contained the lanyard grenade firing device (initiator). A switch—battery—flash-bulb unit was also incorporated into the design so that the operation of the lanyard device could be monitored photographically. See Fig. 3 for a cross-sectional view of the test grenade and Fig. 4 for a picture of the various parts that make up the test grenade. The various spools on which the lanyards were wound were mounted on the initiator end of the simulated grenade in close proximity to the lanyard pin. One of these spools with a lanyard wound on it is shown in Fig. 5. The weight of the test grenade was about 4 pounds.

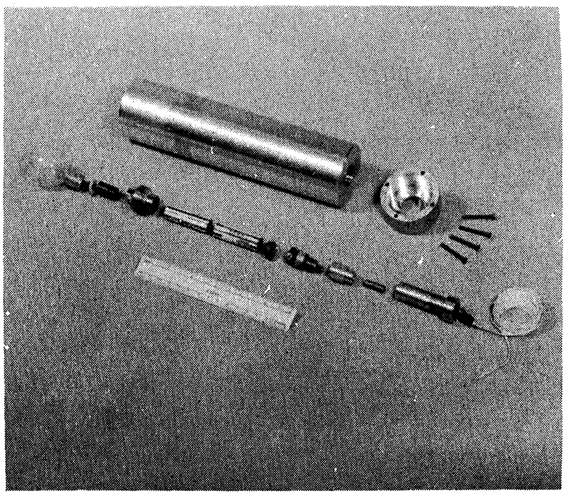


Fig. 4. Simulated grenade, exploded view.

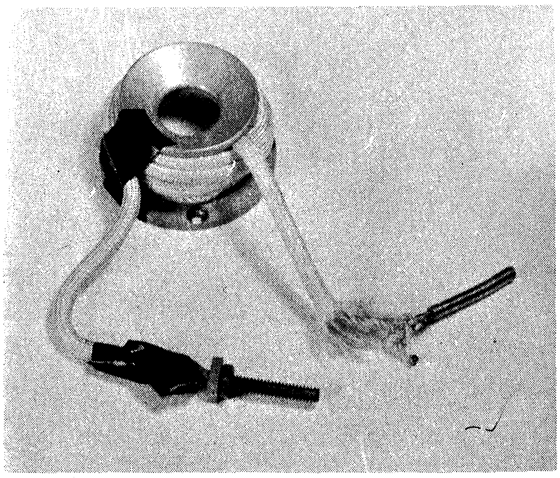


Fig. 5. Spool **and lanyard.**

The lanyard and flash-bulb device were not used for the initial black-powder ejection tests. The test grenade was placed in the mortar and shots were made with 3, 6, 9, and 12 grams of black powder. The time interval from firing to impact was measured by stop watch and the ejection velocity and peak altitude were then calculated from this time interval, neglecting air drag. The equations are, simply,

$$\text{Ejection velocity} = V_o = g\frac{T}{2}$$

$$\text{Peak altitude} = S_p = \frac{1}{2}g\left(\frac{T}{2}\right)^2 , \qquad (1)$$

where T is the total time interval from firing to impact and g is the acceleration of gravity. Neglect of air drag in these calculations causes only a negligible error in the quantities calculated. Table I gives the results.

Figure 6 shows the test grenade as used for the lanyard-operation tests. The lanyard is not shown. In Fig. 7 the test grenade and mortar are shown together in one photo. In this figure a spool with an inside, wound lanyard is located on the lower end of the test grenade. In order to monitor the lanyard operation, the mortar was fired adjacent to a 16-foot-high pole having markers at two-foot intervals. The position of the grenade at the time of flash-bulb operation (i.e., the time at which the lanyard pulled the pin) was obtained from 16-mm moving pictures (64 frames/sec) of the flight. Lanyards made of several weights of nylon cord with various amounts of heat insulation were tested.

TABLE I

EJECTION VELOCITY OF SIMULATED GRENADE FOR SEVERAL AMOUNTS OF BLACK-POWDER EJECTION CHARGE

Weight of Black Powder, grams	Time of Flight T, sec	Ejection Velocity V_0 ft/sec	Peak Altitude S_p, ft
3	5.	80.7	101
6	8.	129.	258
9	9.3	149.	348
12	11.	176.	486

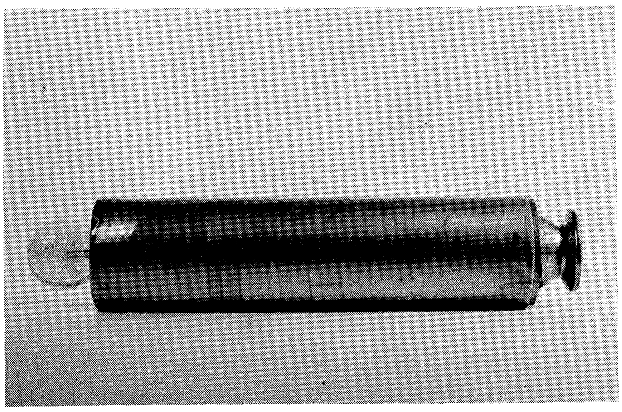


Fig. 6. Test grenade used for lanyard tests.

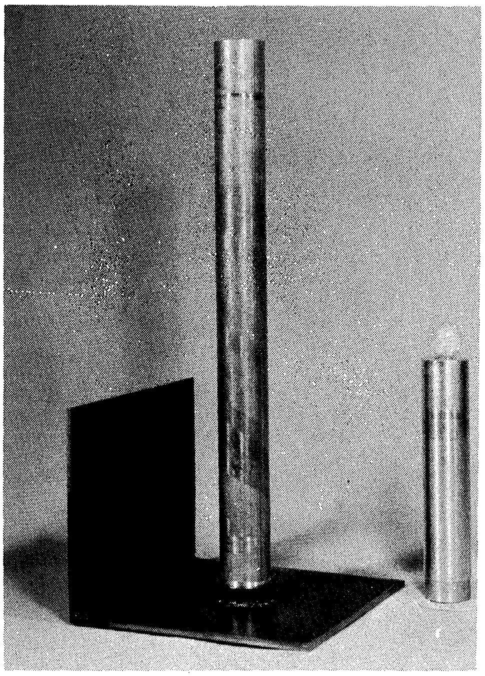


Fig. 7. Test grenade and mortar.

A sequence of photographs showing part of one test are shown in Fig. 8. The photographs show the test grenade nearly 14 feet above the top of the mortar adjacent to the pole. In photograph 8a the photoflash bulb has not yet been operated; in 8b the lanyard has pulled the pin and the flash has just become visible; in 8c the flash still persists. The photographic reproduction may not show these details clearly; however, the original photographs do show the flashbulb operation. This particular test was made with a 3-gram, black-powder ejection charge. The lanyard was made of a 225-pound-test nylon cord. The ends of the cord were heat insulated by sleeves of fiberglas.

The ejection velocity was obtained from the film sequence for this particular test by measuring position vs time as the test grenade emerged from the mortar. The result obtained was 64 ft/sec, a slightly lower velocity than the 80 ft/sec obtained for the 3-gram ejection test on the grenade without lanyard. This lower velocity must be due to the drag effect of the unwinding of the lanyard.

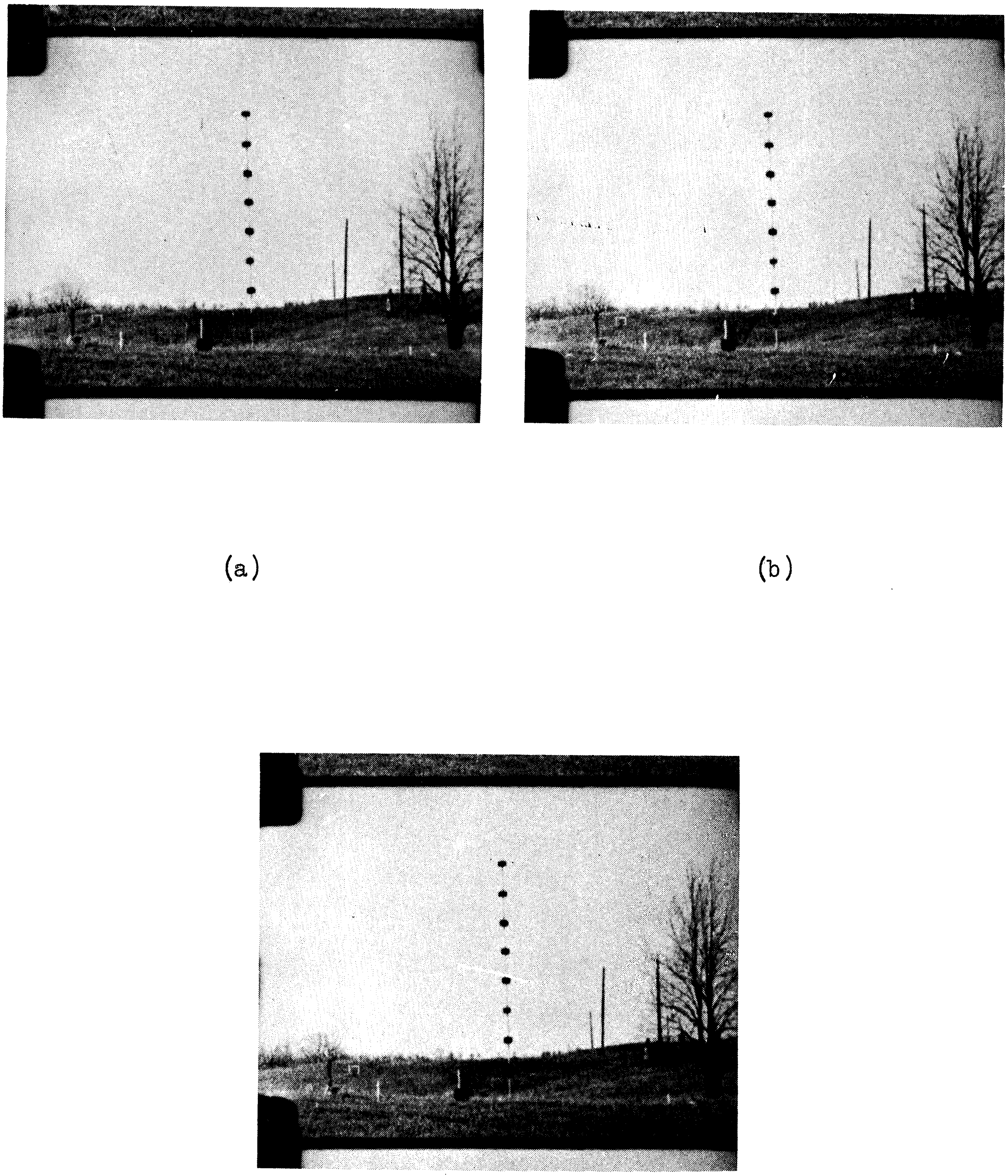
After approximately 30 lanyard tests, a useable lanyard design was obtained. This lanyard was made of 225-pound-test nylon cord, the ends of which were protected from the heat of the black-powder blast by a double thickness of fiberglas sleeving. With fiberglas sleeving 2 feet long on the lower (mortar) end of the lanyard and 8 inches long on the upper (pin) end of the lanyard, the danger of burning the lanyard would be eliminated. With shorter lengths of fiberglas sleeving,burning of the nylon might result. The velocity of ejection would be suitable for black-powder charges in the range of from 3 to 6 grams. A powder charge of 9 grams or higher would probably result in some broken lanyards. A statistically large number of tests have not been made of this design as of the present date, so it is not possible to give a number for the lanyard reliability.

2.2 SIMULATED HIGH-ALTITUDE AND LOW-TEMPERATURE TESTS

It has been decided that no further work will be done on simulated high-altitude and low-temperature tests of the various explosives. Inasmuch as the Aerobee tower and storage facilities at Fort Churchill will be heated, the grenades will not be at low temperatures when the rocket is fired.

The grenade structures should be shipped in heated boxcars so that they do not experience extremely low temperatures during shipping. This does not seem to present a difficulty, for similar precautions must be made in shipping the Aerobee and Nike boosters.

The results of the National Northern tests are included here for completeness. The following is a quotation from the letter of January 6, 1956, G. C. Gill (Univ. of Mich.) from C. M. Saffer, Jr., of National Northern:



(a) (b)

(c)

Fig. 8. Photographic sequence showing operation of flash bulb.

"The data at 90,000 feet have been averaged by Paul Rowe and are as follows:

RDX/Al--------168 Δ Psi.
RDX/TNT/Al----160 Δ Psi.
Tritonal------ 80 Δ Psi.

"The effect of cold appears to be negligible."

2.3 SOUND RANGING—SOUND INTENSITY AT THE GROUND

Calculations have been carried out to estimate the order of magnitude of pressure of the sound wave arriving at the ground from explosions of 4-pound grenades. Two approaches were used, both based on the assumption that the propagation (i.e., the relative excess pressure at a certain distance) is similar for explosions with the same energy parameter E/P_o, where E is the energy of the explosion and P_o is the ambient pressure.

The first approach followed the calculations of Brode.[1] It was assumed that at the distance of $R_o = 3.63(E/P_o)^{1/3}$ from the explosion the excess pressure is 0.07 P_o. This relative excess pressure of 0.07 was scaled down in the ratio $(P_o/P_g)^{1/2}$ to effect the preservation of energy integrated over the wave front in propagating from the rarefied atmosphere to the ground-pressure (P_g) level.[2] The attenuation in propagating beyond the distance R_o was neglected, and only the spherical spread of the wave in this region was considered. Thus, if H is the altitude of the explosion, the excess pressure π_g at the ground was calculated from the equation

$$\pi_g = 0.07\left(\frac{P_o}{P_g}\right)^{1/2} \frac{R_o}{(H - R_o)} . \tag{2}$$

The second approach made use of the explosions chart given by Schardin.[3] The chart shown in Fig. 9 gives the overpressure as the function of the distance with different explosive weights as the parameter. The explosive charge of 4 pounds (1.81 kg) was scaled up in the ratio P_g/P_o, and the distance R at which the overpressure of 0.02 exists for the scaled explosion was determined from the chart. The ground excess pressure was calculated, assuming again the spherical spread of the wave from radius R onward and scaling the overpressures inversely to the square root of ambient pressure:

$$\pi_g = 0.02\left(\frac{P_o}{P_g}\right)^{1/2} \frac{R}{H - R} . \tag{3}$$

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1. See Report 2387-6-P of this series, page 14.
2. *Ibid.*, page 13.
3. H. Schardin, "Measurement of Spherical Shock Waves," *Communications on Pure and Applied Mathematics*, Vol VII, No. 1 (Feb., 1954).

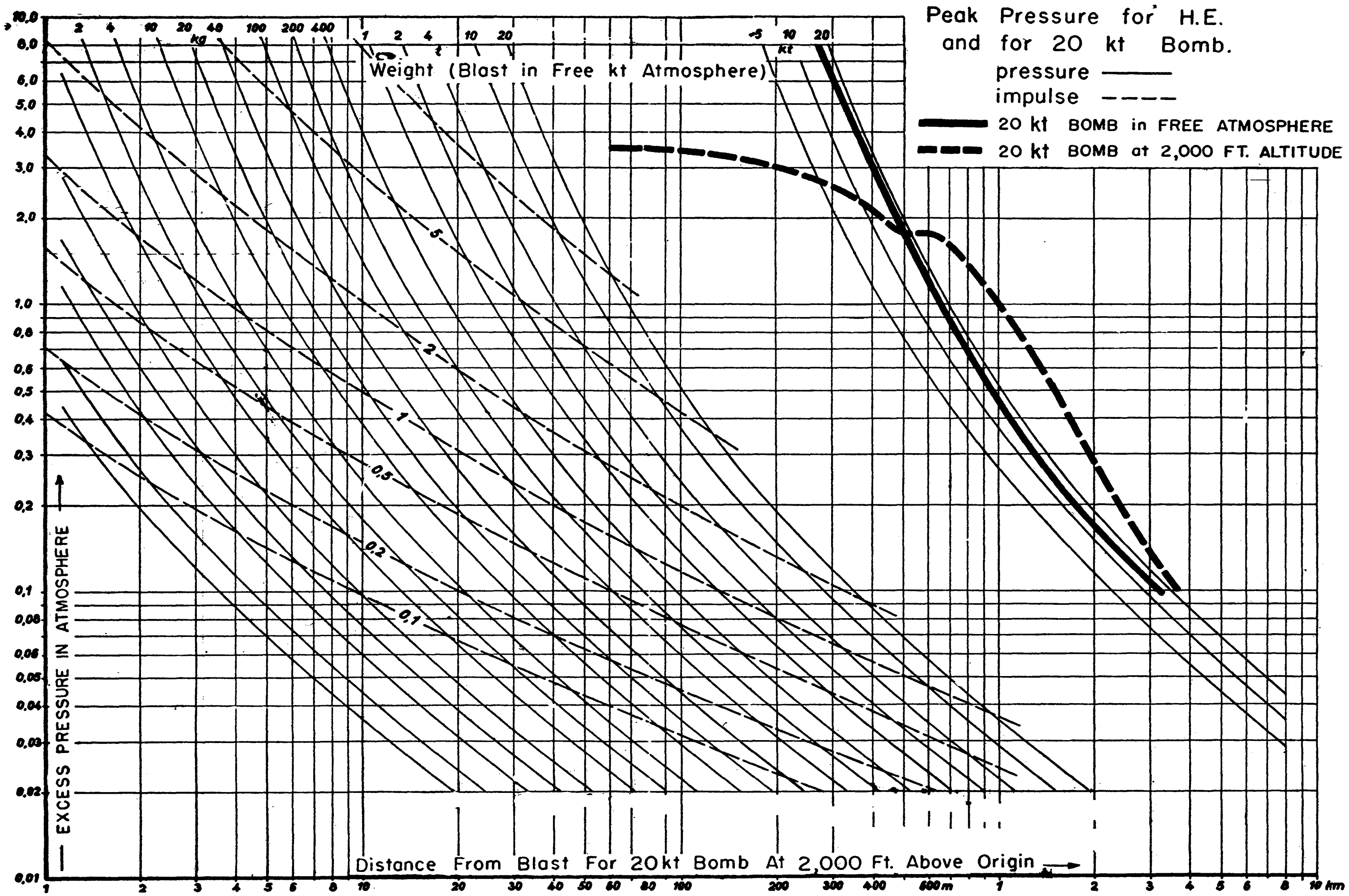

Fig. 9. Blast peak pressure and impulse (from Schardin).

The results of the calculations are plotted in Fig. 10.

The propagation laws on which the computations are based might break down at the very low densities which exist at the altitudes above 70 km. Thus the computed amplitudes might depart considerably from the actual values at the high-altitude end of the plot.

When the explosions do not occur directly overhead, the amplitudes should be multiplied by the cosine of the elevation angle to take into account the longer path of propagation from a given altitude.

The calculations do not take into account the velocity of the grenade at the time of the explosion. The velocity of the Aerobee at the burnout is approximately 20% of the detonation velocity of the explosive, i.e., of the highest velocity in the explosion process. Thus it is not unreasonable to expect a considerable reduction in the intensity of the wave traveling downward. This effect will decrease for explosion closer to the peak of the trajectory. It will tend to increase the intensity of the downward wave when the grenades are exploded on the downleg.

2.4 PROGRAMMING FOR MIDAC

The process of spin correcting the DOVAP cycle counts has been programmed for MIDAC, the MIchigan Digital Automatic Computer. A test run, using data from the SC-31 sphere experiment, is being made to check out the program.

2.5 DOVAP CYCLE COUNTING

2.5.1 Hand Counting of the DOVAP Cycles.—As indicated in the last quarterly report, an experiment has been set up to evaluate the DOVAP cycle hand-counting procedure. The purpose of the experiment was to determine the length of time required to obtain the count of the DOVAP cycles necessary to establish the rocket trajectory.

In order to carry out the spin correction, it is necessary to read off the cycle count each half second of rocket flight for eight DOVAP channels. If the spin correction were not required, it would be sufficient to read off the cycle count for four DOVAP channels at the times of the grenade explosions only. It is known that the spin-correction procedure will be necessary for the Fort Churchill flights, but this was not known with certainty at the beginning of the counting experiment. For this reason an attempt was made to estimate both the time necessary to read off eight channels at half-second intervals (this will be referred to as the detailed trajectory) and the time necessary to read off only four channels at the times of the grenade explosions (referred to as the simplified trajectory).

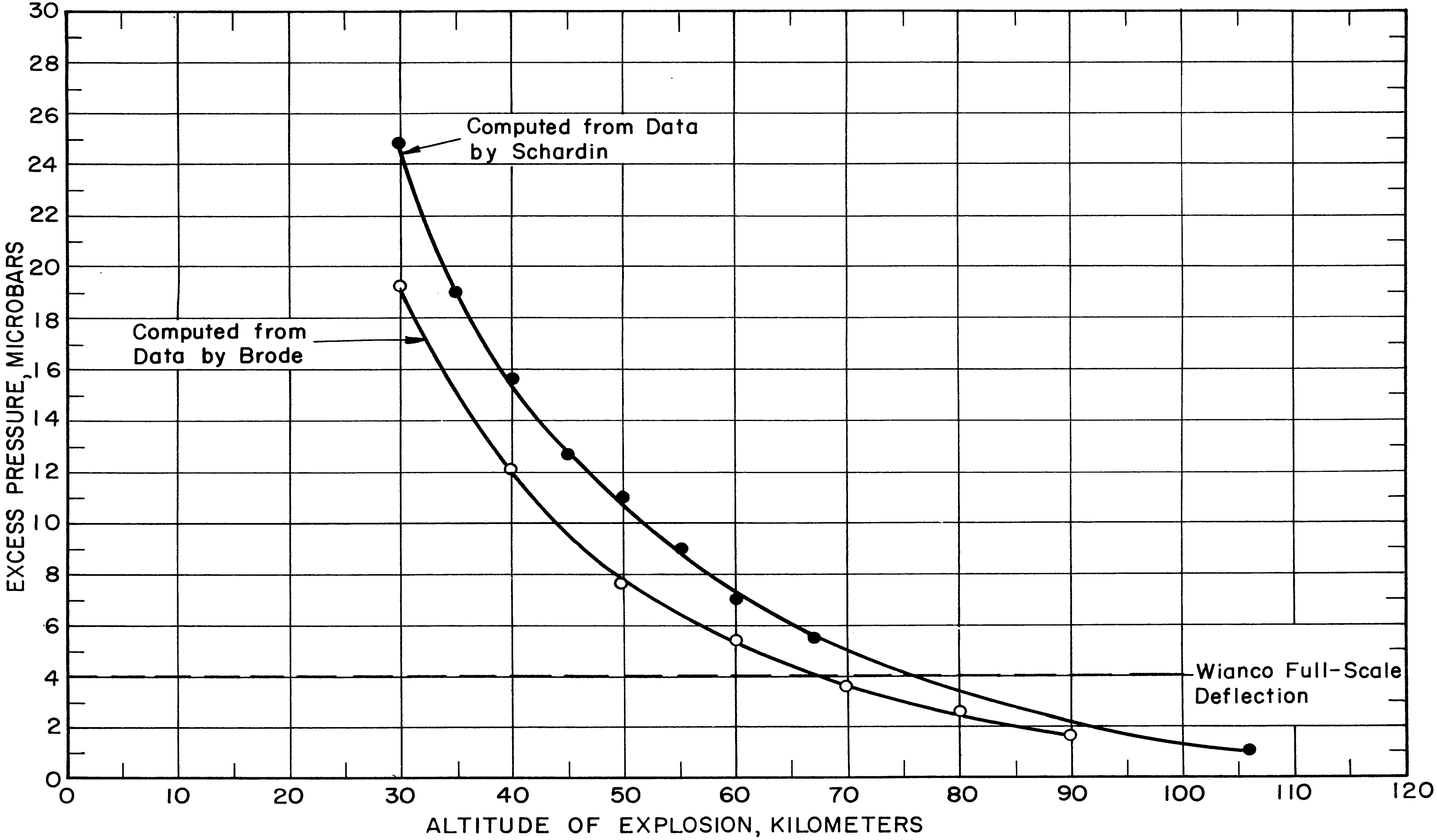

Fig. 10. Intensity of wave at the ground (4-pound charge).

The records were counted up to 95 seconds of flight time, which is thought to correspond to the altitude of 85 km for the Aerobees to be used in the experiment.[4] This altitude is somewhat above the highest altitude for which explosion sound ranging has been carried out so far.

Two operators were employed and trained for the period of one week in cycle counting on DOVAP film of flight SC-31. This is a record especially suitable for training purposes since it has many "bad" sections in which the counting has to be carried out by special techniques. The sections in which the individual cycles cannot be distinguished are reduced by interpolation: the average frequency of the section is assumed to be the mean of the frequencies immediately to the right and to the left of the section. The technique used consists of measuring half of the section with calipers set to a multiple of the cycle length to the left of the bad section; half of the section is measured with calipers set to a multiple of the cycle length to the right of the bad section.

This technique proved very successful. However, the count of SC-31 while using this technique differed in certain bad sections from the BRL count by one cycle. Correspondence with BRL elucidated the fact that our basic count was correct. However, BRL blamed a blemish occuring in K_1 between 64 and 65 seconds on a phase error in the upward radiation path. An extra cycle was added here by BRL to keep the count for channel K-1 consistent with the counts for the other channels. The reason and the procedure for adding cycles in this manner will be the topic of a discussion with BRL.

Subsequent to the training period, the two operators started counting cycles on two copies of DOVAP record SC-30. The films were obtained through the courtesy of BRL.

The operators worked independently. The starting point for the count was at 2 seconds of flight time. For the initial few seconds the cycles were counted individually. When the DOVAP frequency increased sufficiently, the cycles were counted in groups of 5, 10, 20, and 25, with the help of dividers opened for the appropriate distance. Such counting by means of dividers is possible because the frequency shift in the higher frequency region is small; the setting of the dividers opened to cover 25 cycles has to be changed by less than the length of one cycle between two successive intervals of 25 cycles. Moreover, it is known in which direction to adjust the setting. On the upleg the setting has to be made smaller with each successive interval before burnout and has to be made larger with each successive interval after burnout.

The operators mark the film each 100 cycles (each 10 cycles up to the first 100 and each 50 cycles from 100 to 1000). The count is written on the film each 200 cycles (each 100 cycles up to the first 1000). This facilitates greatly the tracking down of errors.

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[4] "Aerobee Sounding Rocket," Aerojet Engineering Corporation, June, 1952, Fig. 6.

The operators read off and record their counts at 5, 10, 15,... seconds. The supervisor, with the help of one operator, compares the counts at those points, and when a discrepancy arises in a certain five-second section, counts are taken from the two films at one-second intervals within this section until the one-second interval in which the error occurred is identified. The supervisor and one operator then recount this interval on both films and determine which of the previous counts was erroneous.

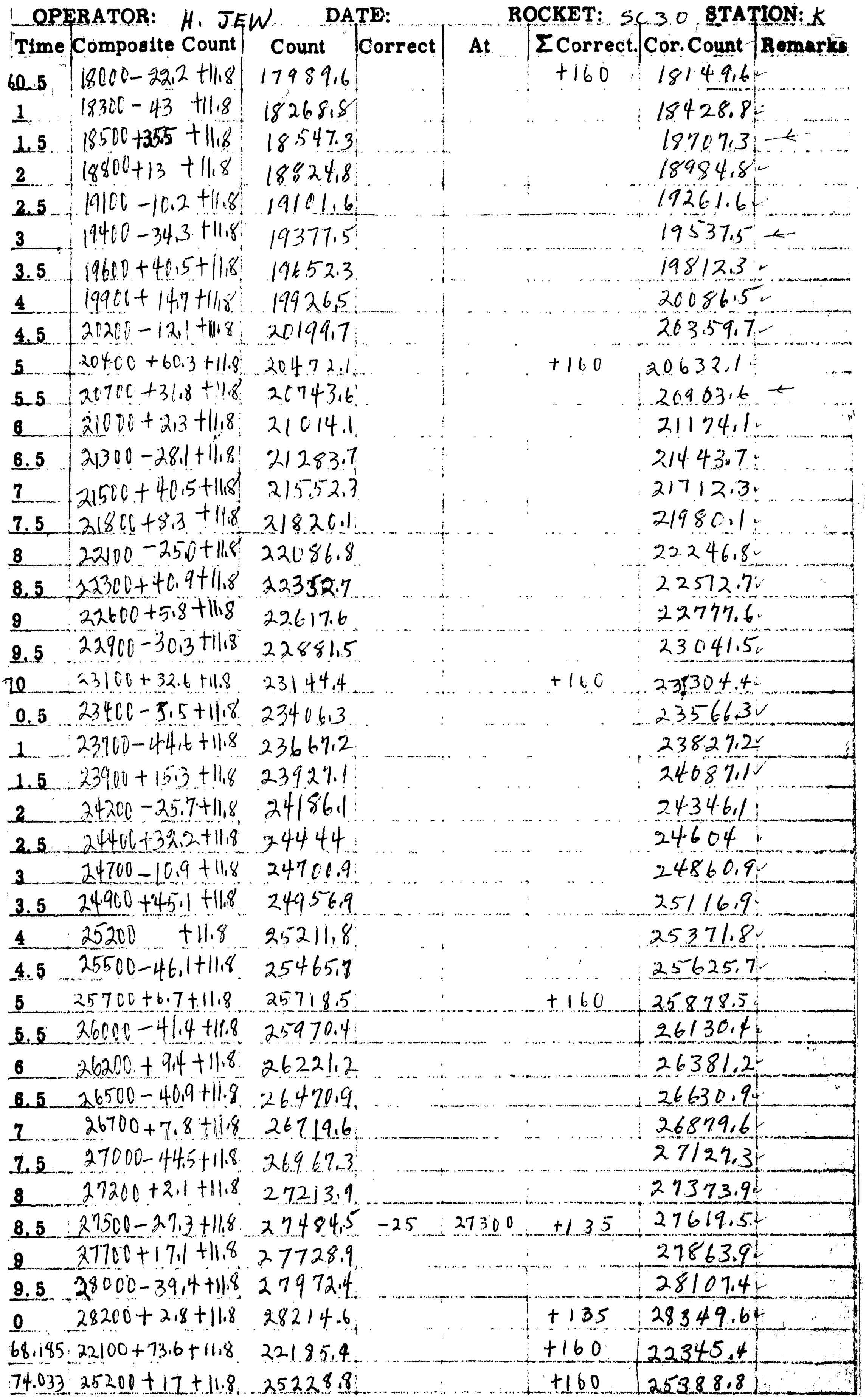
The method is based on the assumption that the two operators will not commit identical mistakes in any five-second interval. (Two different errors in the same interval do not present a problem.) Since most of the errors fall into only a few categories (± 1; ± the number corresponding to the dividers setting that the operator is using in this particular section; ± 100; ± 200; ± 1000), this possibility is not to be ruled out. It is necessary therefore to employ careful operators so that the probability of an operator making an error in a five-second section will be small. In the experiment carried out, the number of mistakes made by an operator in counting a channel to 95 seconds ranged from zero to five.

All the counts, even before the comparison, are systematically recorded in a special notebook. This not only makes the procedure for finding the errors orderly and relatively quick, but also gives a record of an operator's performance. A page from this notebook is shown in Fig. 11.

After the counts have been compared and the errors corrected, the grenade explosion times are marked on the film, the counts at those times read off, and the appropriate corrections applied. This again is done independently by the two operators and the final results compared. Errors in wrong marking of explosion times and wrong read-off of the count occur, but can be spotted immediately.

This simplified trajectory has been obtained for four channels in five working days. It is believed that this can be taken as a figure indicative of future operations, provided some care is taken in choosing suitable operators.

The detailed trajectory has been obtained as follows. Subsequent to counting eight channels according to the procedure described above, each operator read the count off his copy of the film at half-second intervals. The counts were recorded in the notebook, the known corrections applied, and the corrected counts compared. This final comparison was quite time-consuming, as discrepancies of 0.3 and 0.4 cycle were frequently encountered in the high-frequency region. The operators checked the readings until agreement within ±0.2 cycle was obtained. The complete procedure of obtaining the detailed trajectory took eighteen days for the eight channels. It is thought that this time can possibly be somewhat improved upon if the read-off at half-second intervals is carried out simultaneously with the initial count and not postponed until after the record has been counted and the counts at five-seconds compared.



OPERATOR: H. JEW DATE: ROCKET: SC 30 STATION: K

Time	Composite Count	Count	Correct	At	Σ Correct.	Cor. Count	Remarks
60.5	18000-22.2 +11.8	17989.6			+160	18149.6	
1	18300 - 43 +11.8	18268.8				18428.8	
1.5	18500+35.5 +11.8	18547.3				18707.3	←
2	18800+13 +11.8	18824.8				18984.8	
2.5	19100 -10.2 +11.8	19101.6				19261.6	
3	19400 -34.3 +11.8	19377.5				19537.5	←
3.5	19600 +40.5+11.8	19652.3				19812.3	
4	19900+ 14.7 +11.8	19926.5				20086.5	
4.5	20200 - 12.1 +11.8	20199.7				20359.7	
5	20400 +60.3 +11.8	20472.1			+160	20632.1	
5.5	20700 +31.8 +11.8	20743.6				20903.6	←
6	21000 + 2.3 +11.8	21014.1				21174.1	
6.5	21300 -28.1 +11.8	21283.7				21443.7	
7	21500 + 40.5 +11.8	21552.3				21712.3	
7.5	21800 +8.3 +11.8	21820.1				21980.1	
8	22100 -25.0 +11.8	22086.8				22246.8	
8.5	22300+40.9+11.8	22352.7				22512.7	
9	22600 +5.8 +11.8	22617.6				22777.6	
9.5	22900 -30.3 +11.8	22881.5				23041.5	
70	23100 + 32.6 +11.8	23144.4			+160	23304.4	
0.5	23400 - 5.5 +11.8	23406.3				23566.3	
1	23700 - 44.6 +11.8	23667.2				23827.2	
1.5	23900 + 15.3 +11.8	23927.1				24087.1	
2	24200 -25.7 +11.8	24186.1				24346.1	
2.5	24400+32.2+11.8	24444				24604	
3	24700 - 10.9 +11.8	24700.9				24860.9	
3.5	24900 +45.1 +11.8	24956.9				25116.9	
4	25200 +11.8	25211.8				25371.8	
4.5	25500-46.1+11.8	25465.7				25625.7	
5	25700 +6.7 +11.8	25718.5			+160	25878.5	
5.5	26000 -41.4 +11.8	25970.4				26130.4	
6	26200 + 9.4 +11.8	26221.2				26381.2	
6.5	26500 - 40.9 +11.8	26470.9				26630.9	
7	26700 + 7.8 +11.8	26719.6				26879.6	
7.5	27000 - 44.5 +11.8	26967.3				27127.3	
8	27200 +2.1 +11.8	27213.9				27373.9	
8.5	27500 - 27.3 +11.8	27484.5	-25	27300	+135	27619.5	
9	27700 + 17.1 +11.8	27728.9				27863.9	
9.5	28000 - 39.4 +11.8	27972.4				28107.4	
0	28200 + 2.8 +11.8	28214.6			+135	28349.6	
68.185	22100 + 73.6 + 11.8	22185.4			+160	22345.4	
74.033	25200 + 17 + 11.8	25228.8			+160	25388.8	

Fig. 11. Sample page from cycle-counter's notebook.

This counting procedure is based on the availability of two copies of the record. A somewhat similar procedure could be used if only one copy of the film was available; the second operator would start counting from a different point, so as not to make his count coincide with the marks of the previous operator. However, the two counts would not be completely independent and the comparison would be more laborious. The availability of two copies is therefore advocated.

2.5.2 Comparison of the Economy of Hand Counting vs Machine Counting of DOVAP Cycles.—The study to determine the relative merits and the price quotations of the two cycle-counting machines was continued.[5] These machines are the Stroboscopic Film Reader (built by Electronic Associates, Inc., Long Branch, New Jersey) and the Putman Cycle Counter (built by the University of Denver, Denver Research Institute, Denver, Colorado). Informational price quotations were as follows:

Stroboscopic Film Reader, without digitizer and printout device,	$42,734.13.
Putnam Cycle Counter, including the film-transport mechanism,	$37,500.00.

The correspondence with the builders of the Putnam machine elucidated the fact that some portions of the circuitry are very critical as regards tolerances, parts placement, leads placement, and shielding. It appears, therefore that some repairs might require expert advice and might put the machine out of operation for a considerable period.

The minimum cost of machine counting would thus be $37,500.00. This figure neglects the cost of the operator. A fixed location for the machine would presumably be required, contributing to the group's problem of lack of space.

The estimate of the personnel expense involved in hand counting cycles for the initial 95 seconds of the trajectory is given in Table II. The estimate is based on the experiment described in the previous section.

TABLE II

ESTIMATE OF PERSONNEL EXPENSE

Detailed Trajectory

2 Operators (full time), $2/hr + 50% overhead	18 days	$ 864.00
1 Supervisor (1/4 time), $3.5/hr + 50% overhead	18 days	189.00
Total Personnel Cost, hand counting to 95 seconds, per rocket		$1,053.00

Simplified Trajectory

2 Operators (full time), $2/hr + 50% overhead	5 days	$ 240.00
1 Supervisor (1/4 time), $3.5/hr + 50% overhead	5 days	52.50
Total Personnel Cost, hand counting to 95 seconds, per rocket		$ 292.50

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[5] For a brief description of the two machines, see Univ. of Mich. Eng. Res. Inst. Quarterly Report 2387-10-P.

The estimated cost of the cycle counting for the IGY program will be based on the assumption of ten rocket flights. It will be assumed that out of these ten flights, for six rockets the trajectory will be computed up to the last upleg grenade, i.e., up to approximately 95 seconds; for two rockets the trajectory will be computed up to the peak, i.e., up to approximately 180 seconds (or roughly at twice the cost given in Table II); for two rockets grenade explosions on the downleg are assumed, which would necessitate counting the cycles to approximately 280 seconds (or roughly at three times the cost given in Table II). Because of envisaged personnel changes, a 20-operator-days training period (one operator full time - $240.00, one supervisor-instructor 1/4 time - $105.00) is taken into account in figuring the total cost. A sum of $1000 is set aside for building or purchasing additional devices to facilitate the hand counting. The total cost of hand counting under these assumptions is presented in Table III.

TABLE III

TOTAL COST OF HAND COUNTING

Detailed Trajectory

6 Rocket Trajectories up to 95 sec	$1,053 per flight	$6,318.00
2 Rocket Trajectories up to 180 sec	2,106 per flight	4,212.00
2 Rocket Trajectories up to 280 sec	3,159 per flight	6,318.00
Training of Operators		345.00
Additional Equipment		1,000.00
Total Cost of Cycle Counting for the IGY Program		$18,193.00

Simplified Trajectory

6 Rocket Trajectories up to 95 sec	$292.50 per flight	$1,755.00
2 Rocket Trajectories up to 180 sec	585.00 per flight	1,170.00
2 Rocket Trajectories up to 280 sec	877.50 per flight	1,755.00
Training of Operators		345.00
Additional Equipment		1,000.00
Total Cost of Cycle Counting for the IGY Program		$6,025.00

It thus appears that the hand counting is much more economical, even if the detailed trajectory data are necessary. The penalty in this system is that the data will be available only after a certain delay. The delay will be only a few days in the case of simplified trajectory with only upleg grenades. It will be approximately three weeks in the case of a detailed trajectory and upleg grenades; and it will be as large as ten weeks in the case of a detailed trajectory and downleg grenades. It should be pointed out that the downleg grenade explosions will be limited to the very small number of two or three and will be of secondary interest only. It will thus be possible to obtain the temperature profile from the upleg explosions without waiting for the downleg data.

It has been decided, in view of these facts, to adopt the hand-counting procedure for the DOVAP cycles. The existing setup which has been used in the counting experiment is thought to be adequate.(This equipment can be stored away conveniently when not in use.) A simple device to facilitate the counting will be constructed and tried out during the next half-year period.

2.6 UPPER-ALTITUDE LIMIT OF THE GRENADE EXPERIMENT

A study was initiated to determine the upper-altitude limit to the feasibility of the grenade experiment. The experiments conducted so far extended to an altitude of approximately 82 km. It is planned to increase this altitude range in the IGY series of experiments.

In connection with this, a number of problems have to be considered.

A. The validity of the formula for the velocity of sound, $C^2 = \gamma RT/M$, where γ is the ratio of specific heats, T the temperature, R the universal gas constant, and M the mean molecular weight, has to be examined for the highly rarefied gases. Moreover, the finite amplitude propagation presents special problems.

B. It is thought that the dissociation of O_2 starts at approximately 80 km. The mean molecular weight of the air is not known accurately beyond this point. The experiment will yield directly only derived "temperature" T_{29}, based on assumed constant mean molecular weight of 29 g/mole and constant ratio of specific heats 1.4. This temperature will be related to the true temperature by the following formula:

$$T_{29} = \frac{29}{M} \cdot \frac{\gamma}{1.4} T ,$$

where T is the true temperature, γ the actual ratio of the specific heats, and M the actual molecular weight.

C. The attenuation of pressure-wave will be much more severe for the high-altitude propagation. Moreover, the sound at the microphone will be weaker because of the longer distance from the explosion. Thus the "audibility" at the ground can be the limiting factor.

D. The accuracy of DOVAP above 80 km might be considerably lower than the accuracy at lower altitudes because of the ionosphere-propagation effects.

3. SAMPLING

In the Final Report of the previous series on sampling (2232-18-F, Feb., 1956) it was recommended that:

a. sample bottles be prepared for flight on two Aerobees,

b. control experiments be run on these bottles before and after flight to detect separation due to causes other than an atmospheric phenomenon,

c. new flight samples be obtained and analyzed at Michigan and, if possible, by Professor F. A. Paneth, and

d. valid residuals of previously obtained samples be reanalyzed on the new analyzer.

Progress in carrying out these recommendations was made during the interval of the current report as follows.

3.1 FLIGHT BOTTLES

Work on the preparation of flight bottles involved tests of the new Consolidated leak detector and tests of the flight sealers, both 1 inch and 2 inch.

The new leak detector was installed so that it could operate in connection with either of the bottle pumping stations. In first runs it performed well and could be used to detect and locate leaks which would not have been detectable (in a short time) with the Philips gages mounted in the bottles. A serious loss in sensitivity developed shortly, however, and only after considerable difficulty was the fault located in the collector by the Consolidated field-service representative. Currently the leak detector is working very well and continues to be invaluable in the preparation of bottles.

Further tests were conducted on the pyrotechnic sealers for sealing the bottles in flight. One-inch sealers were successfully used on SC-17, SC-29, and V-2 59. Additional tests were required on this sealer, however, to insure satisfactory operation with the slightly modified intake tubes planned for the new Aerobees. A continuation of tests of the 2-inch sealer was desired to check reliability. Some tests of the feasibility of substituting smokeless powder (which will fire in a vacuum) for black powder were also carried out.

A series of tests were made on the 1-inch sealer using 6-inch lengths of Revere Type-L copper tubing. The total black-powder (Type A-5) charges varied from 62 to 76.6 grains. The sealer and tube were mounted in various combinations of vertical and horizontal positions. In each case a satisfactory seal was obtained. Next, checks were made with the tube mounted on a bottle and again a good seal was obtained. Finally the bottle was mounted as in the rocket and a successful seal made.

In another series of tests attempts were made to make seals using Du Pont 5066 Smokeless powder. Various amounts between 10 and 14.5 grains (with 3.8 grains of A-5 black powder in the squib) were used. No good seals were obtained. The major difficulty was inconsistency in the amount of force obtained, which varied with the position of the powder with respect to the squib. The attempt to used smokeless powder was abandoned.

Several tests were carried out with 2-inch sealers, using black powder only. Two new sealers were constructed similar to the one reported previously, except that the piston weight was increased in order to achieve a more even distribution of momentum. Also, the guides and screws were strengthened. A series of 11 tests were carried out using between 5 and 14 grams of black powder. No good seals were obtained for a variety of reasons, but the later ones were much improved with respect to the first ones and it is felt that successful seals will be made with the new sealers. It was determined that 7.5 grams of powder is about the right charge.

3.2 ANALYZER

This section describes various analyses performed on the new Michigan microanalyzer, the construction and testing of which was reported previously. Both residual upper-air samples and control samples were analyzed. A description of the samples follows; the results are given in Table IV.

Sample B-25 was contained in a 500-cc steel bottle which was previously checked and found to show negligible adsorption of nitrogen. After the check the bottle was made up with the end fixtures of a complete bottle for control tests. It contained a vial of ground air prepared by Paneth. It was pumped from 22 February to 16 March 1954 with nearly continuous baking. On 16 March 1954 it was cold-sealed off from the pumping system and on 9 April 1954 its intake tube was sealed as in flight. On 19 July 1954 the internal vial was ruptured. The bottle was then stored until the current analysis. It is interesting to note that the basic bottle showed no N_2 adsorption and the air sample in the complete bottle showed no change in helium or neon.

Sample B-8 was the residual of the contents of the bottle B-8 flown on Aerobee SC-17 on 19 December 1950. The original analysis was performed at Durham and considerable separation was detected. After the analysis the residual gas was sealed in a vial and sent to Michigan. Since the amount of sample was very small, only two analyses for O_2, N_2, He, and Ne were made. The residual after these analyses was too small for another, but was vialed for an argon analysis by mass spectrometry. This analysis will be performed on the Consolidated spectrometer in the Department of Chemical and Metallurgical Engineering of the University. In Table IV it may be seen that in the recent Michigan analyses a decrease in helium and neon was detected, whereas the Durham analyses showed increases. It is unlikely that the Michigan analyses are in error since three interspersed ground-sample analyses on the same amounts of air were correct. It may be significant that the Durham sample was 0.185 cc NTP in the flight steel bottle, whereas the Michigan sample was .02 cc NTP in a soft-glass vial opened five years later.

TABLE IV

ANALYSES MADE ON NEW MICHIGAN MICROANALYZER

Sample No.	Container	Source of Air	Quantity (ccNTP)	Date Admitted to Final Container	Date of First Analysis	Durham Analysis			Michigan Analysis		
						%O_2	He	Ne	%O_2	He	Ne
B-25	500-cu in. steel bottle (no fixtures)	Durham ground air	0.26	7-19-54	1-12-56	—	—	—	—	0.98	0.98
B-8	Soft-glass vial	67-69.6 km, WSPG	0.0157	8-53 approx.	2-29-56	5.25	2.02	1.18	15	0.521	0.82
C-6-B-L	Soft-glass vial	100.3-103.9 km, WSPG	1.0	8-54 approx.	3-26-56	17.41	2.443	1.045	13.5	2.08	1.05
E-1	500-cu in. steel bottle (no fixtures)	Ann Arbor ground air	0.189	4-3-56	4-12-56	—	—	—	almost none	0.956	1.01

Note: The O_2 values are percent by volume of the entire sample. The helium and neon values are volume of gas, relative to nitrogen, in sample/volume of gas, relative to nitrogen, in ground air.

Sample C-6-B-L is the balance of sample in bottle C-6-B-L after Paneth's analysis. The bottle was flown on V-2 59 on 20 May 1952. It was a stainless-steel, low-pressure bottle of 2100 cubic inches. Our analytical result agrees qualitatively with Paneth's.

Sample E-1 was from bottle E-1, which is a new bottle to be fabricated into a flight bottle.

4. LABORATORIES VISITED

During this quarter the following places were visited:

Evans Signal Laboratory
National Northern Fireworks Ordnance Corporation
The Franklin Institute.

5. FUTURE PROGRAM

5.1 GRENADE DESIGN

The design of the grenades and grenade structure will be completed and tests of the grenade components and of the grenade assembly will be started.

5.2 ROCKET INSTRUMENTATION

The design of the rocket instrumentation will be started. A wiring diagram will be prepared, and the physical parts layout will be planned in conjunction with the design of the grenade assembly.

5.3 DATA REDUCTION

Some of the details of the test of the hand-counting procedure have yet to be completed. Following this, it is planned to discuss the accuracy of DOVAP with BRL personnel. The check of the MIDAC program for spin correction will continue.

5.4 UPPER-AIR SAMPLES

Two Aerobees for collecting upper-air samples will be instrumented and flown.

6. ACKNOWLEDGEMENT

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