ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

Quarterly Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

(August 1, 1956 to October 31, 1956)

F. L. Bartman
W. J. Wilkie
V. C. Liu

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
CONTRACT NO. DA-36-039 SC-64659

January 1957

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The design of the grenades, the grenade rocket-nose cone, the grenade section, and the grenade instrumentation section was completed. Units of these elements were constructed and wired. Preliminary full-scale ground tests with live grenades were successfully conducted at Otis Air Force Base. The equipment was shipped to Fort Churchill and the prefiring operations for Grenade Aerobee SM1:01 were started.

Sampling Aerobees SC-34 and SC-35 were fired successfully at WSPG on August 9 and 10, respectively.

THE UNIVERSITY OF MICHIGAN PROJECT PERSONNEL

Both Part Time and Full Time

Allen, Harold F., Ph.D., Research Engineer
Bartman, Frederick L., M.S., Research Engineer
Billmeier, William G., Assistant in Research
Chapelsky, Orest, Assistant in Research
Gleason, Kermit L., Instrument Maker
Harrison, Lillian M., Secretary
Howe, Carl E., Ph.D., Assistant in Research
Jew, Howard, M.A., Research Assistant
Jones, Leslie M., B.S., Project Supervisor
Lee, Charles K., Assistant in Research
Liu, Vi-Cheng, Ph.D., Research Engineer
Loh, Leslie T., M.S., Research Associate
Malkani, Sundru J., M.Sc., Assistant in Research
Mull, Robert J., Electronic Technician
Otterman, Joseph, Ph.D., Research Associate
Prince, Milford W., Machinist
Samborski, Cassimere, Instrument Maker
Schaefer, Edward J., M.S., Research Engineer
Schumacher, Robert E., B.S., Assistant in Research
Stohrer, Albert W., B.S., Research Associate
Taylor, Robert N., Assistant in Research
Titus, Paul A., B.S., 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.E., Research Engineer
Zeeb, Marvin B., Research Technician

1. INTRODUCTION

This is the sixth 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.

2. GRENADE EXPERIMENT

The effort on the grenade experiment was devoted primarily to the continuing development, construction, and testing of the pre-IGY Aerobees to be flown at Fort Churchill in November. A smaller portion of the effort was applied to preparations for the data reduction to be carried on after the pre-IGY and IGY grenade Aerobees are flown.

2.1. GRENADES

Twelve preproduction grenades were tested at the Halifax range of the National Northern Company on July 2 and 3. These tests were to determine the feasibility of the design and to indicate, within limits, the reliability.

The grenades were true prototypes of the intended production version with only minor exceptions, the principal exception being the lanyard material. The test lanyards were fabricated from nylon cord and rubber tubing instead of rubber extruded directly over the nylon cord.

All twelve grenades were "duds" in that not one was actually detonated. The detonator caps were successfully fired but the booster charges did not take.

Although none of these grenades was successful, the tests themselves were considered to be satisfactory because a great deal of information was gleaned which would be useful in eliminating malfunctions in future grenades.

A memo report was issued covering in more detail tube actual firings, memo report no. 2387-A, dated July 25, 1956. The report is included as Appendix A of this report.

At the request of Picatinny Arsenal, vibration, transportation, and 40-ff-drop tests were conducted on five inert grenades to test the reliability of the "cocked" firing mechanism. These tests were conducted by National Northern during July, 1956, and were witnessed by Mr. Frank Shelton of Picatinny Arsenal. These tests were all passed satisfactorily; a brief report by Mr. R. P. Woodburn of the National Northern Fireworks Company is included as Appendix B of this report.

Following the malfunctioning explosive-train results of the July 2 and 3 tests, a different detonator mix and a different booster were used. Also, a precasting technique of loading grenades replaced the cast-in-place technique originally employed. The production detonator consisted of lead azide alone, the booster of RDX. The combination of the explosive-train charge and the new loading technique completely eliminated the earlier explosive's malfunctions. (See Appendix C which is a copy of a report on the tests on the modified booster.)

With the obtaining of lanyard material meeting original design specifications and the elimination of the spring-clip lanyard terminals, which caused an occasional malfunction, no further lanyard difficulties were encountered except for two isolated cases described in another part of this report.

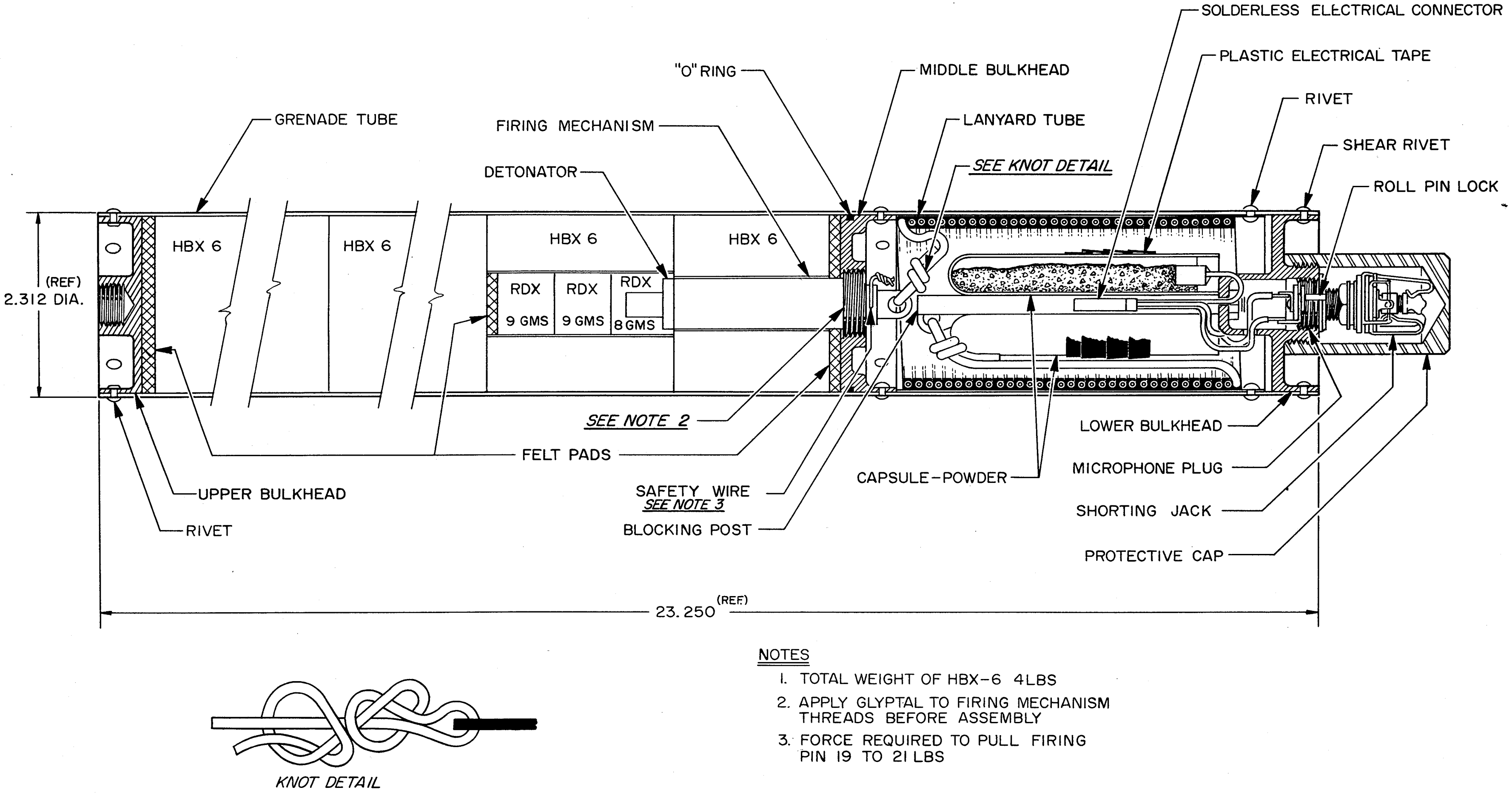
A few words on the philosophy of the grenade design might be considered pertinent. A prime objective, of course, was that the grenade be highly reliable, such reliability being assumed to include safety both in firing and handling. Further objectives were:

a. Simple field loading of grenades into the rocket. Avoidance of multiple loading steps, omission of which could cause malfunction or added risk.

b. Light weight to hold shrapnel to a minimum and to maximize rocket performance.

A look at the cross-sectional drawing of the grenade, Fig. 1, will indicate how these design objectives were approached.

The case of the grenade is 23.25 inches long and consists of light-wall aluminum tubing. The explosive occupies approximately 18 inches of the case, with the remainder being utilized for the ejection combustion chamber and lanyard storage.



NOTES

1. TOTAL WEIGHT OF HBX-6 4LBS
2. APPLY GLYPTAL TO FIRING MECHANISM THREADS BEFORE ASSEMBLY
3. FORCE REQUIRED TO PULL FIRING PIN 19 TO 21 LBS

Fig. 1. Cross section of grenade.

The firing mechanism consists of a firing pin and cocked spring, encased in a threaded container, and retained by a pull pin. The firing mechanism was originally designed by a commercial company for a time-delay mechanism to be used in another rocket and was adapted to the grenade with some modification. The original design had no specific pull-force requirements for the pin and was dependent on the friction of an "O" ring seated in a groove on the pin to provide an adequate minimum pull-out force. The "O" ring friction system did not provide a consistent and predictable pull force.

If the pin had been inserted into the "O" ring more than once, if oil or grease were present, or if the surface of the pin varied, the pull-out force varied over wide limits. Variations from 5 pounds to 40 pounds were encountered in pull-out force tests.

A minimum pull-out force sufficiently high to prevent accidental firing during manufacture was discussed with Picatinny Arsenal and by mutual agreement was considered acceptable at 10 pounds.

The firing mechanism was modified to incorporate a shear wire as the principal restraint to premature pulling of the pin. The use of the "O" ring was continued but the material was changed to silicone, which gave more repeatable results.

Initial tests on a simulated firing mechanism indicated very uniform pull-out forces for the shear-wire design, but the wire could easily be sheared inadvertently by applying torque to the pin. A further modification was incorporated which mechanically prevented torque loads from being applied to the wire and which prevented the pin from being wired until it was sealed and properly locked in position. Tests of this modified design indicated highly consistent pull-out forces of from 19 to 21 pounds. The design pull-out force had been doubled arbitrarily because the extra margin was felt to be practical without causing any greater risk of broken lanyards or other malfunction, a surmise later borne out by tests.

To simplify loading of the grenade, the grenade was made a completely self-contained unit which needed only to be inserted in the mortar barrel and screwed into a threaded socket. A microphone plug, mounted on the centerline of the grenade, automatically makes the proper electrical contacts when the grenade is screwed in place. To assure that proper contact is made requires only that the grenade be bottomed on the threaded socket. Actually as much as 1/8 inch of variation can be tolerated insofar as the electrical contacts are concerned, but for other reasons it is desirable to properly seat the grenades.

Soft aluminum shear rivets are used to provide simple highly repeatable release-load values for launching the grenade. The base of the grenade remains in the mortar tube and becomes the anchor for the lanyard.

A threaded socket and torque lugs are incorporated in the grenade top which accommodate a special wrench for each insertion or removal of the grenade in the mortar tube.

A shorting-jack and protective cap are provided for handling and shipping or storing.

Figures 2 through 7 are photographs of the grenades and of some of the grenade equipment used in the developmental tests.

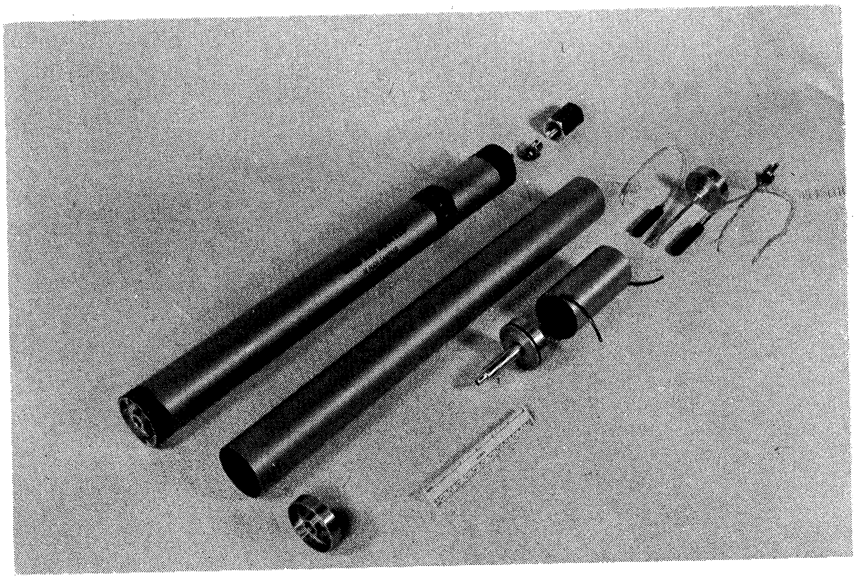


Fig. 2. Assembled grenade and components.

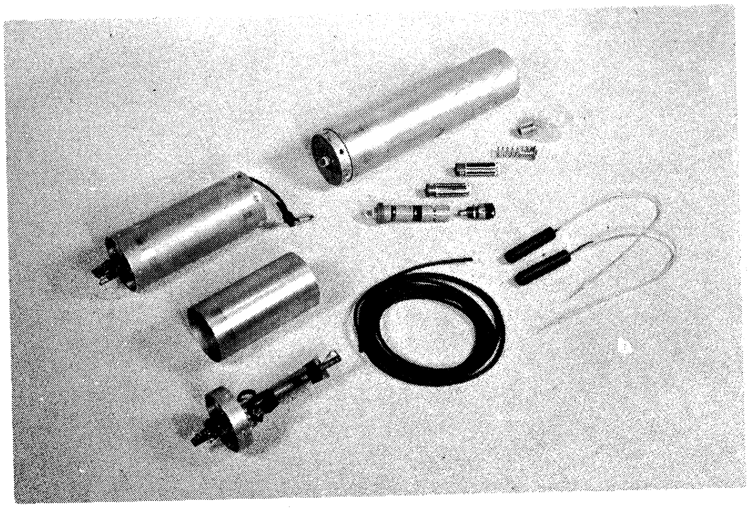


Fig. 3. Components of dynamically similar dummy grenade used for development testing.

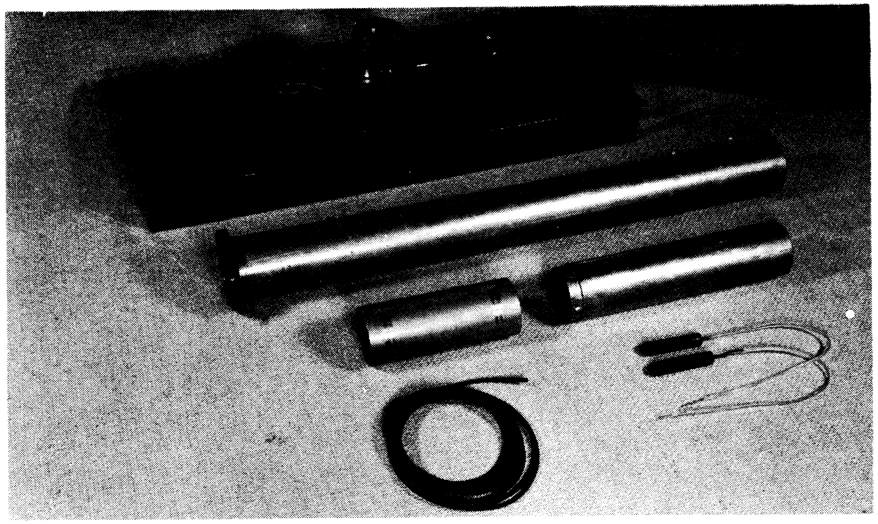


Fig. 4. Equipment used for simulated high-altitude testing of ejection capsules.

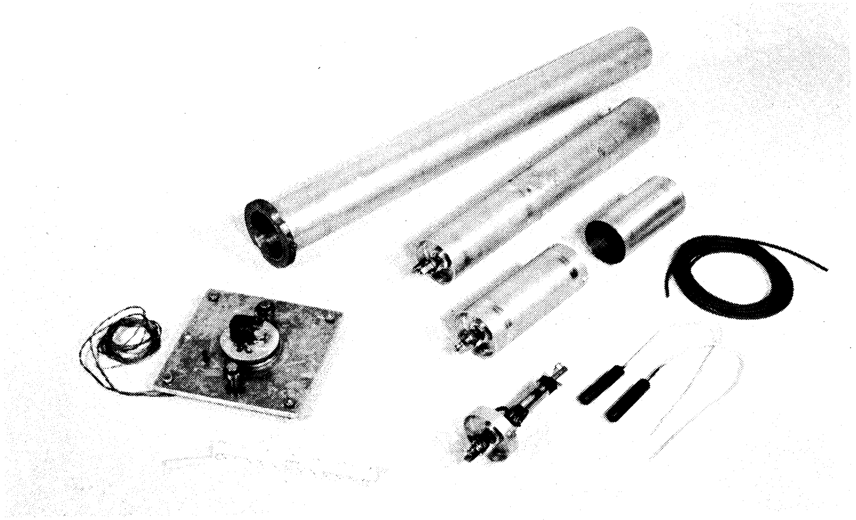


Fig. 5. Portion of equipment used for dynamic pull tests of experimental lanyards.

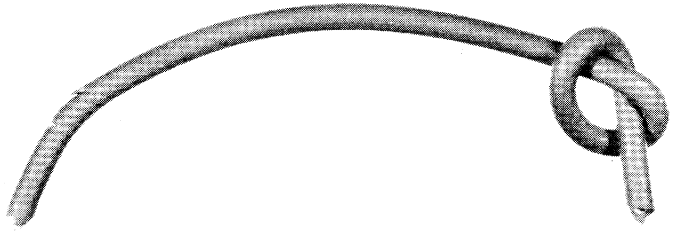


Fig. 6. Portion of lanyard retrieved from first of two duds from production grenades. Mechanical damage in form of razor-sharp cuts are visible at and near break at left end. The nylon core was melted at the break. (Knot is merely for identification of specimen.) Lanyards from 2 of 66 grenades failed in this manner. The other 64 functioned satisfactorily.

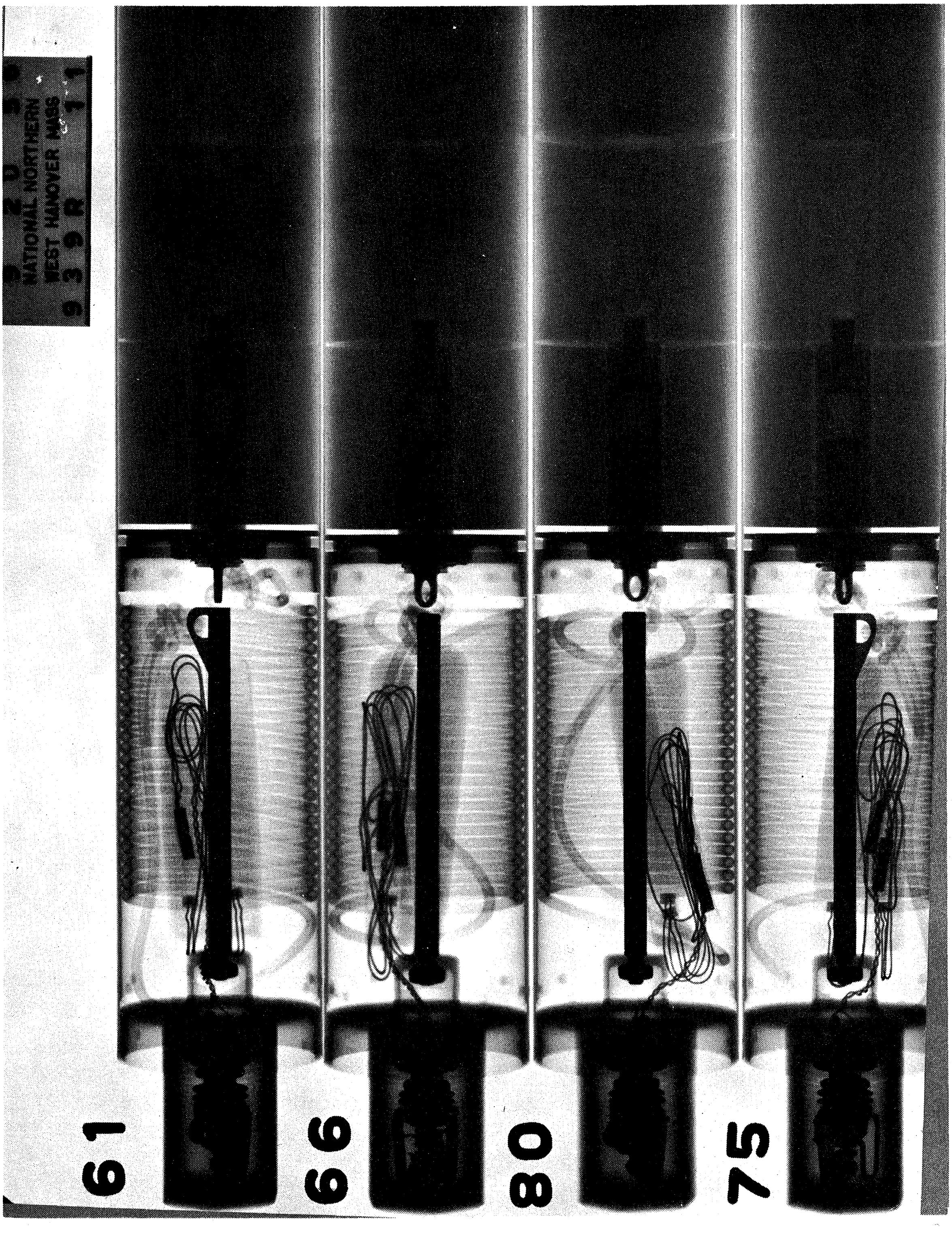


Fig. 7. X-ray inspection photograph of production grenades. Grenades are loaded and ready for firing.

2.2. NOSE CONE

The design of the nose cone involved resolving some conflicting requirements into an acceptable compromise. The multiple intersections of mortar tubes and nose surface made it desirable to use a right circular cone as blunt as practical. The aerodynamic requirements called for a long, slender, preferably ogive, nose. The design was finalized as a 30° (included angle) right circular cone (Fig. 8). This nose angle compared favorably with the angle of the standard Aerobee ogive nose.

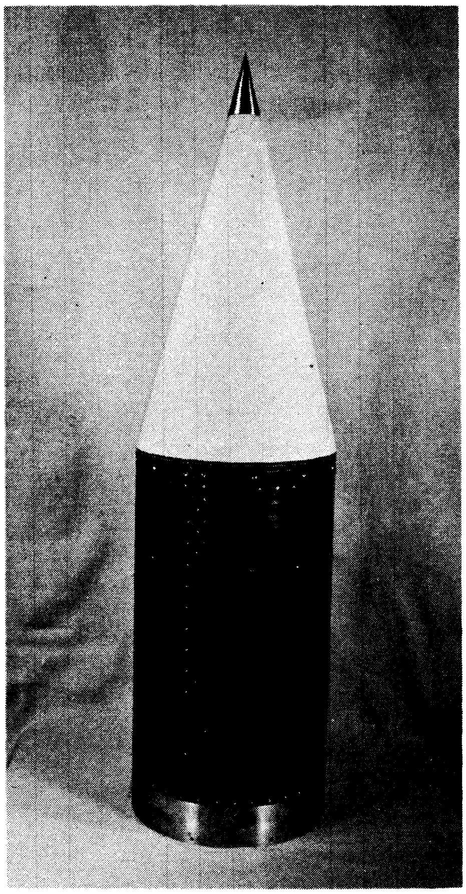


Fig. 8. Finished nose cone installed on grenade section. Frangible covering is punctured by grenades on launching.

Because the degree of shrapnel damage which might be encountered was unknown, the cone skin was intended to be reasonably thick, and the mortar-tube openings were designed larger than the barrel diameter so that considerable nicking of the edges could be tolerated before interference with ejection would be encountered.

The nose-cone assembly was designed as a metal unit, but difficulty in locating a source which could make delivery in time for the November firings required a redesign in laminated wood, delivery of which could be made in time to avoid postponement of the firings.

A frangible covering of asbestos paper was glued to the nose cone and lacquered to provide a smooth aerodynamic surface. Where the paper bridged the mortar openings, the paper was supported by styrofoam plugs inserted in the nose and resting on the grenades. The plastic foam also helps to decelerate any shrapnel which might be directed into a loaded mortar. By resting on the grenade, the plug moves immediately with the grenade and punctures the frangible skin. Due to its extremely light weight, the plug causes no appreciable increase in the ejection force required.

For ease and speed in loading live grenades into the rocket, the nose cone is prefabricated as a complete assembly, which is screwed to the grenade section after the latter is loaded.

2.3. GRENADE SECTION

The grenade section of the rocket is located at the forward end of the rocket, ahead of the instrumentation section and immediately behind the nose cone. The grenades are stored in a cluster of 18 closely-spaced mortar tubes axially parallel to the rocket centerline (Fig. 9). Each grenade is fired from its own mortar, eliminating the need for moving parts.

A microswitch is mounted near the muzzle end of each mortar to sense the ejection of the grenade. The normally "on" switch is held in the "off" position while the grenade is in the mortar and returns to the "on" position after the grenade travels approximately 18 inches. The blast from the ejection charge may tend to delay the closing of the switch momentarily, but such delay would be of negligible importance. Tests under actual firing conditions gave highly satisfactory results.

Time being of utmost importance, it was felt that tests to determine the adequacy of the microswitch spring blade, when subjected to the ejection blast, would be difficult to justify. Therefore, positive stops were incorporated in the switch-mounting brackets to prevent the spring blades from being sprung beyond their normal range of operation.

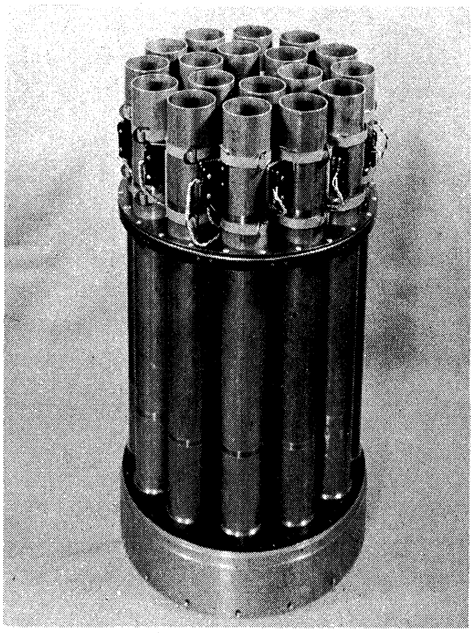


Fig. 9. Grenade section of rocket with skin removed. The high density of grenade packaging possible with this configuration is evident in this view. Microswitches visible on mortar barrels are grenade-ejection indicators.

The microswitch and method of mounting were selected to assure maximum reliability without the necessity for individual adjustment of the switches and without the necessity of special loading techniques, the omission of which might cause malfunction.

The very close quarters available for the microswitches necessitated a removable skin for access to the switches and wiring.

The mounting ring at the aft end of the grenade section is designed to fit the standard Aerobee nose extension interchangeably. The skirt of this ring is of sufficient length to provide space for a grenade-shorting "pull away" plug and, equally important, to provide protection for the grenade firing jacks when the section is not attached to the instrument section of the rocket.

A substantial bulkhead is provided at the base end of the mortars to transmit the launching loads from the mortars to the rocket skin and also to provide armor protection for the instrument section in case of shrapnel penetration.

2.4. INSTRUMENTATION SECTION

The instrumentation section consists of a cylinder 15 inches long mounted between the rocket-tank section and the grenade section. To minimize the problem of joint fits, a standard Aerobee nose extension was used as the container. Considerable modification was necessary to adapt the extension to the particular requirements of this experiment.

Many electronic components, batteries, connectors, and miscellancous items had to be installed in this section in such a manner that everything be securely anchored to withstand the dynamic loads of launching and yet be readily accessible for adjustment, testing, or replacement.

For accessibility, three large doors were provided. The doors were the maximum size possible within the limits posed by the length of the container and the location of the tower-launching rails. To maintain the structural integrity of the unit, flanged doublers were riveted to the openings.

Two vertical internal bulkheads were provided, and the doors themselves were designed as structural members. In addition, higher strength alloys were used at no increase in weight since welding was not a limitation on material selection. The resulting unit represents a tightly knit, redundant sheet-metal structure not inconsistent with current aircraft practice.

The internal bulkheads serve another purpose in providing adequate anchoring space for various components. The bulkheads are of adequate strength to permit extensive hole drilling for mounting equipment.

Figures 10, 11, and 12 are three different views of an unpainted instrument section.

2.5. ELECTRICAL EQUIPMENT

The pre-IGY grenade-rocket circuit-block diagram is shown in Fig. 13. This diagram explains functionally the operation of the rocket electrical equipment.

Physically, this equipment was located in the various sections of the rocket as follows:

a. The grenade section contained the grenade squib wiring, the pull-away

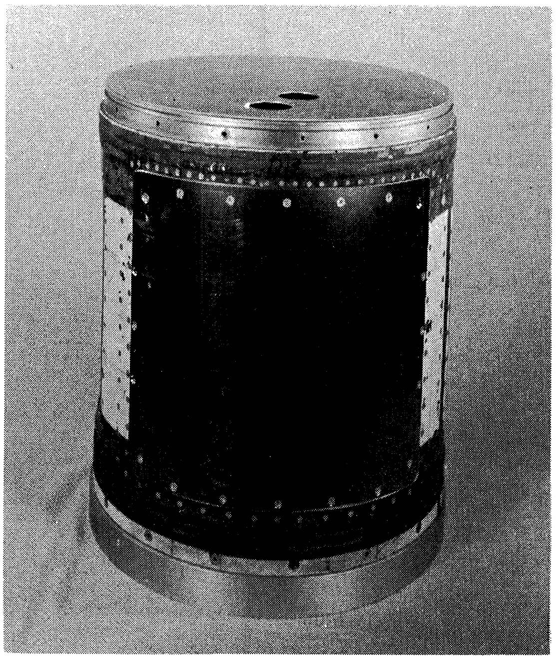


Fig. 10. Instrumentation section of rocket with structural access door in place.

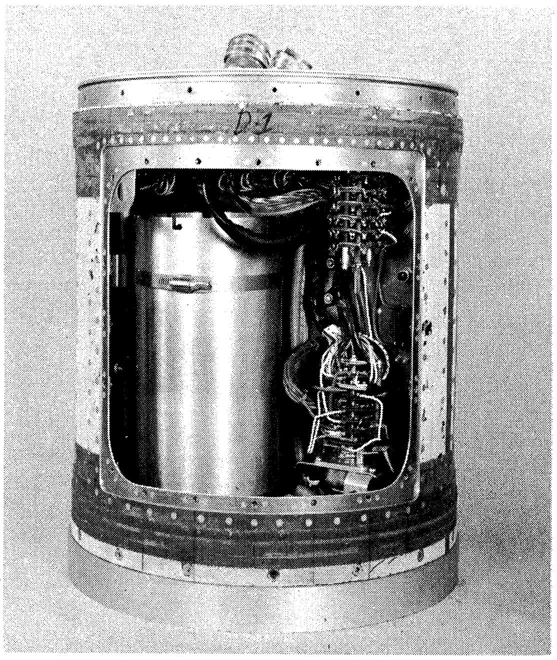


Fig. 11. Instrumentation section with door removed to show access to instruments. Three such doors are provided which are positioned so they can be opened in the launching tower.

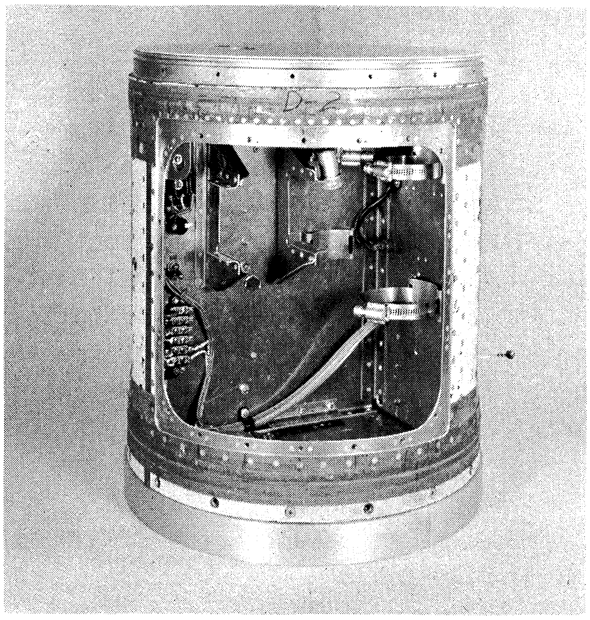


Fig. 12. Instrumentation section prior to installation of equipment. All sheet-metal parts are designed as structural members of the complete unit.

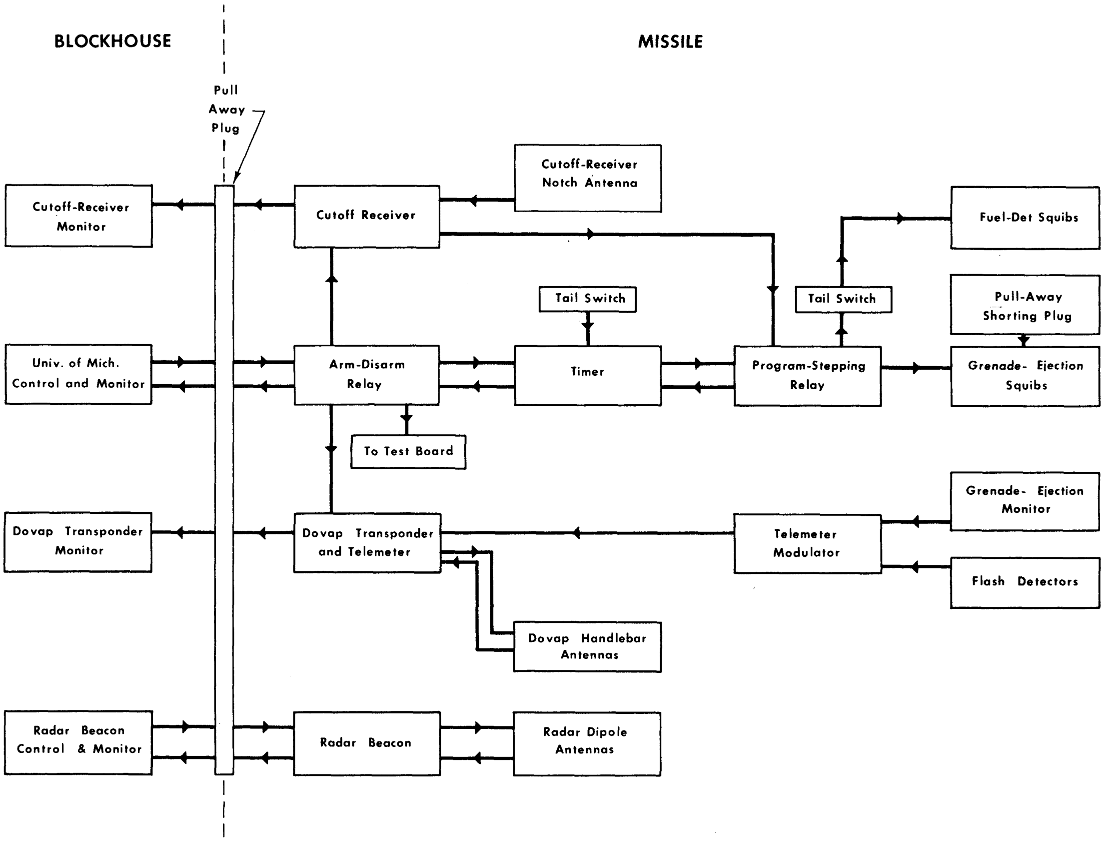


Fig. 13. Pre-IGY grenade-rocket circuit-block diagram.

shorting plug, and the ejection-monitor microswitches. These features are shown in Figs. 14, 15, and 9, respectively.

b. The instrumentation section was divided into three compartments. Compartment 1 contained the DOVAP Transponder, arm-disarm relay, and program-stepping relay (Fig. 11). Compartment 2 contained the timer, Cutoff Receiver and Radar Beacon. Figure 12 shows this compartment with the above-mentioned units removed. Items contained in the third compartment were the flash-detector-amplifier-telemeter modulator unit and several battery packs. Figure 16 shows this compartment without the Cutoff-Receiver battery pack. Each of the three compartments contained, in addition, one of the three Kodak Ektron photosensitive cells, which were used as the flash detectors. The mounting bracket for one of these is shown in the upper left hand corner of Compartment 3 in Fig. 16.

c. The main body of the missle contained the DOVAP handlebar antennas (Fig. 17) and the through missile wiring.

d. The tail section contained the tail-junction box, fuel-line detonator block, tail switches, Cutoff-Receiver notch antenna, and Radar Beacon dipole antenna. Figure 18 shows these two antennas installed on the tail fins of the rocket.

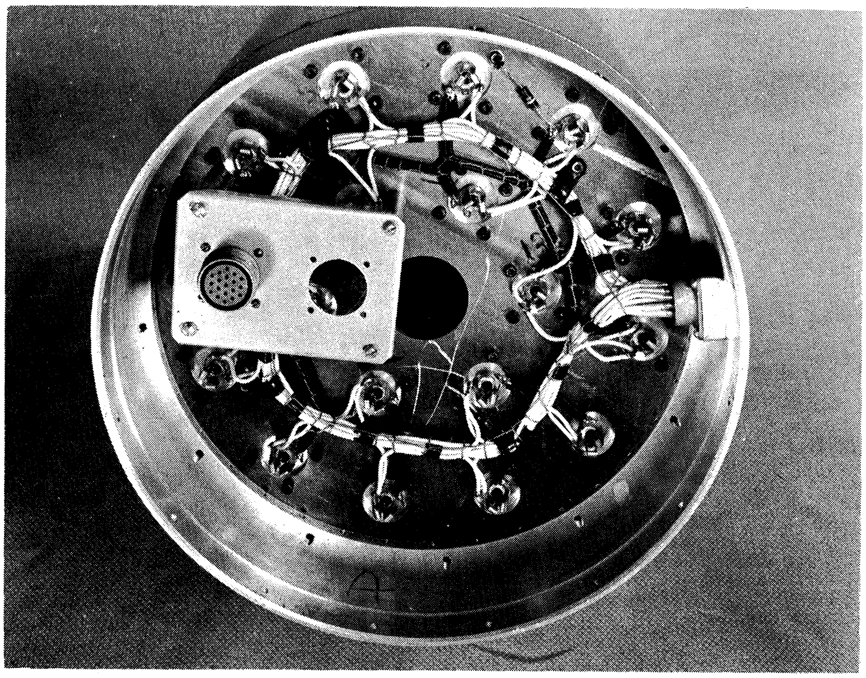


Fig. 14. Bottom of grenade section showing grenade squib wiring.

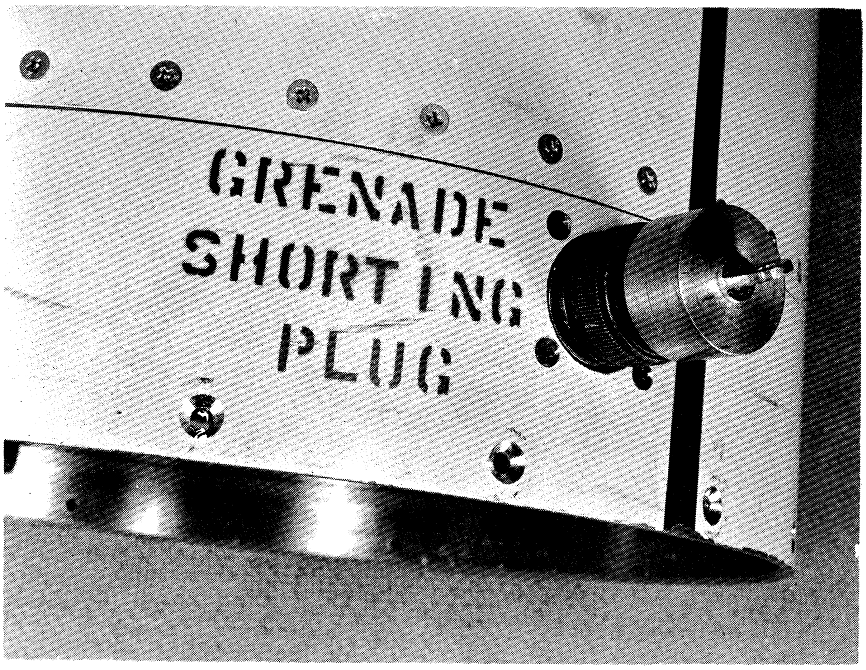


Fig. 15. Grenade section showing pull-away shorting plug in position.

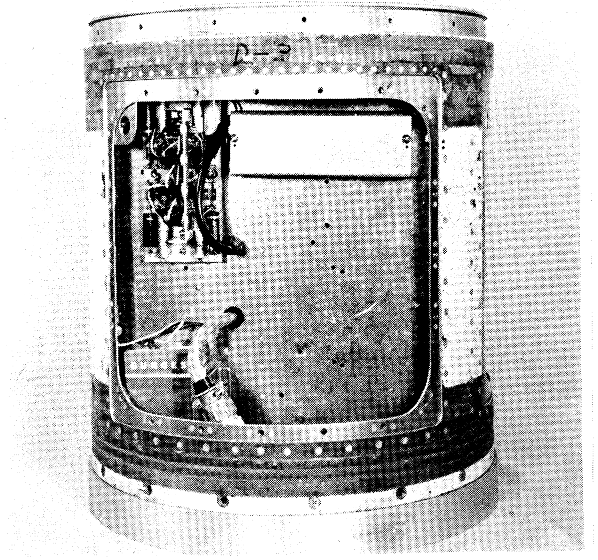


Fig. 16. Compartment 3 of the instrumentation section. Mounting bracket for Kodak Ektron photosensitive cell is shown at upper left.

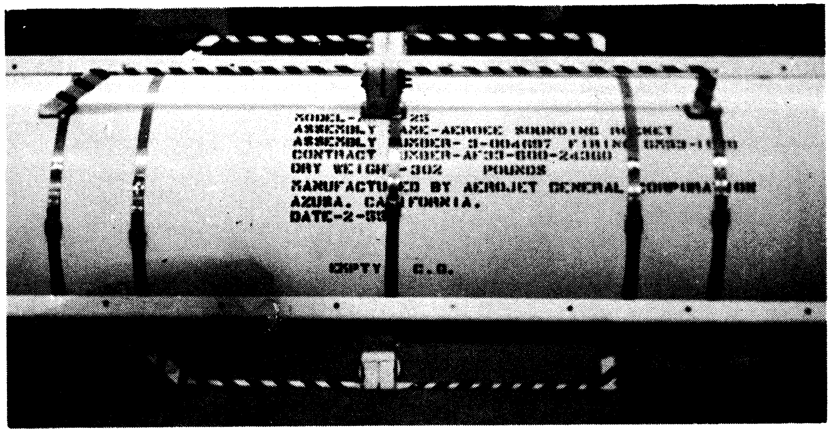


Fig. 17. DOVAP handlebar antennas, Aerobee SM1:01.

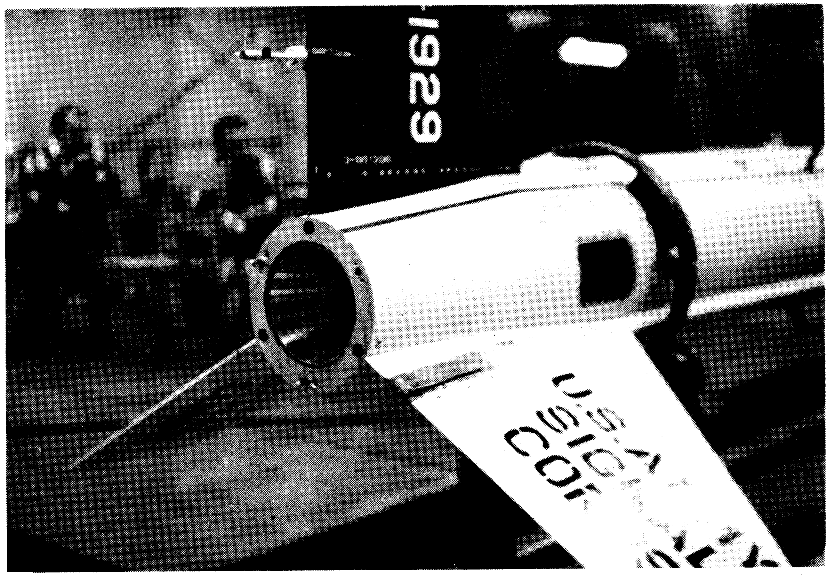


Fig. 18. SM1:01 tail section showing radar dipole antenna and Cutoff-Receiver notch antenna.

Each of the four main sections was electrically connected to the adjacent one by means of removable AN-type connectors. The major components of the instrumentation section, i.e., the Cutoff Receiver, the DOVAP Transponder, the Radar Beacon, the timer, the battery packs, and the flash-detector amplifier, were also connected into the circuit by removable electrical connectors.

2.6 GROUND TESTS AT OTIS AIR FORCE BASE

Ground tests of the grenades and the complete warhead were conducted on September 24 and 25 at Otis Air Force Base.

A lot of approximately 90 grenades were loaded by the National Northern Company. A portion of these were shipped to Fort Churchill and the remainder were fired in the ground tests.

At the request of Picatinny Arsenal two grenades were chilled for approximately four hours in dry ice and were fired successfully while so chilled. These firings were accomplished by manually pulling the lanyards, since only the explosives were being tested. Previous cold tests indicated that the black powder ejection charges and the Neoprene lanyard coating would not function at this temperature.

Ten grenades were fired from single-barrel mortars with one malfunction. One lanyard failed. A portion of the failed lanyard was recovered before the unexploded grenade was destroyed. Examination of the lanyard revealed several razor-sharp cuts in the Neoprene coating within an inch of the break and a similar cut at the break, with the nylon definitely melted. The cuts were felt to be the cause of the failure. No immediate cause could be determined for the cuts themselves.

Eighteen grenades were fired from a completely assembled warhead with 100 percent success. Shrapnel damage was confined largely to the inside of the mortar barrels, with a few scattered nicks in the wooden nose cone. (Figure 19 shows the nose cone, grenade section, and instrumentation section after the test.) Except for some mortar replacements the entire unit was reusable. The largest piece of shrapnel that could be found is shown in Fig. 20.

A second complete warhead was fired, this time with 17 successful grenades out of 18. One lanyard broke, and the dud had to be destroyed. A section of the lanyard was first recovered, and this section showed a similar razor-sharp cut at the break. Some additional inspections are indicated in the manufacturing process to find and eliminate this cause of malfunction.

Although the total number of grenades fired was small, the following results are considered indicators of reliability.

a. Of 48 grenades, all exploded high order.

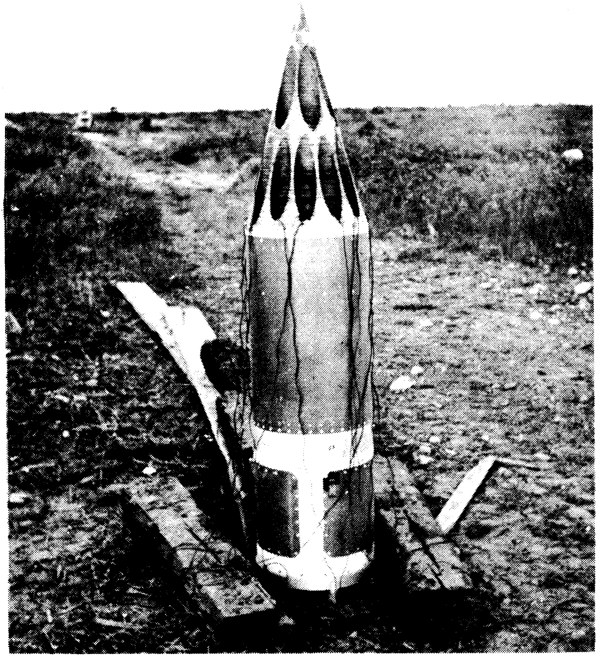


Fig. 19. Complete warhead after successful 18-round test. Shrapnel damage was light and confined predominately to the inside of mortar barrels. Lanyards can be seen draped down the sides of the warhead. Approximately 5 feet of lanyard is consumed in the grenade explosion.

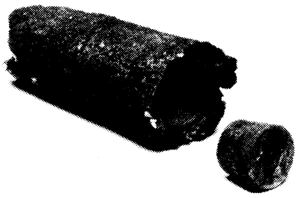


Fig. 20. Shrapnel from grenade. Large tubular portion is the body of the firing mechanism; small item is the head of the firing pin. Shrapnel apparently was seldom this large as this is the only large piece found after the ground tests.

b. Of 46 grenade launches attempted, all were successful. No squib, powder failures, or detonator failures occurred.

c. Of 46 grenades launched, 44 were successfully fired as planned. Two lanyards broke from causes which we felt could be eliminated by additional inspection during the manufacture. Counting the failures, the indicated reliability of this lot is 96%.

The two complete warhead tests each included an instrumentation section identical with that which was to be flown on the pre-IGY grenade rocket. All units were used as they would be in the rocket flight with the following exception. The Cutoff Receiver and the Radar Beacon were merely physically mounted in the instrumentation section; they were not operating during the test. The DOVAP unit was operating during the test. A 36.94 mc signal was applied to the input from an oscillator located in the blockhouse; the 77.84-mc signal output was monitored in the blockhouse by a Bird wattmeter and an oscilloscope. A record of the telemeter input was made on a Brush recorder. Briefly, the firing operations consisted of the following:

a. Preliminary test run of unloaded rocket.

b. Button up rocket and load grenades.

c. Yank out shorting pull-away plug.

d. Start timer with simulated tail switch.

All electrical and electronic equipment operated satisfactorily in both complete warhead tests. Telemeter signals were as expected. The DOVAP unit showed a slight amplitude modulation at the instant of each grenade explosion but continued operating perfectly throughout the test. The Cutoff Receiver and Radar Beacon suffered no apparent damage and were operated successfully in the laboratory after the tests.

2.7 PERFORMANCE CALCULATION BY AEROJET

In July, 1956, the Aerojet General Corporation was requested to supply an evaluation of the grenade-experiment payload-section design. Specifically, they were asked to calculate stability and probable peak altitude of a Model AJ10-25 Aerobee carrying a payload section 63.6 inches long, the top 20.6 inches being a 40° included-angle right circular cone, the total weight to be 200 pounds, changing to 110 pounds after the grenades are ejected, and the center of gravity to be 36 inches from the top with grenades and 39 inches from the tip without grenades.

Although the nose cone was subsequently changed, i.e., different length, different weight, and 30° included-angle cone, the Aerojet General results are given in Appendix D for they indicate qualitatively the effect on the rocket performance of the grenade experiment type of nose section.

2.8. PRE-FLIGHT OPERATIONS AT FORT CHURCHILL

During the last month of this quarter three sets each of the nose cones, grenade sections, instrumentation sections, and through-missle cables were completed and tested. This equipment, plus the necessary tools and a supply of spare parts, was shipped to Fort Churchill with only a slight delay in their arrival.

The prefiring operations at Fort Churchill began on October 19, 1956. Some minor modifications had to be made on the rocket instrumentation, as follows:

a. The dipole-antenna mounts had to be moved to different fins than those on which they had been installed by Aerojet.

b. A mounting bracket had to be provided for the Radar Beacon pre-selector.

c. A wafer had to be added to the arm-disarm relay so that the Cutoff-Receiver B^+ voltage would be turned on and off, as well as the 6-volt filament and bias supply.

A test was run to determine the total operating life of the Cutoff Receiver. It had been suspected that the effective life time was small; however, this test indicated approximately 50—60 minutes operating time.

In order to determine whether or not the process of shipping the grenades to Fort Churchill had damaged the grenades in any way, one was selected at random, disassembled, and inspected thoroughly. No damage was discovered. In addition, two grenades were fired singly from a mortar to check on their operation after shipping. These tests were performed at the SIPRE wooden tower which was about halfway between the launcher and Twin Lakes stations at Fort Churchill. The grenade tests also provided a check on the Signal Corps ground detectors and were conducted in such a manner as to indicate approximately the minimum current at which the grenade squibs would fire. Both grenades exploded properly, the Signal Corps ground flash detectors received signals, and the minimum current that will fire a grenade-ejection squib was determined to be 500 milliamperes.

The DOVAP antennas were installed on the missile. After preliminary checks on the missile equipment, two horizontal tests were held. On the first one, the Radar Beacon did not operate properly. On the second one, a parasitic antenna enabled the radar to work. As of November 1, 1956, the first pre-IGY grenade Aerobee (SM1:01) was ready for weight and c.g. measurements.

2.9. DATA REDUCTION

All the MIDAC programs for DOVAP data reduction were checked out, and they operated properly.

3. AIR SAMPLING

Much of the effort on sampling during the quarter was spent on the final preparations and firing of Aerobees SC-34 and SC-35 at White Sands on August 9 and 10, respectively. In October an analysis of one of the flight bottles was accomplished.

3.1 AEROBEES SC-34 and SC-35

For a complete description of the flight objectives and the design of these rockets, the reader is referred to the "Installation Letter" from E. J. Schaefer, University of Michigan, to Commanding Officer, U. S. Naval Ordnance Missile Test Facility, WSPG, dated 18 May, 1956, and to previous reports of this series.

The rockets used were the early type Aerobees XASR-SC-1, serials 17 and 10. These vehicles develop 2600 pounds of thrust for 45 seconds. Nitrogen pressurization was used in the flights to avoid contamination of the air samples with helium. With 230-pound payloads, the peak altitudes were predicted to be 260,000 feet. The parachutes were 8-feet-diameter FIST ribbon type.

SC-34, originally scheduled for 1430 MST on August 7 was fired at 0853 MST on August 9. The rocket, the tracking instrumentation, and the scientific instrumentation operated almost perfectly. The peak altitude was 280,440 feet MSL. This altitude was reached in spite of 35 pounds of weight added at station 40" to limit the peak altitude to 260,000 feet. With the added weight, the total take-off weight was 1169.5 pounds. The sample canister was accurately located by radar (at 0° 50' 22" azimuth, 28.05 miles from the launcher in the White Sands Transverse Mercator System) and was inspected and recovered on the same day by Michigan personnel. The impact site was relatively level, sandy terrain. In external appearance the canister was virtually undamaged. A later, more careful inspection of the inside of the canister at the base laboratory revealed more impact damage than was apparent at the impact site. The support rods were bent or sheared off and the bottle-support plates had buckled somewhat. The one-inch sealers had broken loose from the underside of the bottle-support plate, but both one-inch seals appeared to be good. The two-inch seal had been made but was opened on impact when the seal was driven into the sealer mechanism by the buckling of the support plate. The one-inch bottle with a Pirani checked OK. Thus, the score for this rocket was: two-inch bottle not good, one one-inch bottle good, one one-inch bottle perhaps good.

A last minute change to a personnel-type parachute for SC-35 to be fired the next day was contemplated but rejected on the basis that the change would introduce a great risk of total failure due to a major change in equipment under field conditions without suitable testing. The only change made in SC-35 was to reduce the black powder charge from 9.5 grams to 9.0 grams. This was indicated as being desirable by the fact that the two-inch sealer jaws were considerably flattened.

SC-35, which had originally been scheduled for 1430 MST on August 9 was fired at 0822 MST on August 10. Again, everything worked in a most satisfactory manner. The peak altitude was again higher than expected, at 281,752 feet, and again in spite of added weight. The extra weight in this case was 45 pounds added at station 39.5", making the total take-off weight 1179 pounds.

The impact site (location not yet received from WSPG) was similar to that of SC-34. The external apparent damage and the internal damage examined at leisure were negligible and all three bottles, both the two with gages and the one without, appeared and checked to be good.

Table I summarizes the pertinent bottle and trajectory data of the two flights.

3.2. SAMPLE ANALYSIS

Upon completion of the Aerobee sampling flights, preparations were made to analyze the upper-air and ground-control samples. At this point August 15 a crack appeared spontaneously in the fractionating column of the analyzer and was repaired. The next day another crack appeared. This was the second of a series of about 12 new cracks and cracks in repaired places which appeared in the analyzer up to September 21. The majority of the cracks were in the fractionating column which had only been flame-annealed (rather than oven-annealed) after its construction. Since it was impossible to predict an end to the spontaneous cracking, it was decided to anneal the entire apparatus. On the advice of the manufacturers of the Kimball glass used in the analyzer an annealing temperature of 500°C was decided upon. Tests showed that the Mariamte insulating material of the analyzer's own baking oven would not withstand this temperature. Therefore, a new temporary oven of screen, aluminum foil, and Fiberglas was constructed and placed over the analyzer. Baffles were provided for the heating elements and a fan, rotated by an outside motor, was placed in one end of the temporary oven. The Mariamte base of the analyzer was protected with a reflecting layer of aluminum foil. Nitrogen was piped into the oven to provide a nonoxidizing atmosphere for the annealing.

The annealing process was carried out successfully during one afternoon and evening. Following this, several successful analyses of ground air and the contents of bottle B-15 were carried out. The ground-air samples (Nos. 12 and 13) yielded the expected results. Four runs of ground sample No. 13 were interspersed with the three analyses of the contents of B-15. B-15 was chosen for the first analysis because checks of its Pirani gage subsequent to the rocket firing indicated a small leak. The operations and results on B-15 are given in Table II.

TABLE I

SAMPLING AEROBEES SC-34 AND SC-35

						At Closing					
Sample Bottle	Rocket Number	Date of Sampling	Time of Sampling MST	Peak Altitude km MSL	Opening Altitude km	Closing Altitude km	Total Velocity km/sec	Velocity of Sound km/sec	Mach No.	UARRP Ambient Pressure mm Hg	Tube Diam. cm
B-18-PR	SC-34	9 Aug 56	0856	85.5	85.3	85.5	0.16	0.29	.55	.0038	5.08
B-25	SC-34	9 Aug 56	0856	85.5	85.3	85.5	0.16	0.29	.55	.0038	2.54
C-22	SC-34	9 Aug 56	0856	85.5	85.3	85.5	0.16	0.29	.55	.0038	2.54
B-10	SC-35	10 Aug 56	0825	86.0	85.6	85.9	0.12	0.29	.41	.0036	2.54
B-15	SC-35	10 Aug 56	0825	86.0	85.6	85.9	0.12	0.29	.41	.0036	5.08
C-23	SC-35	10 Aug 56	0825	86.0	85.6	85.9	0.12	0.29	.41	.0036	2.54

TABLE II

BOTTLE B-15

Operation	Amount of Sample	He Ratio	Ne Ratio
Analysis No. 1	.0082 cc NTP	1.636	1.111
Analysis No. 2	.0061 cc NTP	1.643	1.14
Placed some sample in soft glass vial	.0128 cc NTP	--	--
Analysis No. 3	.0036 cc NTP	1.674	1.131

The average separation factor for helium is 1.65 and for neon 1.13. An estimate, accurate to perhaps ± 30 percent, of the pressure in the bottle at the time of sampling before appreciable air had leaked in is 0.0016 mm of air. This compares with the UARRP value of ambient pressure at 85.9 km of 0.0036. Thus, 45 percent of the ambient pressure was collected, a satisfactory result in the light of the probable error in the accepted ambient pressure value. If the separation values are corrected for the leak, they become 2.30 and 1.26 for helium and neon, respectively.

Thus, it appears that the earlier results of diffusive separation have been confirmed. This tentative conclusion, however, must be treated with reserve until such time as all the upper-air samples and the associated controls are analyzed.

3.3. ANALYZER AT MAINZ

The air analyzer at the Max Planck Institute for Chemistry at Mainz, which was assembled under the direction of Professor F. A. Paneth, is now in full operation. In September it was the pleasure of the project to receive Dr. Heinrich Wänke of the Institute in Ann Arbor. Dr. Wänke returned to Mainz after observing the Michigan analyzer and carried with him bottles B-25 and C-22 for analysis at Mainz.

4. RESEARCH INVESTIGATIONS

A progress report on the development of a physical theory of a semi-rarified gas flow around a simple geometric body will be given in the next quarterly report.

5. LABORATORIES VISITED

During this quarter the following places were visited:

a. Otis Air Force Base, Massachusetts
b. Fort Churchill, Canada.
c. White Sands Proving Ground.

6. FUTURE PROGRAM

6.1. GRENADE EXPERIMENT

The pre-IGY grenade Aerobees will be fired at Fort Churchill. Data reduction on these flights will be started and the equipment performance analyzed.

6.2. AIR SAMPLING

Analysis of upper-air control samples will continue.

7. ACKNOWLEDGMENT

Thanks are due to the Meteorological Branch, Evans Signal Laboratory, for cooperation and financial support. The help of the National Northern Fireworks Company at the Otis Air Force Base is greatly appreciated.

APPENDIX A

THE UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
ANN ARBOR

Memo 2387-A

Subject: FUNCTIONAL TESTS, HIGH-ALTITUDE GRENADE

To:
Evans Signal Laboratory, Attn: Mr. William G. Stroud (2)
National Northern, Attn: Mr. Robert Woodburn (2)
Picatinny Arsenal, Attn: Mr. Gary Weingarten (1)
Picatinny Arsenal, Attn: Mr. Frank Shelton (1)

(Note: To expedite distribution of the test data, this report was copied verbatim from the notes taken during the tests.)

Test Site: Halifax, Massachusetts, Range of National Northern Company

Observers and Crew:

Robert Woodburn,	National Northern
Albert Gioiosa,	National Northern
Rudolph Veinaglia,	National Northern
Kenneth Peterson,	National Northern
Frank Shelton,	Picatinny Arsenal
Marvin Zeeb,	University of Michigan
Wallace Wilkie,	University of Michigan

Range: Approximately 290 ft from grenade launcher to cameras and observers

Date: 7-2-56

Test	Grenade	Time	Remarks
1	10	12:00 M	Weather clear. Grenade functioned O.K., except H.E. didn't blow. Detonator ruptured grenade without setting H.E. off.
2	5	12:45 PM	Grenade didn't fire - circuit trouble. Corrected - grenade launched. Lanyard tube rivets sheared, pin pulled, lanyard uncoiled only a few turns. Mortar base was collapsed from detonator thrust (probably). H.E. didn't blow.
3	3	2:50 PM	Lanyard partially uncoiled - lanyard tube rivets sheared. Detonator blew - H.E. didn't. Possibility that detonator is firing prematurely, blowing pin out and shifting bulkhead and tube causing rivets to shear.

Date: 7-2-56 (continued)

Test	Grenade	Time	Remarks
4	12	3:25 PM	Pin pulled - detonator blew - H.E. didn't. Lanyard tube ejected. Mortar base yielded, indicating thrust above that of black powder. Middle bulkhead nearly ejected from bottom of tube.
5	6	3:55 PM	Lanyard No. 9 appears to have been installed in grenade No. 6. Lanyard intentionally disconnected from anchor post. Detonator blew - H.E. went low order. Pin was apparently blown out. Lanyard tube ejected - middle bulkhead almost ejected; middle bulkhead almost ejected. Lanyard uncoiled few turns.
6	1	4:30 PM	Rear bulkhead removed. Lanyard pulled manually. Detonator blew - H.E. didn't. Lanyard tube ejected; middle bulkhead almost ejected.

Date: 7-3-56

Test	Grenade	Time	Remarks
7	11	2:15 PM	Test number is in sequence. Some tests on 7-2-56 were photographed with grenade numbers listed as test numbers. Grenade No. 11 - .035 music wire substituted for pull-pin safety shear wire. Lanyard disconnected from post. Test for shock triggering of detonator Pin did not pull. Lanyard tube rivets sheared - lanyard uncoiled. Detonator did not blow, indicating no shock ignition.
8	7	2:50 PM	Standard grenade with 8 rivets in lanyard tube. Lanyard uncoiled, pin pulled, detonator blew; H.E. didn't. Lanyard-tube rivets sheared (probably from middle bulkhead after detonation).
9	9	3:25 PM	Standard grenade with 8 rivets in lanyard tube. Lanyard uncoiled; pin did not pull - was disconnected from pull-pin. No evidence of snap-clip failure by springing open (normal method of failure from overload).

Date: 7-3-56 (continued)

Test	Grenade	Time	Remarks
10	2	3:50 PM	Standard grenade with 8 rivets in lanyard tube. Normal except H.E. didn't blow.
11	4		Standard grenade with 8 rivets in lanyard tube. Normal operation except H.E. didn't blow. Silicone tube ruptured approximately 14 inches from anchor post; nylon slightly singed. Spring clip on anchor post holding on one hook; hook partially sprung.
12	8		Standard grenade with 8 rivets in lanyard tube. Normal operation except H.E. did not blow.

Grenades loaded with 1 lb HBX-6 and 3 lb sand.

Detonators - Mark 31 cup loaded with 600 milligrams total charge:

150 milligrams	lead styphnate
150 "	lead azide
300 "	tetryl.

Booster - 60 grams tetryl.

Additional Comments:

1. The 12 grenades used in these tests were damaged during loading. The damage consisted of sheared rivets between the middle bulkhead supporting the H.E. charge and the grenade case. A field repair was effected using ordinary steel nails clipped short and taped in the rivet holes. Because the middle bulkhead and the lanyard tube are in contact with each other, any free motion in the middle bulkhead (caused by poor fit of the nails in the rivet holes) would induce additional load in the lanyard tube. Earlier tests at the University of Michigan indicated that two rivets in the lanyard tube were adequate; however, Tests 2, 3, 4, and 5 indicated that premature detonating was probably caused by shearing of the lanyard tube rivets. When the lanyard tube rivets were increased to eight, which was enough to substitute for those in the middle bulkhead, normal uncoiling of the lanyard and pulling of the pin took place.

2. Test 9 failed to detonate because the lanyard was disconnected from the pull-pin. The snap clip showed no evidence of failure or wrenching open. The question was raised about the possibility that the clip might have been inadvertently left unconnected during assembly. Subsequent grenades were visually inspected for lanyard connections by two observers.

3. The detonators were quite powerful. In all tests when the detonators blew, the grenade cases were ruptured. Middle bulkhead usually would be pushed,

piston fashion, to within an inch of the end of the grenade tube, pushing the lanyard tube ahead of it. Firing mechanism opened up banana-peel fashion at detonator end.

4. The firing mechanisms all functioned properly.

5. High explosive did not blow in any test except a partial low-order detonation in Test 5. Detonator blast appeared sufficient, but tetryl boosters didn't take.

6. All grenades launched properly. Black-powder capsules all fired. Shear rivets for grenade release functioned properly. Misfire in Test 2 was determined to be in external firing circuit. Same grenade was fired when circuit was checked and corrected.

7. Lanyards all withstood the black-powder blast. Two types of lanyards were used: a 225-lb-rated nylon cord with a silicone-rubber cover and a 175-lb-rated nylon cord with a red-rubber cover. Both types were successful. Two of the silicone covers ruptured (possibly from punctures during assembly) permitting the nylon to be singed. No lanyard failures resulted, however.

8. Data is insufficient to determine advisability of requiring self-destructor.

Conferences 7-3-56 following Tests:

Conferees:		
	Frank Shelton	Picatinny Arsenal
	Robert Woodburn	National Northern
	Marvin Zeeb	University of Michigan
	Wallace Wilkie	University of Michigan

The following recommendations were made and agreed to in the conference immediately following the grenade firings on 7-3-56:

1. For additional margin of safety, the number of rivets will be increased from 8 to 12 in the middle bulkhead and from 2 to 8 in the lanyard tube.

2. To preclude additional rivet failures due to loading technique, future grenades shall be precast in a separate mold. Precasting is desirable also from the safety standpoint in that the firing mechanisms can be installed and safetied in an empty grenade prior to loading the precast H.E.

3. National Northern will run additional simulated grenade tests to solve the booster problem. Six additional, possibly more, grenades will then be loaded for test.

4. National Northern will try detonators without lead styphnate to reduce sensitivity to shock. National Northern will substantiate mixes used with statistical records of prior use.

5. Inspection to be 100% on all grenades with independent inspection of lanyard connections by two inspectors with signed affidavits suggested. X-ray inspection also suggested.

6. Picatinny will approve design from safety standpoint but requests transportation, vibration, and 40-ft drop tests for final approval of firing mechanism. National Northern is equipped to run these tests. University of Michigan will ship 5 additional grenades to be inert loaded for these tests. Salvage parts will be used for some of these grenades.

7. University of Michigan will continue functional tests using inert H.E. charge.

W. J. Wilkie
7-9-56

APPENDIX B

25 July 1956

40' Drop Test - University of Michigan P-939R

Test No. 1

(No. 22 Grenade) Nose-Down
Twisted out forward bulk head. 10-15 degree hit. OK upon examination. No damage from Vibration Test.

Test No. 2

(No. 24 Grenade) Nose-Up
Rear bulkhead forced out. Post broke. Lanyard uncoiled three coils. Lanyard case rivets showed signs of shearing. Middle bulkhead intact. Pull pin loop broken. Slight damage to lanyard. OK upon examination. No damage from Vibration.

Test No. 3

(No. 22 Grenade) Horizontal
Hit slightly toward base. Rear bulkhead forced out. Rod broke. Case tore approx. 1 1/2" from end. OK upon examination. No damage from Vibration.

Test No. 4

(No. 20 Grenade) Nose-Up 45°
Grenade bent in middle. Sheared 3 rivets in rear bulkhead. OK upon examination. No damage from Vibration.

Test No. 5

(No. 21 Grenade) Nose - Down 45°
Rear bulkhead forced out. Bent and tore case wall above lanyard rivets. Post bent. Case split about 170° on line of rivets. OK upon examination. No damage from Vibration.

Note: Examination consisted of cutting open the grenades and checking the condition of the firing mechanism, lanyard fastenings, propellant tubes, etc.

R. P. Woodburn

APPENDIX C

25 July 1956

Booster Test - University of Michigan P-939R

Test No.	Result	Remark
1	Low Order	Old Type Detonator
2	High Order	"
3	Low Order	"
4	High Order	"
5	Low Order	"
6	High Order	New Type Detonator
7	" "	"
8	" "	"
9	" "	"
10	" "	"
11	" "	"
12	" "	"
13	" "	"
14	" "	"
15	" "	"

New Type Detonator - approx. .6 gram Lead Azide
Lead Styphnate and Tetryl omitted. All boosters used were tetryl with cavity in one end to accept detonator.

R. P. Woodburn

APPENDIX D

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

27 September 1956 210:690:hs

Mr. F. L. Bartman
High Altitude Engineering Lab.
East Engineering Building
University of Michigan
Ann Arbor, Michigan

Dear Mr. Bartman:

The proposed Aerobee AJ10-25 design attached to your letter of July 24th to Mr. M. L. Stary was evaluated and the significant results are given below.

A comparison of the performance at burnout and at summit with a 40 degree conical nose and the standard ogival nose follow:

	40° Cone	30 Caliber Ogive
Velocity at burnout	3670 ft/sec	4275 ft/sec
Altitude at burnout	60,400 ft	67,350 ft
Altitude at summit	44.5 mi	63.1 mi

Figure 1 shows a time history of velocity and altitude up to the point of negligible drag.

The static stability at burnout expressed by M_α (see Fig. 2) using either a conical or ogival nose is considerably above that estimated for models which have made successful flights. Note that the conical nose improves the stability slightly after 20 seconds of flight and during the critical period near burnout.

The variation of dynamic pressure and center of gravity with time are shown by Figures 3 and 4 respectively. These are included to aid in the evaluation of static stability.

Assuming a rigid vehicle, the natural frequency in pitch due to aerodynamic loading was computed. (Refer to Figure 5.) As the shape of the nose did not appreciably effect the natural frequency, only one curve is shown. Flights of some previous models have indicated coupling between the frequency in pitch and spin at or near burnout when the frequency was between one half and one cycle per second. The occurrence of the undesirable effects of coupling appear less likely for this model as the frequency in pitch near burnout is 2 cycles per second.

We would be glad to furnish additional data should you require it.

Very truly yours,

AEROJET-GENERAL CORPORATION

R. Baggs for
Y. C. Lee, Department Head
Study and Applied Research Department
Liquid Engine Division

RBH

Encl. Fig. 1 - 5.

Dry Weight less Payload = 273 lbs
Propellant Weight = 678 lbs
Helium Weight = 5 lbs

Thrust at Sea Level = 4100 lbs
Specific Impulse (S.L.) = 195
Launching Elevation = S.L.

Note:
Summit Altitude (Ogival Nose) = 63.1 Mi
Summit Altitude (40° Conical) = 44.5 Mi

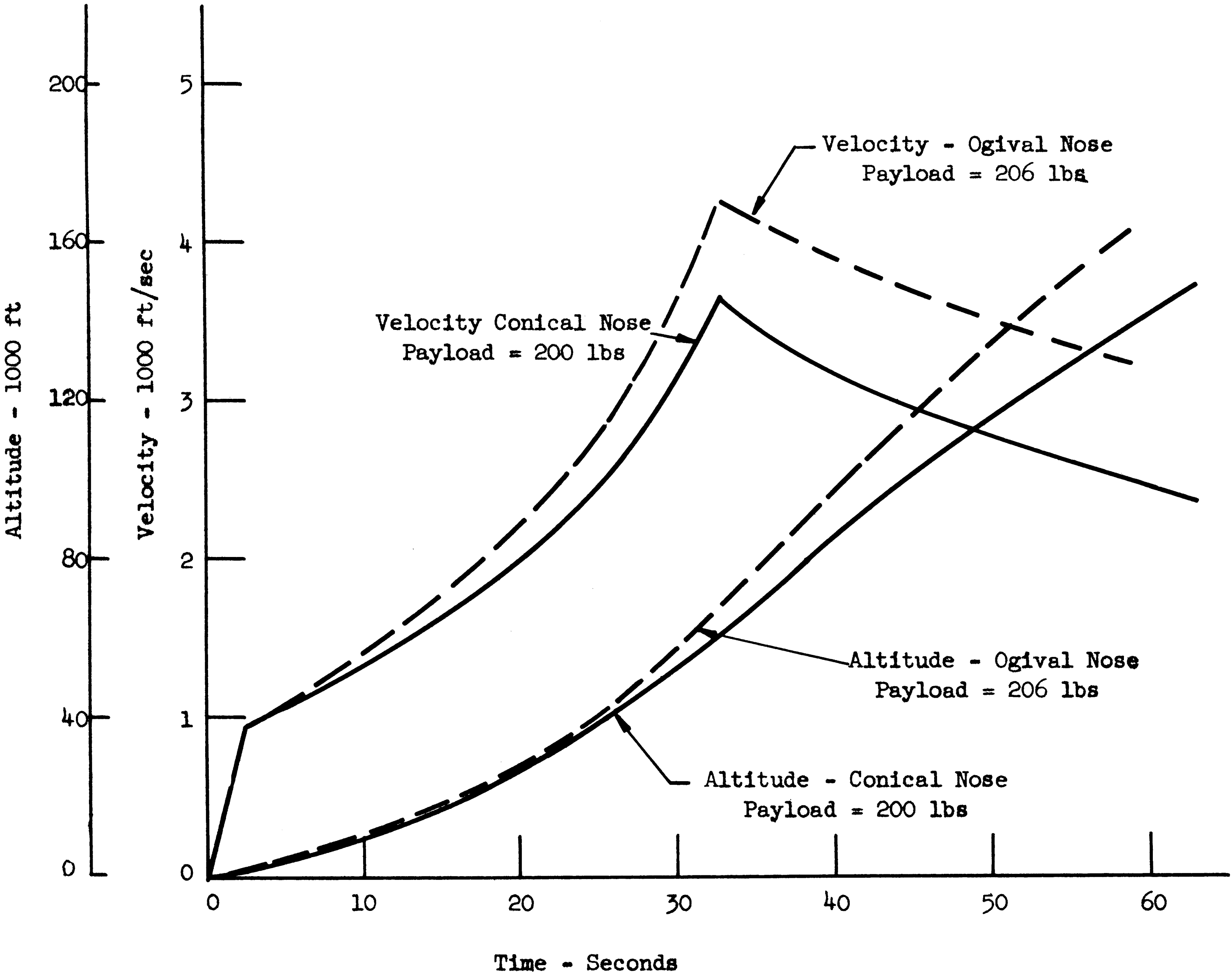


Fig. 1. Variation of Velocity and altitude with time using ogival and conical nose cones (Aerobee AJ10-25).

Dry Weight less Payload = 273 lbs
Propellant Weight = 678 lbs
Helium Weight = 5 lbs

Thrust at S.L. = 4100 lbs
Specific Impulse = 195
Launching Elevation = S.L.

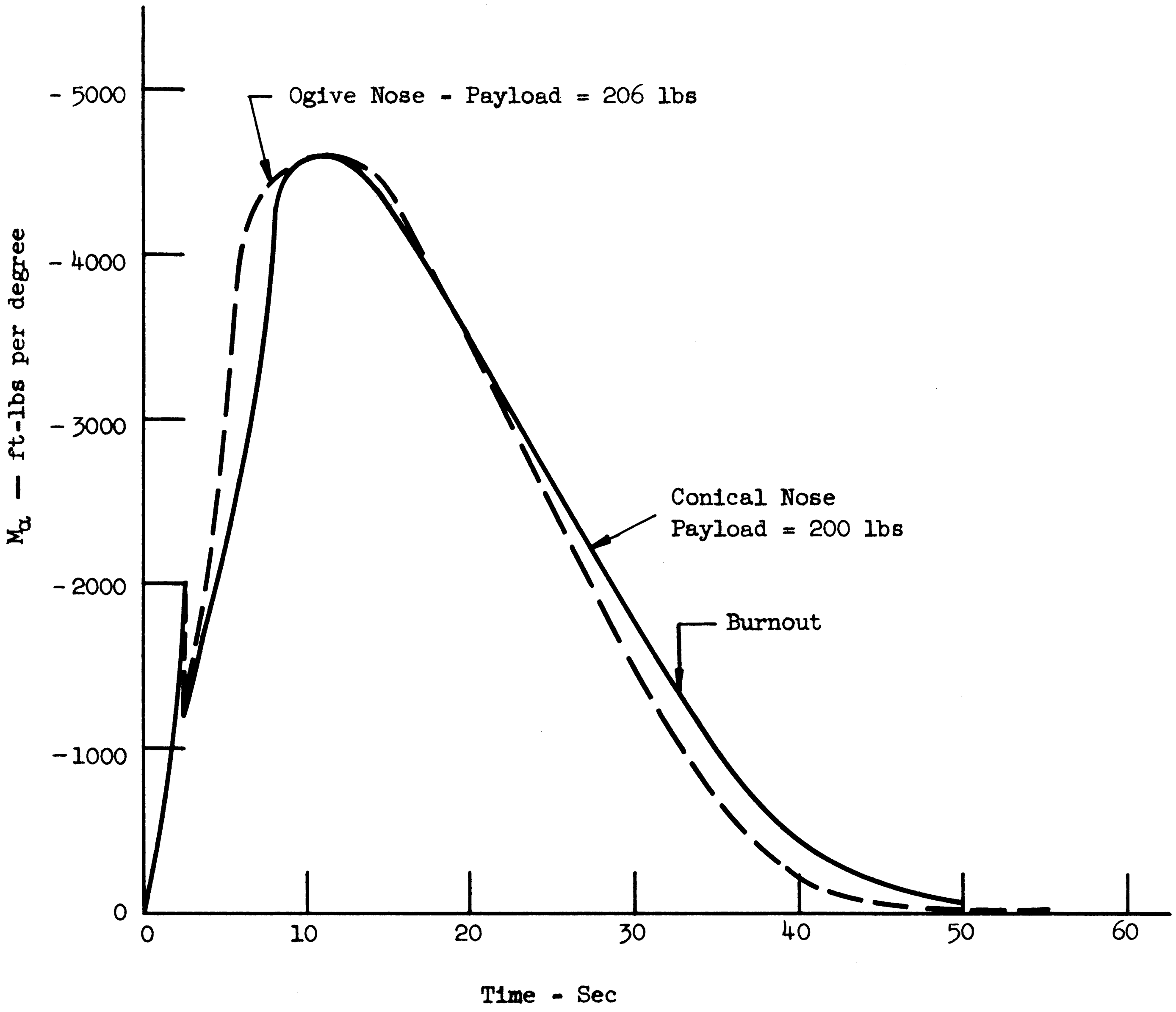
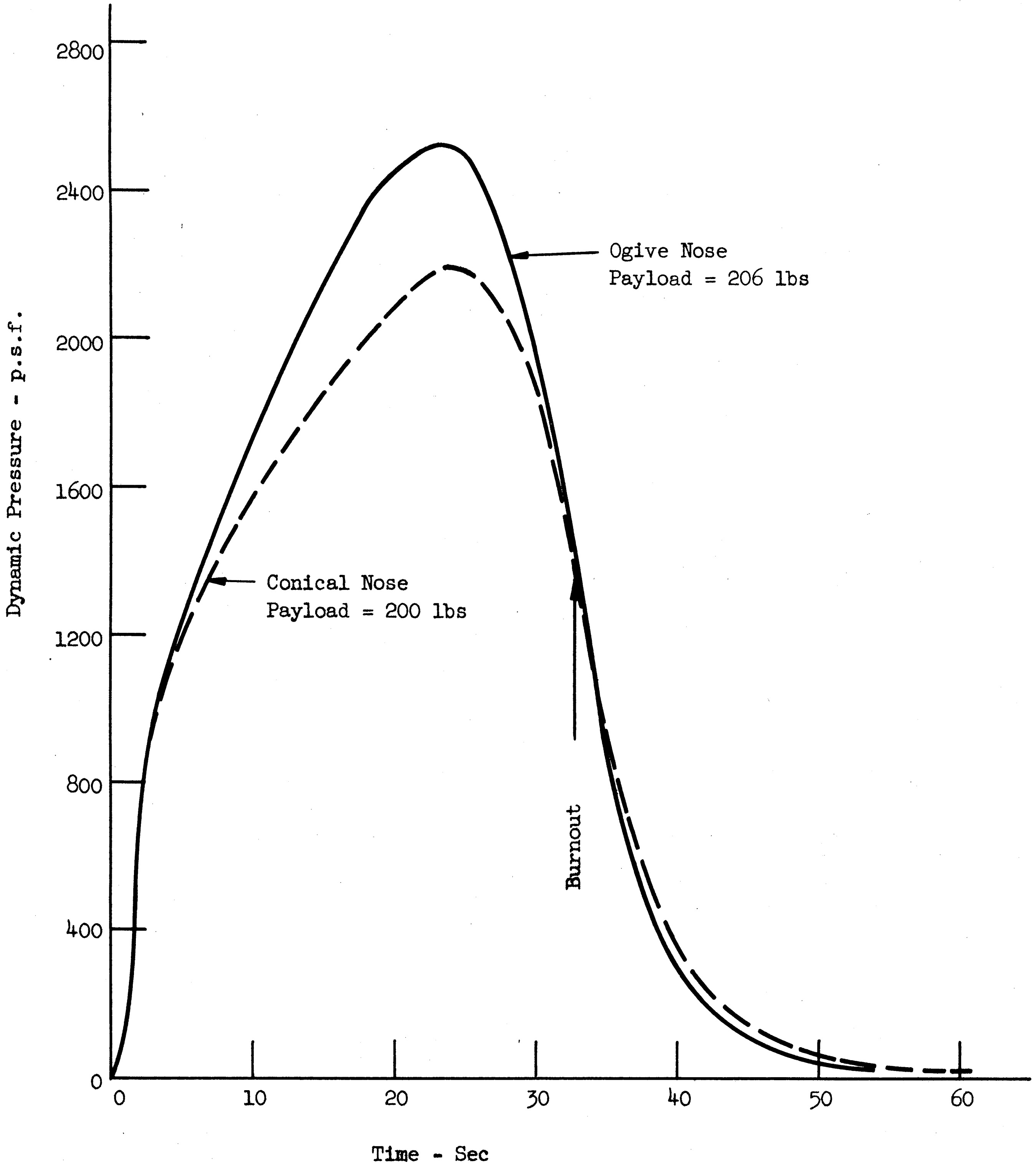


Fig. 2. Variation of M_α with time using ogival and conical nose cones (Aerobee AJ10-25).



Dry Weight less Payload = 273 lbs
Propellant Weight = 678 lbs
Helium Weight = 5 lbs

Thrust at S.L. = 4100 lbs
Specific Impulse = 195
Launching Elevation = S.L.

Fig. 3. Variation of dynamic pressure with time using ogival and conical nose cones (Aerobee AJ10-25).

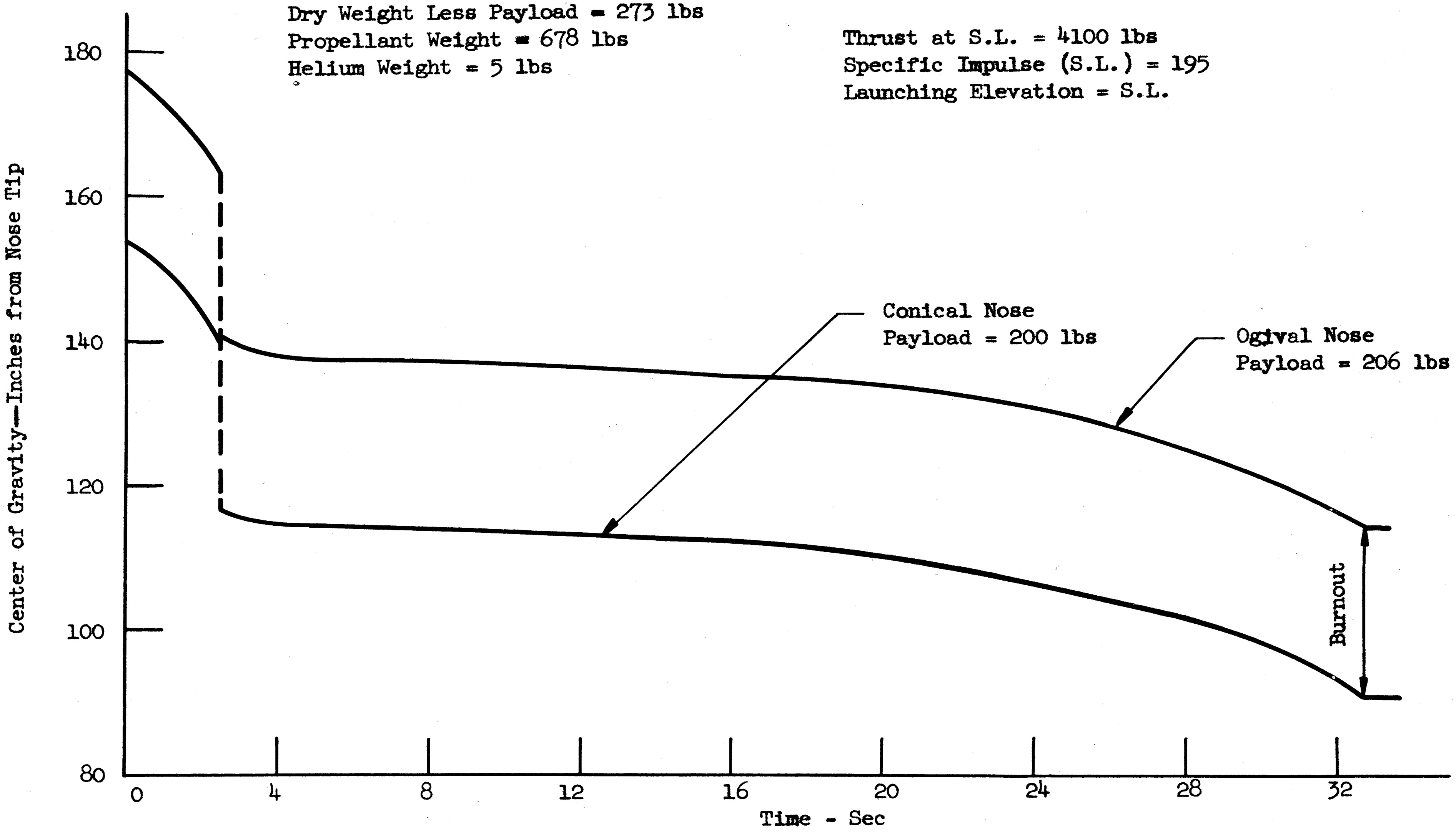
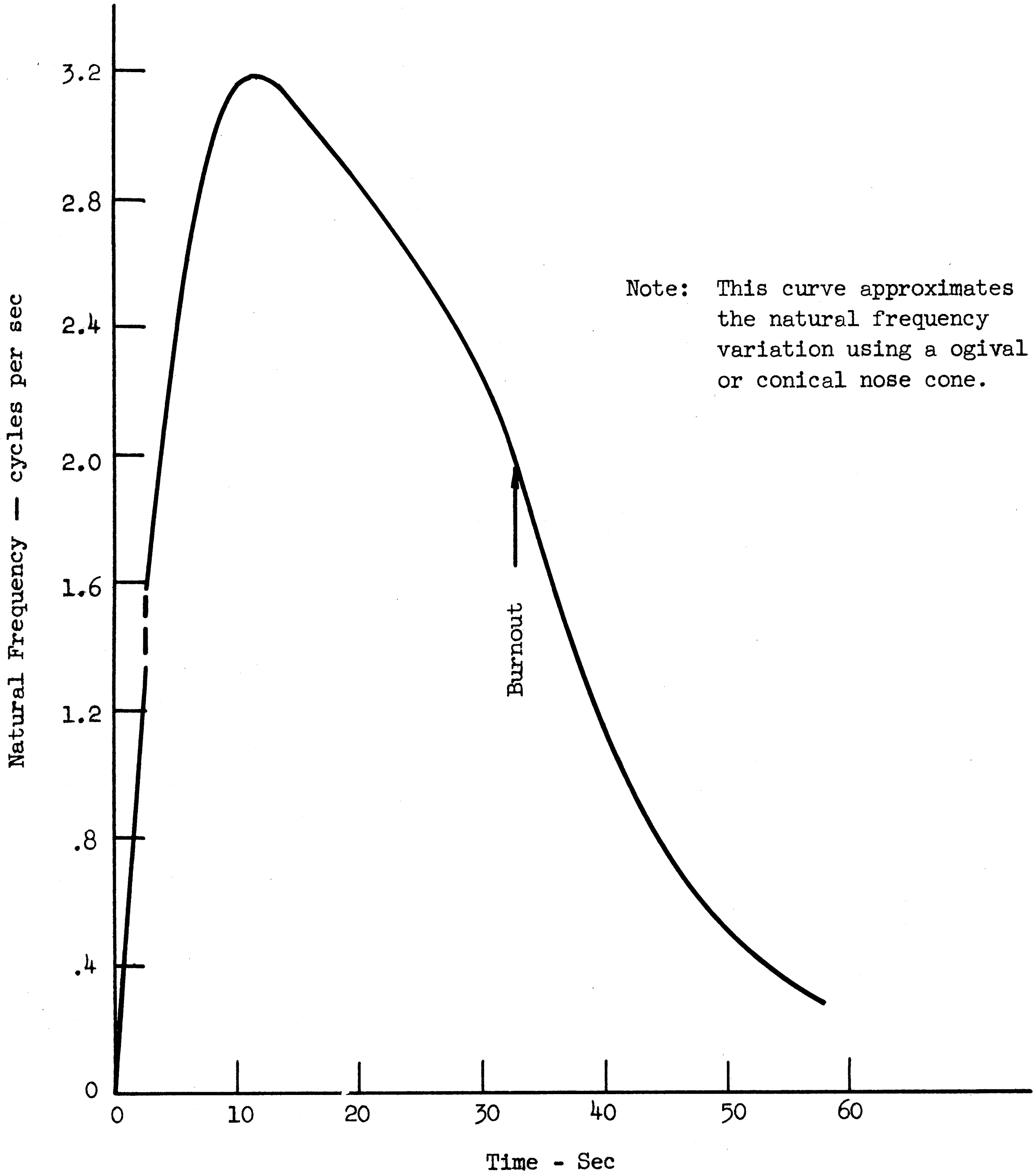


Fig. 4. Variation of center of gravity with time using ogival and conical nose cones (Aerobee AJ10-25).

Dry Weight less Payload = 273 lbs
Propellant Weight = 678 lbs
Helium Weight = 5 lbs

Thrust at S.L. = 4100 lbs
Specific Impulse = 195
Launching Elevation = S.L.



Note: This curve approximates the natural frequency variation using a ogival or conical nose cone.

Fig. 5. Variation of natural frequency with time (Aerobee AJ10-25).