Description of document: **Three Technical Reports released by US Army Dugway Proving Ground, 1953 - 1966**

Requested date: 23-January-2010

Released date: 03-March-2010

Posted date: 09-August-2010

Titles of documents:

Date/date range of document: Evaluation of a Controlled Glide Shape, #32938, Jul-Dec 1959
Status Report No. 53-1 Biological Bomb for Balloon Delivery, #AD31 0695, 15-May-1953
Review of the High Altitude Research Program (HARP) #526112, Jul 1966

Source of document: FOIA Officer
US Army Dugway Proving Ground
Legal Office
5450 Doolittle Avenue MS#2
Dugway, Utah 84022-5002

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY DUGWAY PROVING GROUND
DUGWAY UT 84022-5000

REPLY TO
ATTENTION OF:

March 3, 2010

Office of the Command Judge Advocate

Pursuant to your Freedom of Information (FOIA) request dated January 23, 2010, please find the following documents enclosed.

a. Evaluation of a Controlled Glide Shape, #32938

b. Status Report No. 53-1 – Biological Bomb for Balloon Delivery, #AD310695

c. Review of the High Altitude Research Program (HARP) #526112

The fourth document you requested is titled "Feasibility Study of Unmanned Aerial Vehicle for BW Use." This document, while in our holdings, does not belong to us. This was a test performed by Raytheon Company Missile Systems Division of Bedford, Massachusetts. Their distribution statement clearly prohibits release without the written consent of Raytheon. You may want to contact that company directly since we have no authority to release their document.

Your request was processed in accordance with the provisions of the Freedom of Information Act (FOIA), 5 USC Section 552. While you agreed to pay processing costs, they were less than the minimum charge.

If you have questions regarding our response to your request, please direct them to Ms. Teresa S. Shinton, FOIA Officer, US Army Dugway Proving Ground, Legal Office, 5450 Doolittle Avenue MS#2, Dugway, Utah 84022-5002; telephone (435) 831-3333; email: teresa.shinton@us.army.mil

Sincerely,

Teresa Shinton
for
Kateni T. Leakehe
Major, US Army
Command Judge Advocate

Enclosures

MD DIVISION
TECHNICAL PROGRESS REPORT
(July - December 1959)

Project 4B04-14-030
Task 4B04-14-030-03
Subtask I-3

Evaluation of a Controlled Glide Shape (U)

W. Kenneth Bullivant
W. KENNETH BULLIVANT
Principal Investigator

for H R Cunningham
ROBERT W. BINGHAM
Chief, Concepts Branch
MD Division

D. W. Falconer
D. W. FALCONER
Chief, MD Division

[redacted]

CONTENTS

MD DIVISION - DIRECTORATE OF DEVELOPMENT

TECHNICAL PROGRESS REPORT for July - December 1959

PROJECT 4B04-14-030

PROJECT TITLE BW Munitions Research (U)

Task 4B04-14-030-03

Task Title BW Munitions Concepts (U)

Subtask I-3 Title Evaluation of a Controlled Glide Shape (U)

EXPENDITURE ORDER: 00504

TARGET DATE: 30 June 1960

I. INTRODUCTION

The objective of this task is to conduct a statistically designed air drop experiment with the non-rotating glide shape which will evaluate that shape with an electro-mechanical controller based on the design of Allied Research Associates. The glide shape investigation will be terminated after the air drop experiment and a final report will be written.

Some work on the aerodynamic stabilization of the glide shape will be continued if it does not interfere with progress of the gyro-control investigation. It is planned that some of these plain models be included in the air drop.

II. REPORT OF PROGRESS

A. GYRO-CONTROLLED GLIDE SHAPE

It was decided that 200 gyro-controlled glide shape units would be fabricated for use in the air drop experiment scheduled in the fourth quarter of FY 60. Aluminum sheet stock for use in the fabrication of wings, bodies and tails, which had been ordered and paid for in FY 59, arrived in July. Arrangements were made immediately for the purchase of materials and parts to be used in the fabrication of the gyro-control devices in accordance with drawings and specifications supplied by Allied Research Associates, Inc. Before the purchases were made, however, orders were received by the task group to suspend shop work and spend no money for materials for the glide shape program. On 6 October, permission was granted to purchase the required material and to continue with the program as planned providing the total cost of materials and parts did not exceed $4000. At the time of writing, practically all required materials have been ordered and some units of several parts have been fabricated using raw stock presently on hand. Minor modifications are being made to the detail design of the device in order to simplify the fabrication and assembly without altering the performance capabilities.

It was planned that preliminary drop tests would be conducted utilizing the two gyro-type automatic control units on hand, which had been supplied through the original contract with the Allied Research Associates, Inc. For these preliminary tests, six glide body shells, wings and tails were designed and fabricated to include the physical features of the configuration which had given best glide performance in previous tests.

A small parachute and release mechanism were fitted into the body shells and minimum weights were added to bring the center of gravity to the centerline of symmetry and wing leading edge position on the models. The parachute release mechanism incorporated the use of a mechanical timer (12 second maximum limit) and an electric squib. Figures 1 and 2 are photographs of the model in the flying condition and in the attitude which would be assumed after release of the parachute, respectively. Figure 3 shows some details of the timer and parachute release arrangement.

Three glide models as described in the preceding paragraph with elevators set at 10°, 12° and 14° and timers set at about five seconds, were dropped (Test No. 46) from the balloon stationed at 900 feet above the Fort Detrick Grid. This test which was made to check the performance of the parachute release mechanism under typical operating conditions, was completely successful. In each case the model had started to glide when the parachute was deployed and this occurred within one second of the time which had been set. The parachute opened properly and carried the models to the ground at low rates of descent. None of the models was appreciably damaged by ground contact.

Preparations are being made for a test of four models using a helicopter and dropping from an altitude of 1500-2000 feet. Weights of the models will be increased to a value considered reasonable for a munition and the timers will be set at the maximum interval (around 12 seconds). One of the models will be equipped with a complete gyro control unit which will operate a small tail rudder for the purpose of maintaining a constant azimuth glide path. In order to make full use of the 12-second time interval, the gyro wheel of the control unit will be brought up to full operating speed by use of an air jet, immediately prior to release from the helicopter. Further test plans will be based on the glide performance of the models in this test.

B. STANDARD GLIDE SHAPES

1. Drop Tests

Drop Test No. 45B consisted of six liquid fill (10% void) models with .040 inch thick wings having U-shaped floating tips (see Fig. 4). This test was conducted to verify results of previous tests of two nearly identical models which indicated this configuration was particularly attractive from standpoint of glide performance. The drop test results were disappointing. Only two of the six models gave satisfactory glide performance. The only known difference between the two sets of models was in the wing hardness. The wings of the six models of this test were 6061-T6 aluminum alloy, whereas the wings of the previously tested models were 6061-T4 aluminum alloy. The difference in wing hardness is not considered of any significance so far as glide performance is concerned. It might be concluded from this and the previous test that about 50% of the glide models of this particular configuration would give good glide performance.

In an effort to accentuate the effects of the floating tips which are nearly neutrally balanced aerodynamically and overbalanced dynamically, the wing configuration was revised. A wind tunnel investigation of tips was conducted (discussed later in this report) and an aileron linkage was incorporated in the models used in the next drop test (No. 47).

Drop Test No. 47 consisted of 24 solid-body models, each of which weighed three pounds with the center of gravity located at the 10% chord position. Figure 5 is a photograph of a representative model in the flight condition and Figures 6 and 7 are photographs showing aileron linkage details. The wings are made of separate aluminum alloy sheets spot-welded together -- one .063 inch thick containing a spanwise groove for the 3/64 inch diameter long aileron link, and the other .020 inch thick to increase strength and provide a smooth surface. The aileron system was designed to permit a free angular movement of the tips through a range of 8° (4° above and below the median angle which was varied). The three tip types used in the test are shown in Figure 8. Three median angle settings were used for tips "A" and "B" and six for tip "C" (three for 10° and three for 12° flap setting) making a total of 12 different wing configurations. For each wing configuration the elevator deflection was set at -11.5° and -12.5°.

All of the 24 models of drop test No. 47 were released from a height of 900 feet over the Fort Detrick Grid -- 12 from the balloon and 12 from a helicopter. Only six models pulled out of the initial steep dives and continued to glide in relatively straight shallow paths. One model spun to the ground and the remainder glided in small radius helical paths.

2. Wind Tunnel Tests

An extensive wind tunnel investigation was conducted in an effort to find a wing tip with the characteristic of constant hinge moment, regardless of tip deflection or angle of attack of the wing on which it is attached. Figure 8 is a sketch of the wing and tip arrangement as used in the tests. The hypodermic tubing attached to the tip is of a size to fit freely inside the hypodermic tubing built into the wing. A small diameter music-wire torsion spring was located inside the two tubes and attached at the top end of the tip and below the lower end of the tubing outside the tunnel wall. Angles of attack of the wing and tip were measured by sighting from above through the transparent test section wall.

A large number of tip configurations were tested by this method. Figures 9 and 10 are graphs showing the variation of hinge moment with tip deflection and wing angle of attack for tip types "A", "B" and "C". It will be noted that the moment data in Figure 9 and Figure 10 are not non-dimensional. If there were no Reynolds Number effects, the hinge moments would increase in proportion to the square of the velocity.

C. DISCUSSION

A surface is considered stable if the aerodynamic hinge moment versus deflection curve is negative, i.e., any change in deflection produces a change in the hinge moment in the direction to return the surface toward the undisturbed position. Positive slopes are unstable by the same reasoning. A surface with large overbalancing mass forward of the hinge is dynamically stable because a change in the deflection results in an angular acceleration of the body in the direction to restore the surface toward the undisturbed position. If it were possible to "find" a tip surface with zero slope of the aerodynamic hinge moment versus deflection curve and zero slope of the hinge moment versus wing angle of attack curve then the tip would essentially be isolated from the body to which it was attached and would respond only to the accelerations imposed upon it. If this tip were then heavily overbalanced forward of the hinge and connected through linkage to an identical tip on the other wing, a perfectly stable glide body should result.

Examination of Figures 9 and 10 shows that nearly ideal aerodynamic hinge moment characteristics were achieved through limited deflection ranges by the three tip types "A", "B" and "C". The median tip settings for those models of Test No. 47 which gave reasonably good glide performance are indicated on the appropriate curves in Figures 9 and 10.

Time does not permit a rigorous explanation of the theory and analysis of the test results in this report. It is, however, believed that unless a linked aileron system is far superior to other systems it should not be used because of the increased complication of a wing folding mechanism.

The concept of a large floating fin (balanced in the manner described in this discussion) on the centerline of symmetry, looks particularly attractive at this time. Letting the forward overbalancing mass be in the form of a simple gyro rotor, makes the concept even more attractive. This particular location is desirable also from the standpoint of packaging efficiency.

III. CONCLUSIONS

Preliminary drop tests of three mock-up models of the gyro-controlled glide shape with parachute release mechanism were successfully completed. A drop test of a single gyro-controlled model should be conducted within a few weeks.

Fabrication of 200 gyro-controlled glide shapes is expected to be complete by 1 May 1960.

Glide results for the glide shapes not equipped with gyro automatic control have not been good enough to warrant inclusion in the mass drop of the gyro-controlled items. Further work is needed to improve the flight characteristics of the uncontrolled items.

IV. PLANNED WORK

Preliminary drop tests of recoverable gyro controlled glide shape models will continue in order to iron out configuration difficulties as rapidly as possible. The gyro control device supplied by the contractor will be used in these tests.

Method of release of items from airplane will be determined and necessary fixtures will be designed and fabricated.

Aerodynamic stabilization methods will be further studied and tests using the available glide models will be conducted without interfering with progress of gyro control program.

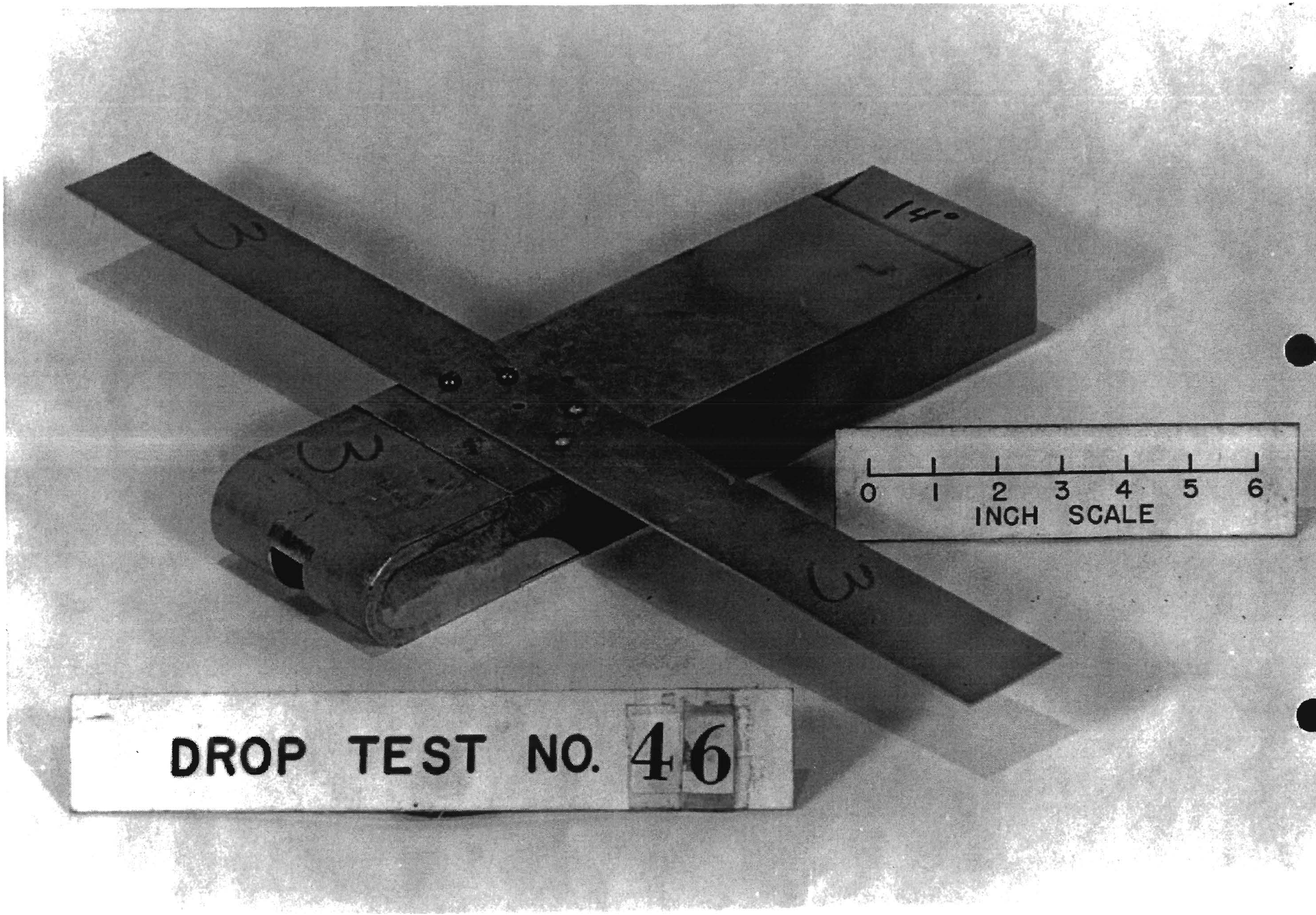


Figure 1 - Gyro-Controlled Glide Model Mockup in Flight Configuration.

C-5070

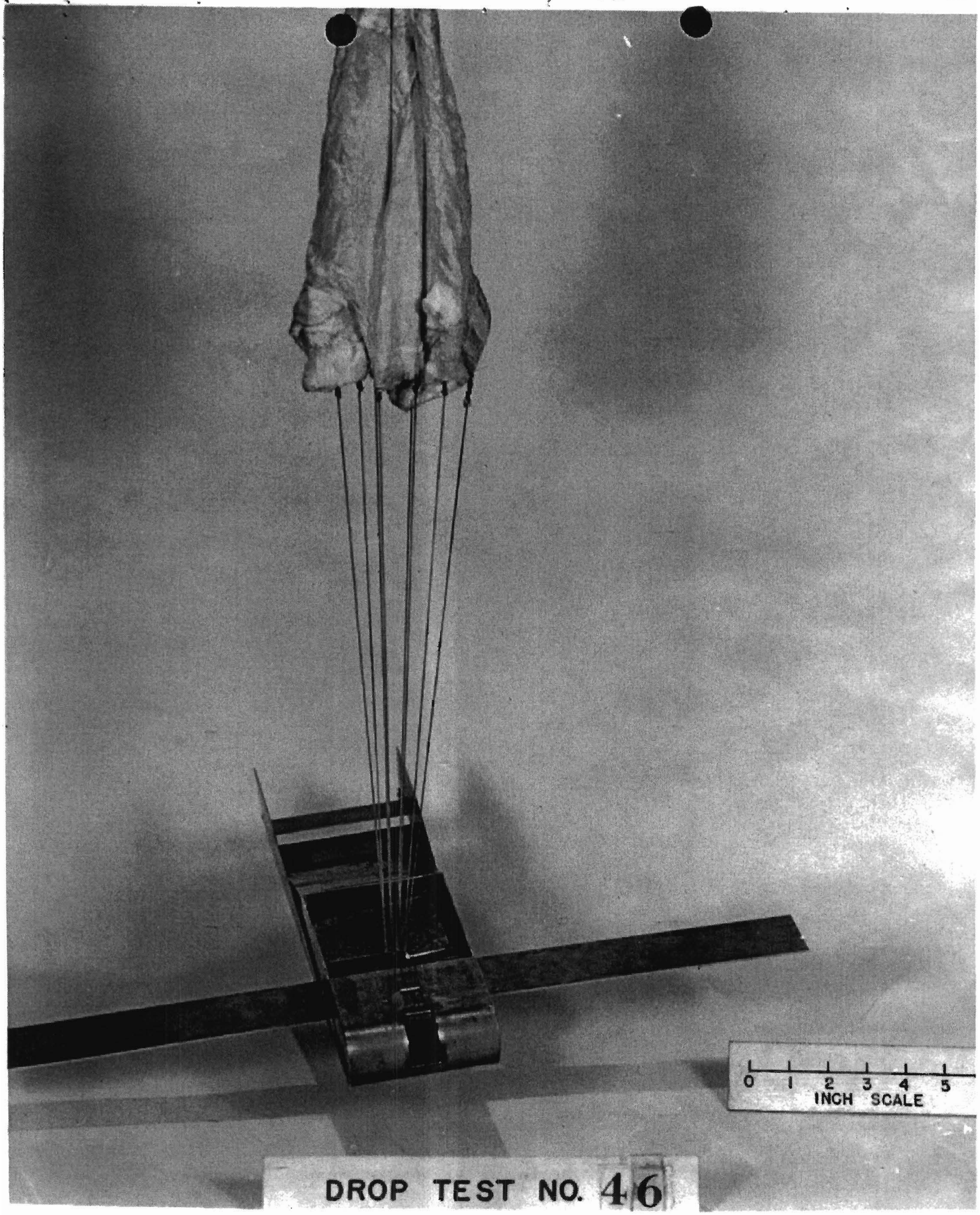


Figure 2 - Glide Model in Approximate Position Assumed after Parachute Release.

C-5078

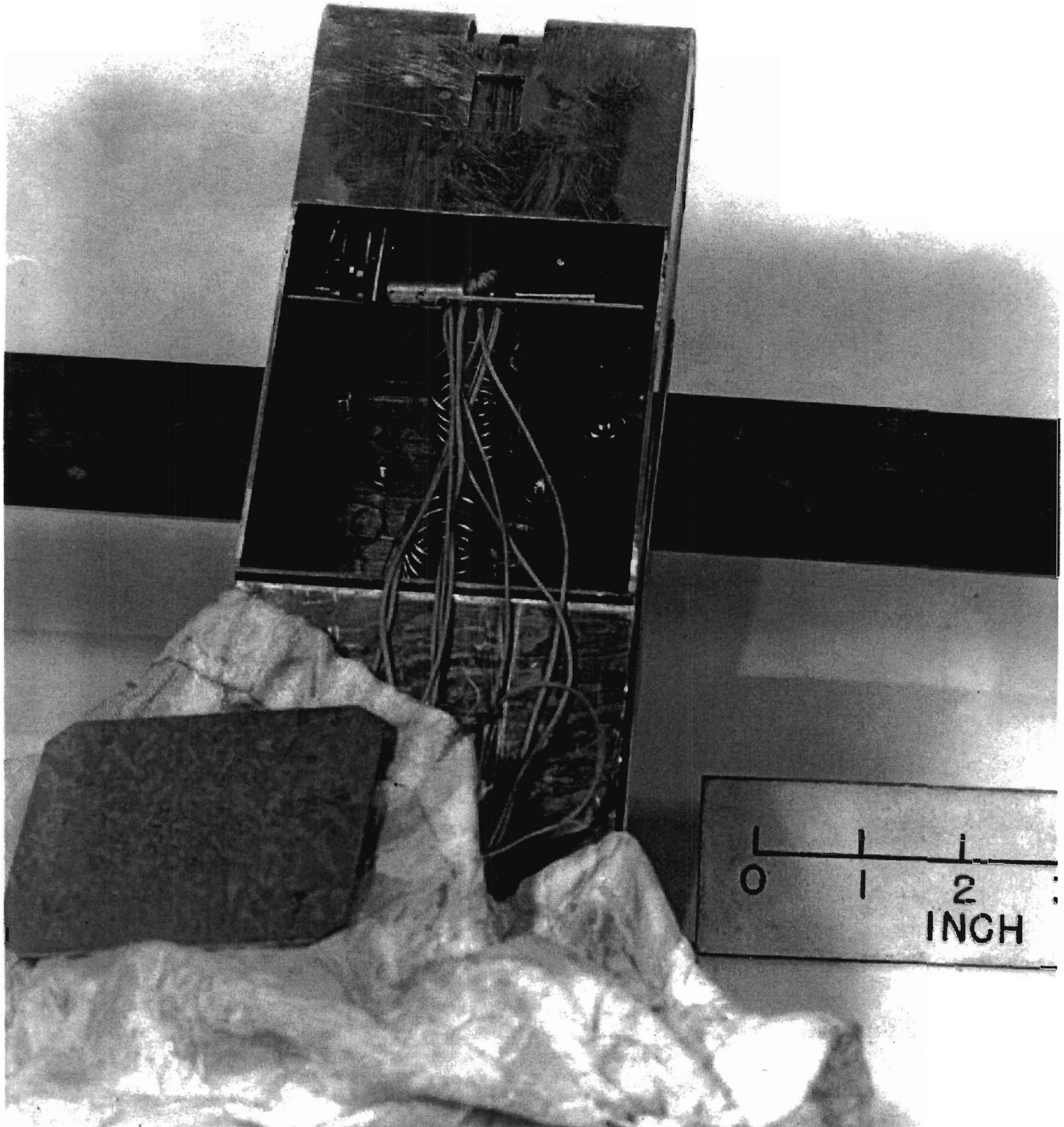


Figure 3 - Detail View of Parachute Release Mechanism

C-5074

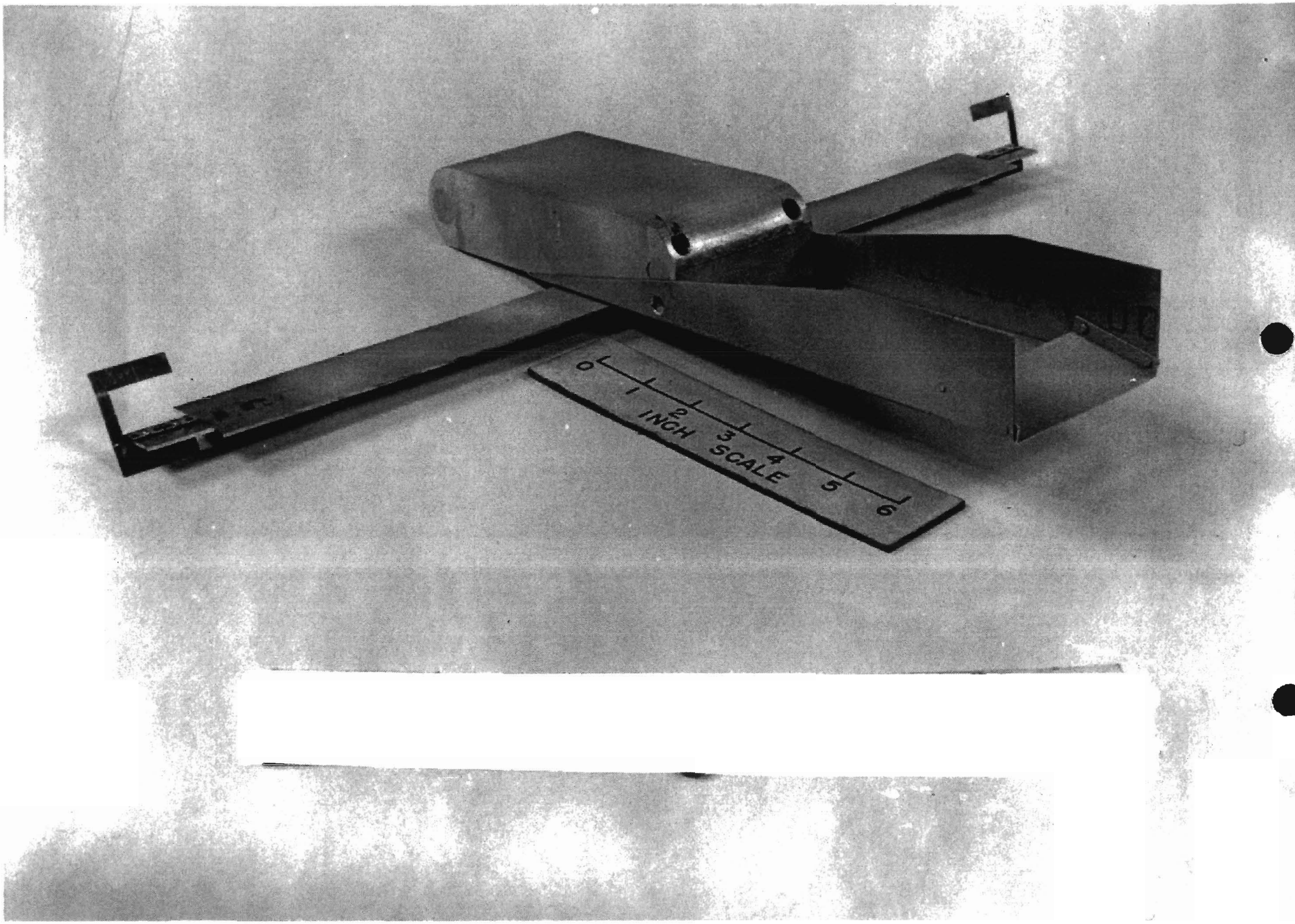


Figure 4 - Glide Model Similar to those Used in Drop Test No. 45B

C 4715

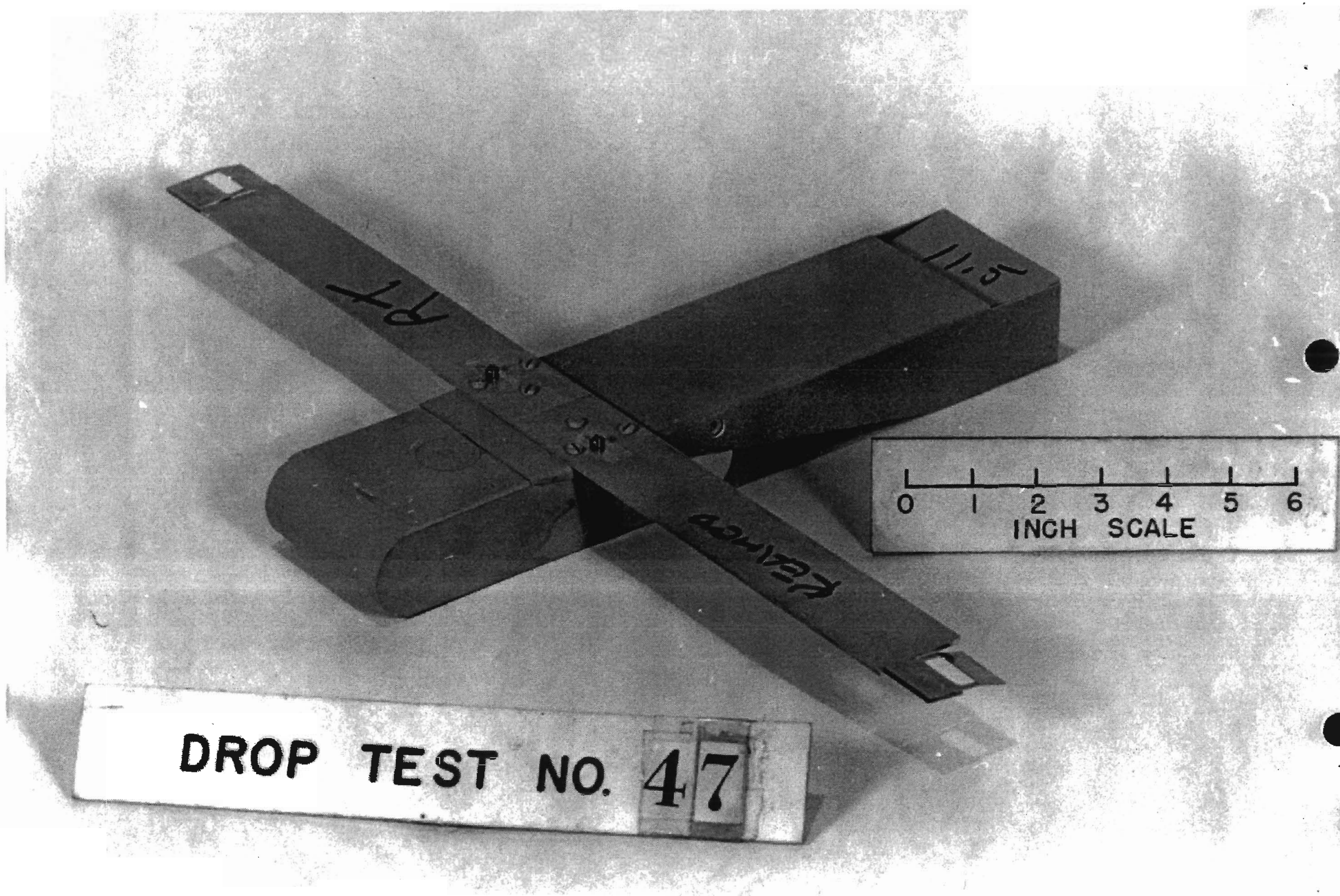


Figure 5 - Glide Model Typical of the 24 Dropped in Test No. 47

C-50%

Figure 6 - Aileron Linkage System

C-5071

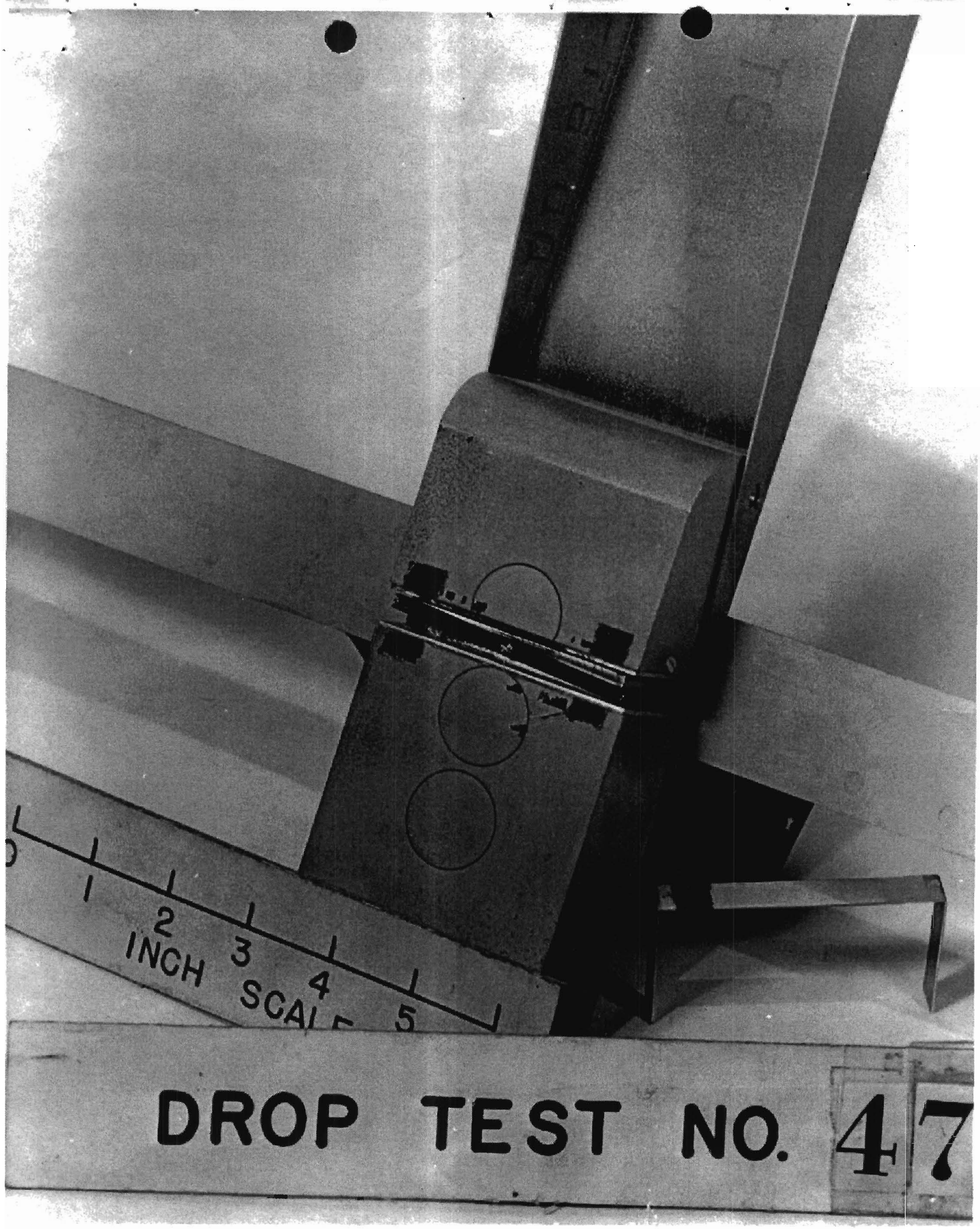


Figure 7 - Detail of Aileron Linkage System.

C-5077

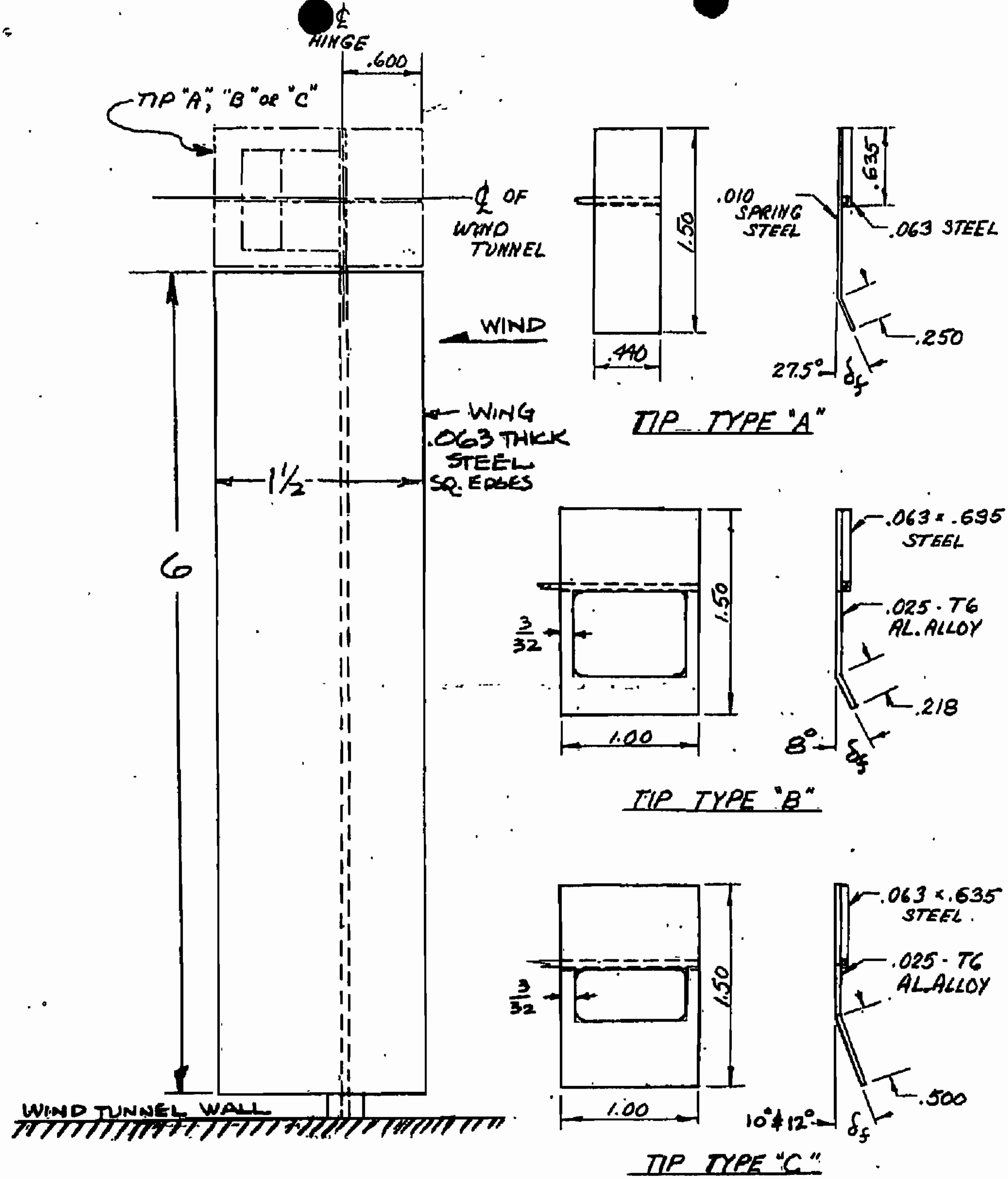


FIG. 8 — SKETCH OF WING AND TIPS AS MOUNTED IN ~~FT.~~ DETRICK WIND TUNNEL FOR MEASUREMENT OF HINGE MOMENTS.

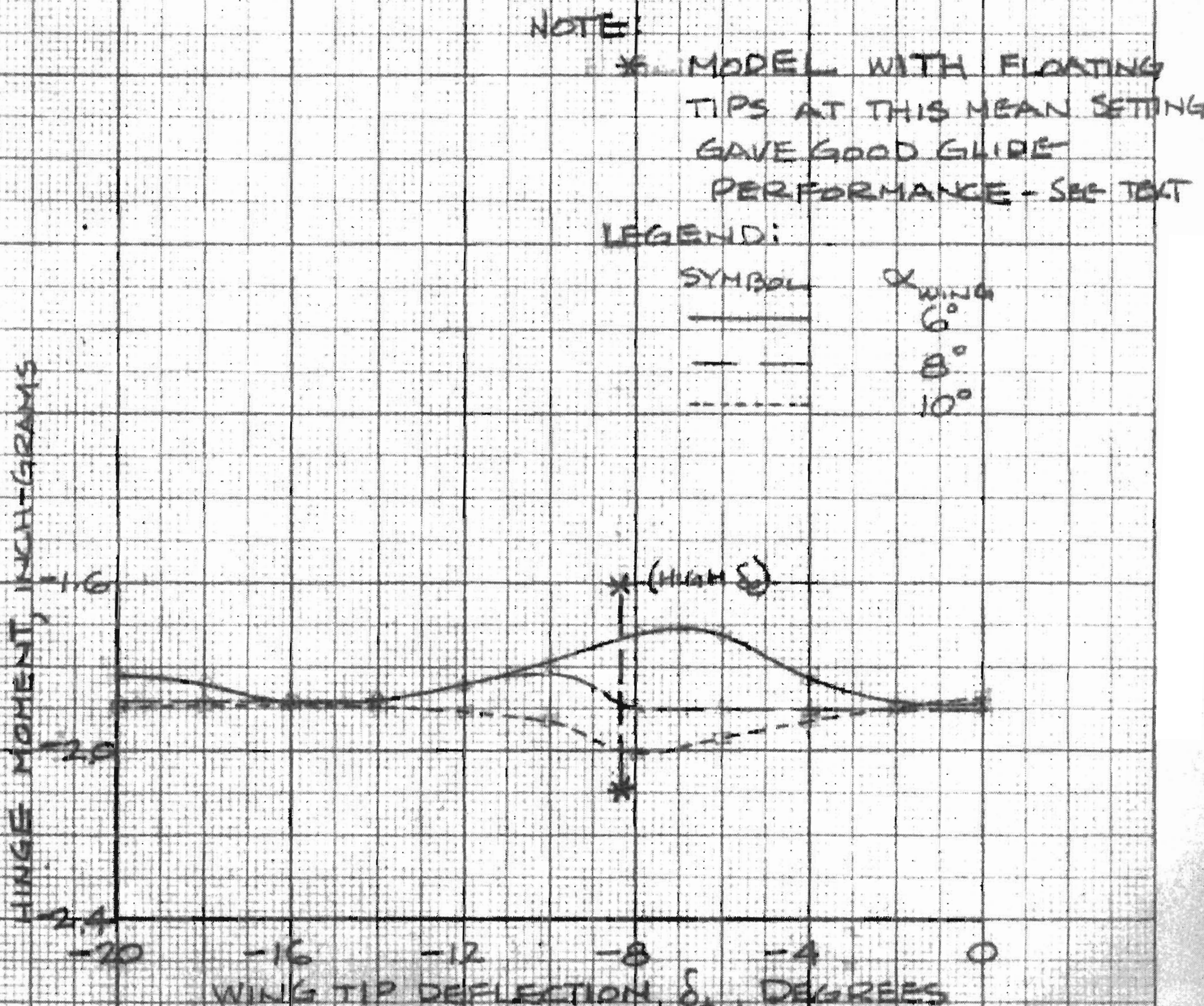


FIG. 9 — AERODYNAMIC HINGE MOMENTS OF WING TIP TYPE "A" (SEE FIG. 8) AT AVERAGE INDICATED AIR SPEED OF 44.1 M.P.H. AS MEASURED IN FT. DETRICK WIND TUNNEL.

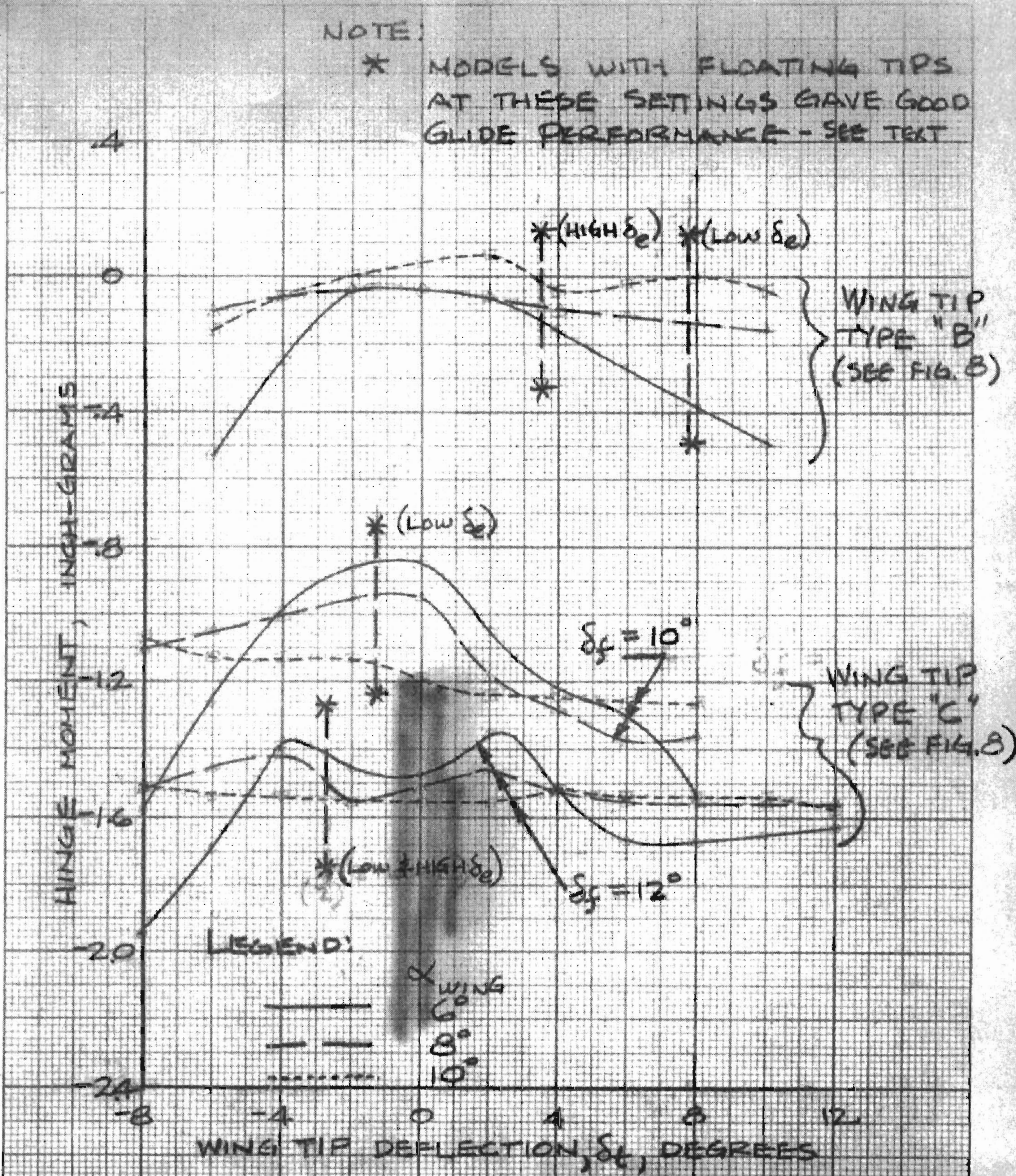


FIG. 10 - AERODYNAMIC HINGE MOMENTS OF WING TIPS TYPES "B" & "C" (SEE FIG. 8) AT AVERAGE INDICATED AIRSPEED OF 45.3 MPH AS MEASURED IN FT. DETRICK WIND TUNNEL.

DISTRIBUTION LIST

No. Copies	Addresses
1	Director of Development Fort Detrick
1	Chief, PP Division Fort Detrick
1	Chief, Process Research Division Fort Detrick
3	Chief, MD Division Fort Detrick
2	Director of BW Engineering Fort Detrick
1	Director of Research Fort Detrick
1	Chief, Entomology Division Fort Detrick
1	Director of Allied Sciences Fort Detrick
1	Chief, Physical Sciences Division Fort Detrick
1	Chief, Technical Evaluation Division Fort Detrick
3	Technical Information Division Documents Section Fort Detrick
1	Scientific Advisor Fort Detrick
1	Program Coordination Office Fort Detrick
1	Director of Medical Research Fort Detrick

Distribution List (Cont'd.)

1 Commanding Officer
U.S. Army Chemical Arsenal
Pine Bluff Arsenal
Arsenal, Arkansas
ATTN: Director for Biological Operations

[redacted]

1 Commanding Officer
U.S. Army Chemical Corps Research and Development Command
U.S. Army Chemical Warfare Labs
Army Chemical Center, Maryland
ATTN: Miss Alice M. Amoss Librarian

1 Commander
Air Research & Development Command
Andrews Air Force Base
Washington 25, D.C.
ATTN: RDTWMB

1 Commander
Air Proving Ground Center
Eglin Air Force Base, Florida
ATTN: PGWBD

1 Commanding General
U.S. Army Chemical Center and Chemical Corps Materiel Command
Army Chemical Center, Maryland

1 Commanding Officer
U.S. Army Chemical Corps Proving Ground
Dugway Proving Ground
Dugway, Utah
ATTN: Technical Library

All copies should be returned to Documents Section, T.I. Division, Fort Detrick, when no longer needed by the addressee.

Any photographs found in this document fall under the following guidance:

Publication of this photograph is not authorized unless approved for release by a Public Information Office at any Army Activity or installation and so noted hereon. Its use in commercial advertisement must by approved by the Public Information Division, Office of the Chief of Information, Department of the Army, The Pentagon, Washington 25, D.C. If published, please credit as "U.S. Army Photograph".

[redacted]

AD310 695

UNCLASSIFIED

CHEMICAL CORPS
BIOLOGICAL LABORATORIES

STATUS REPORT

UNCLASSIFIED

NO. 53-1

"REGRADED ______ BY AUTHORITY OF

GROUP 3
DOWNGRADED AT 12 YEAR INTERVALS
NOT AUTOMATICALLY DECLASSIFIED.
DOD DIR 5200.10

DOWNGRADED AT 12 YEAR INTERVALS
NOT AUTOMATICALLY DECLASSIFIED.
DOD DIR 5200.10

Distribution limited to U.S. Government agencies only; Test and Evaluation, (27 NOV 79). Other requests must be referred to: Commander, US Army Dugway Proving Ground, ATTN: Technical Library, Documents Section, Dugway, Utah 84022-5000.

JOD, DPG

REGRADED UNCLASSIFIED

COPY 15 OF 25 COPIES

15 MAY 1953

UNCLASSIFIED

DPG-11949

BA 2353

[redacted]

UNCLASSIFIED

[redacted]

STATUS REPORT NO. 53-1

BIOLOGICAL BOMB FOR BALLOON DELIVERY

R. E. Stine

15 May 1953

M DIVISION
CHEMICAL CORPS BIOLOGICAL LABORATORIES
Camp Detrick, Frederick, Maryland

Copy ___ of ___ Copies

[redacted]

[redacted]

REGRADED UNCLASSIFIED JOD, DPG

[redacted]

UNCLASSIFIED

STATUS REPORT NO. 53-1

BIOLOGICAL BOMB FOR BALLOON DELIVERY

15 May 1953

APPROVAL RECOMMENDED BY:

G. A. DESHAZER
Chief, M Division

WENDELL H. KAYSER
Assistant Director for
Weapons Development

APPROVED:

JOHN L. SCHWAB
Director

REGRADED UNCLASSIFIED JOD, DPG

CHEMICAL CORPS BIOLOGICAL LABORATORIES
Camp Detrick, Frederick, Maryland

[redacted]

[redacted]

UNCLASSIFIED

CONTENTS

FIGURES

REGRADED UNCLASSIFIED JOD, DPG

[redacted]

SUMMARY

The E77, an 80-pound biological bomb, is intended primarily for the dissemination of dry anticrop pathogens, and will be delivered by a free-flight balloon. It consists of an insulated fiberboard "hatbox", 32 inches in diameter and 24 inches high, opening in clamshell fashion about the vertical centerline to distribute the agent packages. Five agent containers holding approximately 16½ pounds of carrier plus 1 3/4 pounds of agent are grouped around a chemical-type heater designed to maintain the proper agent environment. A neutralization system is included to render the agent innocuous in case of malfunctioning of the balloon delivery system. A combination barometric and mechanical timer fuze provides the control for the neutralizing system, flight termination, munition drop and agent dissemination.

Five preliminary engineering models have been made and were tested at Dugway Proving Ground during February of 1953. Four items were dropped from an airplane at high altitudes, so that the munition might function at a predetermined altitude in order to facilitate obtaining functioning data. Supporting aircraft observed and photographed the functioning of the munition; recording theodolites obtained data from which terminal velocities were calculated. One balloon flight was made during which the munition was released by radio control in lieu of the timer's functioning. This flight was entirely satisfactory and proved the feasibility of the munition. Although no agent was used in these tests, the agent containers, filled with carrier only, were tested separately, being dropped from an aircraft at low altitudes; the functioning was photographed. These tests were also very satisfactory.

This munition is now in the final engineering stages and final engineering tests will be run in July and September of 1953 on thirty items. Agent-dissemination patterns will be included in these tests. No major difficulties are anticipated, but minor modification will no doubt be needed, particularly for production purposes. After these tests, plans and specifications will be rushed into preparation for procurement of the final item.

The report includes, in addition to a complete description of the E77 munition, the historical background, an account of the development program, and a resumé of future planning.

[redacted]

BIOLOGICAL BOMB FOR BALLOON DELIVERY

I. INTRODUCTION

A. DESCRIPTION OF MUNITION

1. The basic configuration of the E77 biological bomb for balloon delivery is that of a right cylinder, 32 inches in diameter and 24 inches high. This cylinder, generally termed the gondola, is made of wood-reinforced pressed fiberboard and lined with a 2-inch layer of styrofoam insulation. The internal arrangement consists of five agent containers, 10 inches in diameter and 17 inches high, grouped concentrically around a chemical-type heater. The agent containers have a total capacity of approximately 3½ cubic feet, which holds 18 pounds of agent-carrier fill, including 1 3/4 pounds of agent. The control instrumentation, or fuze, is mounted as a subassembly on the under side of the gondola top. The E77, when fully assembled for operation, will weigh approximately 80 pounds, with a maximum permissible weight of 95 pounds.

2. The control instrumentation, or fuze, for this bomb provides agent protection, agent neutralization, and bomb functioning. The bomb is delivered by a free-flight balloon, traveling through the troposphere at an average altitude of 40,000 feet, mean sea level, and in an average ambient temperature of minus 67°F. The inside temperature of the gondola is kept within the limits of plus 35° to 65°F by means of a thermostatically controlled, chemical-type heater in order to protect the temperature-sensitive agent. The heater under development is of the exothermic-reaction chemical type, utilizing the reaction of water upon a mixture of sodium monoxide and granular aluminum.

A neutralizer system to render the agent innocuous in case of mishaps during handling or malfunctioning over friendly territory has been included within the gondola. This neutralizer system will render the agent fill inactive within several minutes under the following conditions:

a. If the balloon does not reach 20,000 feet, MSL, within 1½ hours.

b. If the balloon descends 600 feet (20 millibars) at any time during the ascent to 20,000 feet.

c. If the balloon descends to 20,000 feet at any time during a preselected period up to 48 hours after reaching an altitude above 22,000 feet, MSL.

[redacted]

[redacted]

This programming is accomplished by a time switch, a differential-descent switch and a master pressure switch, all wired in series. Under any of the above conditions, a detonating squib in each agent container will be fired, which in turn will release a source of sulphur dioxide. The sulphur dioxide will permeate the carrier and render the agent harmless.

When the bomb arrives over the intended target, as determined by a preselected interval on the master time switch, the bomb is detached from the balloon carrier, a dragchute is released, and the bomb falls to a preselected altitude of from 1,000 feet to 5,000 feet above the terrain. At the desired altitude, the gondola opens in a clamshell fashion to eject the five agent containers and the heater. The opening of the gondola is controlled by the master barometric switch that likewise controls a portion of the neutralizer circuit. As the agent container leaves the gondola, an arming lever is released that permits a spring-actuated, hollow plunger to puncture a small carbon dioxide bottle. The released gas pressure moves a sliding disc which in turn forces the agent-carrier fill from the container in the form of an extended column.

In order to minimize the possibility of detection by radar, the bomb is constructed of non-metallic materials wherever possible. The gondola and agent containers are made of wood-reinforced pressed fiberboard; the control instrumentation and the chemical heater must of necessity be made mostly of metal.

B. BACKGROUND

There is no known predecessor to the E77 bomb as a method of disseminating biological warfare agents. Although objects have been carried by both manned and unmanned free balloons, it was not until World War II that any nation deliberately planned and executed a large-scale balloon delivery system for the express purpose of delivering munitions upon an enemy. During the latter part of World War II, the Japanese launched a well-planned and implemented mass balloon attack upon the North American continent[1]. The balloons, in this instance, carried incendiary or fragmentation bombs. During a six-month period, the Japanese launched 9,000 balloons which crossed the Pacific Ocean at altitudes of 30,000 to 35,000 feet, MSL. Although only 283 units were located, it has been estimated that at least 1,000 balloons reached this continent, the distribution ranging from southern Canada to central Texas and as far east as Iowa.

Since the end of World War II, General Mills, Inc. of Minneapolis, Minnesota, with the support of Defense Department agencies, has carried on a program to develop a feasible balloon-delivery and flight-pattern forecasting system. Sufficient success has been achieved with this pro-

1. The Balloon Bomb: TEIJI TAKADA: SKIZEN, Vol 6, 1951

[redacted]

gram to indicate that a balloon-delivery system is feasible for delivering a payload to a designated area. This forms a justification for the development of the E77.

About the end of December 1952, the task of evaluating General Mills' work and developing an operational balloon-delivery system for the E77 and other munitions was established by the Air Force at its Cambridge Research Center, Cambridge, Massachusetts, under Air Research and Development Command. The system is nearing completion and is proposed for operation by September 1953.

C. INTENDED USE OF MUNITION

This munition is expressly designed for dissemination of pathogenic anticrop agents (TX_1) over large target areas of cereal crops. It will be delivered to the target area by an unmanned balloon and will provide its own protection for the agent fill.

There are many agent candidates that may be carried in this balloon. By adding a suitable antianimal fill such as a pellet, the bomb could be transformed into an antianimal munition.

D. PROGRESS PRIOR TO FISCAL YEAR 1953

In designing and developing this munition, maximum use has been made of stock commercial items in the instrumentation and controls. Fortunately, these commercial items make up a large portion of the components, so that in many instances it was necessary only to assemble these commercial items and check for proper functioning. For other components, such as the heater, it was necessary to develop an item. The heater is still under development.

In general, there have been no problems of great magnitude involved in the development of the munition except for the heater, so the progress has been orderly. It was found during preliminary engineering tests that the bellows-type pressure switch, three-cam timer, holding-relays switches, squibs, cable-cutting cannon and the remainder of the instrumentation performed satisfactorily and as expected. After abandoning several other schemes, the present agent container was developed to utilize air pressure to eject its fill from a fiberboard container. It, too, was a straightforward process after the present satisfactory scheme was decided upon. Although the chemical-reaction type heater has been under development for almost a year and has appeared promising, its performance has never been entirely satisfactory under repeated tests. The problem is that of thermostatically controlling the heat output; specifically, controlling the chemical reaction rate by water metering. Occasionally, the reaction goes out of control, with excessive heat liberation. Because this type of heater may not be satisfactory, several alternate schemes are being investigated. All components of the munition other than the heater are developed and ready to ente[redacted] tests.

[redacted]

II. PROGRESS DURING FISCAL YEAR 1953

Upon establishment of a requirement for this munition by CCTC Item 2297 of 5 April 1951 and CCTC Item 2483, approved by Item 2495 of 23 June 1952 (amended by Item 2575 of 22 October 1952), General Mills, Inc. of Minneapolis, Minnesota, under contract DA-18-064-CML-2104, embarked upon a development program in May 1952. Their project engineer, Marvin A. Sandgren, by September 1952 had completed a preliminary study and had a feasible working design on all components except the heater and agent package. Components of the present design and major problems encountered during development are described in the following paragraphs.

A. INSTRUMENTATION

The timer drive motor is from a Lux Clock Manufacturing Company, Model 1060, 7-day-wind, chart-drive type. The chart disc as shown in Figure 2 is replaced with a three-cam drum and the whisker switches are replaced by micro-switches with roller arms. Certain items in the Lux Clock which was the first proposal were replaced as described for the sake of durability. See Figure 16.

In operation, this time switch actuates three switches. Safety switch No. 1 (see Figure 1) is wired in series with the shelf contact of the pressure switch, Figure 2, and closes 1½ hours after launching. If the munition has not reached 20,000 feet in altitude, the contact arm will still be on the shelf when this time elapses and the neutralizing circuit will be energized when switch No. 1 closes. If the altitude exceeds 22,000 feet, the arm will be off the shelf and nothing will happen when switch No. 1 closes.

Safety switch No. 2 is a double-throw switch wired in series with the contacts of a small relay in the pressure switch. The normally closed contact is wired to the neutralizing circuit which will function if the munition descends to 20,000 feet and the normally open contact is wired to the contacts of the load-opening relay. The munition becomes "armed" when switch No. 2 is actuated, in that the neutralizing circuit is open and the load-opening circuit is "cocked". The time for safety switch No. 2 can be set for 1½ to 48 hours.

The third switch is wired in series with the load-dropping squib which is used to release the munition from the balloon. The elapsed time before this flight-termination switch closes can be set for 3 to 60 hours.

The switch actuators or cams can be moved in relation to each other by loosening a knurled nut on the hub. With the cams set at the fully-wound position it is possible to insert a stop pin which prevents the clock from running. This pin is removed to start the timer just before the munition is launched.

[redacted]

A time-delay switch is shown in Figure 1 connecting the neutralizing squib and the load-opening squib. (Various operations are accomplished by squib-actuated cannon, such as cable cutting, diaphragm puncturing, etc.) This switch is needed to drop the munition from the balloon in the event of malfunctioning resulting in neutralization. Without this feature the neutralized munition might continue in flight for an undesirably long period of time.

When the neutralizing circuit is energized by closure of safety switches No. 1 and No. 2 or the differential descent switch on the 20,000-foot contact on the altitude switch, the neutralizing squib will fire immediately. At the same instant, the hold relay in the altitude switch is energized and the motor in the time-delay switch starts running. After approximately three minutes' delay, the switch contacts will close and the load-dropping squib will fire to release the munition from the balloon. The delay period (5 minutes) gives the neutralizing system time to function.

For a pressure switch, a Johnson Service Company M.D. 104-type Radio Sonde Modulator with a special commutator and other modifications is used. The switch employs a bellows to move a contact arm across the commutator (Figure 2). This commutator will have contact surfaces spaced to provide circuit closures at 20,000 feet for neutralizing and at 1000, 2000, 3000, 4000, 5000 and 10,000 feet MSL for the opening circuit for release of the agent packages.

An auxiliary switch is provided on this modification by insulating the wire shelf on which the contact arm rests during ascent. When the munition reaches an altitude of approximately 22,000 feet, the contact arm drops off the shelf and opens this contact. By wiring this contact in series with the differential descent switch and the timer safety switch No. 1, these switches are removed from the circuit when the balloon has attained an altitude of 22,000 feet.

A centralab selector switch No. 1400 is employed in the circuit to permit easy selection of the desired opening altitudes. This switch has a plastic separator which moves between the pairs of contacts. The selector switch is wired to the altitude switch in such a way that all contacts on the commutator for altitudes below that selected are also shorted into the circuit. With this arrangement, if the munition fails to open at the altitude selected because of a poor contact there is still a possibility of opening at the next lower altitude.

The differential descent switch (Figure 3) is a specially built switch which makes contact after an increase in barometric pressure of approximately 20 millibars (600-foot drop in altitude at a 5,000-foot level). It consists of a plastic outer tube with a pool of mercury at the bottom. A central, smaller-bore plastic tube communicating with the air reservoir above dips into the pool of mercury. The plastic outer tube has an air breather hole located near the junction of the inner and outer plastic tubes. The electrical contact is made by one wire which runs down within

[redacted]

[redacted]

the annular space between the central plastic tube and the outer tube to the pool of mercury and another wire which runs within the central tube to the mercury pool but not touching it. In use, air at ambient pressure is trapped in the air flask by closing the stop cock. As the munition ascends, air bubbles out through the mercury pool. However, if the munition descends, the increasing air pressure pushes mercury up the central plastic tube and electrical contact is made.

Figure 1 shows this descent switch wired in parallel with the timer switch No. 1 and in series with the pressure switch "shelf" contact. When the contact arm drops off the shelf, the descent switch as well as safety switch No. 1 is removed from the circuit.

A single six-volt dry battery similar to the Burgess F4BP is sufficient to operate all of the munition controls. A second battery to provide a safety factor will not be used because of weight limitations.

A safety jack which breaks the circuit to the battery is shown in Figure 1. When the plug is pulled, the circuit to the battery is closed. A test lamp is also provided which lights when plugged in if any switch in the circuit is closed when it should be open. This test plug is inserted in place of the safety jack to check the circuit before wiring in the squibs. This safety jack is not a necessary part of the circuit and could be omitted, but the squib terminals should be checked with a meter or some indicator before wiring in the squibs for the sake of safety for operating personnel.

B. GONDOLA

A right cylinder was chosen for the gondola for several reasons. A cylinder presents a minimum of surface area for a given volume. This is desirable when considering heat losses. Also, a cylinder lends itself well to internal heat distribution by convection. With a heater placed on the vertical axis of the cylinder, the heated air will rise in the center, flow out uniformly across the top, cool, drop to the bottom and return to the heater.

The optimum condition, in regard to heat loss, would be a cylinder with equal diameter and height. However, the munition must fall stabilized and with a low terminal velocity (approximately 100 ft/sec). A munition with a diameter slightly larger than the height will present a large frontal area for reduced terminal velocity and greater stabilization without sacrificing greatly the minimum surface area. An outside diameter of 32 inches and a height of 24 inches was chosen. These dimensions will accommodate the five agent packages, heater and instrumentation.

The case is divided vertically on a plane passing through the axis. The two sections are fastened together so that they will open at the bottom, clamshell fashion, to drop the contents. As the two halves continue to open they eventually separate completely. Photographs of a ¼-scale model are shown in Figures 4, 5 and 6, and of the full-sized

[redacted]

[redacted]

model in Figure 7.

Before positioning any of the components, the two halves are assembled by means of a steel tie band passing around the circumference. The band is made in two sections joined by lengths of cable. A squib-actuated severing device is placed over each cable section. In operation, the two squibs are wired in parallel and if either or both of the squibs fire, the cable will be cut to release the band and the munition will open.

The top of one half-section is made in the form of a lid which can be removed to load the case. The lid is held in place with suitcase latches. The heater is located in the center of the case with five agent packages placed around it. The control instruments, i.e., timer, pressure switch, batteries, etc. are mounted on a tray which fits above the heater and packages. With this arrangement, the controls are readily accessible by removing the half-lid and necessary adjustments and settings can easily be made.

The munition is suspended from the balloon vehicle by cables secured to the support straps passing under each half-section of the case. At the upper ends, these cables are looped over thimbles and the four ends are tied together with a separate small loop passing through the yoke on the snap hooks in such a way that two cables are on each side of the yoke. Two of the squib-actuated cable cutters, as shown in Figures 8 and 10, are placed on this same loop so that when the squibs fire the loop will be cut to free the supporting cables.

The case is fabricated from pressed fiberboard approximately 0.080 inches thick and reinforced with wood. The inner walls of the case have a 2-inch lining of styrofoam insulation either cut and cemented in place or foamed in place. Foam-rubber gaskets are used for all separating surfaces between the halves.

C. DRAGCHUTE

After testing many drag devices and evaluating them, a four-cornered dragchute was chosen. (General Mills, Inc. Report No. 1129, pp. 30-38.) This chute has four shroud lines, one at each corner. Two lines go to one half-section of the case and are tied to the ends of the support straps which pass under the case and are hinged to the bottom at the edges of the cleavage. The other two lines pass through holes in the upper ends of a similar strap on the other case section and then go down to a special clip on the side near the bottom of the case. The chute drag pulls on the case sections so that they will separate at the bottom when the tie band is opened. When the case opens far enough, the two sections will separate and eventually the sections will turn over to a position where the two shroud lines will pull out of the clip on the one half-section. Two

[redacted]

corners are then free and the chute will flag out behind the section to which the other two lines are still secured. With this arrangement, the chute cannot pick up the released agent. This is illustrated by a model in Figures 4, 5 and 6 in which formed wires simulate the support straps. It may be noted that two types of wires are shown in the figures. In Figure 6 the wire passes under the case and is the satisfactory arrangement. In Figures 4 and 5 the wires are attached to the top of the case.

D. HEATER

The interior of the munition must be kept between the temperatures of + 35 and 65°F while at an average altitude of 40,000 feet and an ambient outside temperature of -67°F. It is known that the temperature cannot be kept above + 35°F during hours of darkness unless the munition is heated. Temperature data available from balloon flight records indicate that solar heating will probably not force the temperature above + 65°F during the day. (General Mills, Inc. Report No. 1154 pp. 1-9). It is expected that extensive balloon flights, scheduled for the near future, will give conclusive and detailed information on heat transfer. One 6½-hour flight has been flown at 33,000 feet using an olive drab gondola and a white gondola. Each contained five packages filled with shredded paper, several telemetering thermistors, and recording thermographs placed throughout the gondola interior. With an outside ambient temperature of approximately -45°F, the olive drab gondola leveled off at + 65°F, and the white gondola dropped to approximately + 23°F while in flight. A black-bottomed, white gondola flown at 39,000 feet in daylight had an internal equilibrium temperature of approximately -5°F. (General Mills, Inc. Report No. 1188, Dwg. A-21079-B, Appendix A.)

After eliminating various types of heaters and several exothermic chemical reactions, an arrangement has been devised by T. R. James and A. A. Reid of General Mills whereby water is added to a mixture of granular aluminum and sodium monoxide to produce a reaction liberating approximately 2540 BTU of heat per pound of fuel. The liberation of heat is regulated by controlling the flow of water to the dry chemicals.

The water probably combines with the aluminum and sodium monoxide as follows:

$$Na_2O + H_2O \longrightarrow 2\ NaOH$$

$$2\ NaOH + 2\ Al + 2\ H_2O \longrightarrow 2\ Na\ Al\ O_2 + 3\ H_2$$

The net heat liberated is 239 kg calories for a net weight of 169.99 grams, or 2540 BTU/lb. (General Mills, Inc. report No. 1129 pp. 40-41.)

A theoretical study of the heat requirements of the gondola was made by M. Sandgren of General Mills, based on an ambient temperature of -50°F and approximately 50 hours required heating time. This study showed a heat loss of approximately 300 BTU/hr and a required fuel capacity of 6 pounds. (General Mills, Inc. report No. 1129 pp. 41-45.)

The flying altitude, and hence the ambient temperature and the length of heating time, has since been changed. This will revise the heat requirements, which are now being investigated by actual flight.

Several models of the proposed heater have been built and tested. In one of the earlier models, Figure 9, the mixture of aluminum and sodium monoxide is placed in the lower container and water in the upper container. Water flows to the dry chemicals through two valves located in the plastic block connecting the two containers. One valve is actuated by a bellows filled with methyl chloride. A capillary tube connected to the bellows is also filled with methyl chloride. This capillary tube is located in the munition away from the heater so that the valve will open and close in response to temperature conditions in the munition. The second valve is actuated by a bimetal element located above the chemicals in the lower container. This valve closes to stop the flow of water when the temperature in the lower chamber approaches 200°F.

Some of the water dropping on the chemicals is unavoidably driven off as steam which passes into the condensing coil placed around the upper container. The condensate runs back into the lower chamber. The hydrogen generated by the reaction also leaves by this coil, which is connected to a pressure-relief valve at the top. The pressure valve is used to minimize loss of water during the reaction. The water would boil at a lower temperature without the valve because of the lower pressure at higher altitudes. The hydrogen passes from the valve, through a drying tube to remove moisture, and then out through a vent in the top of the case.

This model was tested in cold chambers approximately 27 times and for various lengths of time up to 23 hours. With 20-mesh aluminum screen, there were temperature surges increasing in magnitude as the test progressed, probably because of poor water distribution and solidifying of the precipitate, which blocked off water contact with fresh chemicals. When powdered aluminum was used, addition of the first drops of water set off a reaction which continued without requiring more water and liberated considerable heat, heating the gondola at times to 176°F. After this initial "fling" the heater settled down and worked as expected. (General Mills, Inc. report No. 1154, pp. 11-13.) Large temperature gradients (20°C) appear within the heated area in many of the tests. Generally, the heater was not reliable, although it was possible to maintain a simulated gondola above freezing for a 67-hour period while the outside air temperature varied between + 36° and -18°F.

There is poor duplication of heat-output rate and duration between runs set up in identical fashion. This may be attributed to many factors. One is that the present solenoid valve setting is difficult, as the stem position is controlled by the degree of compression of two different silicone gaskets. This could induce the troubles experienced with water feed, as the gaskets expand with temperature rise. The water-metering valve should be set to operate consistently in spite of temperature fluctuation or pot disassembly. Also, vaporized water is permitted to collect above the reactor, to flow back later uncontrolled. The evaporated water should be continuously returned to the pot. Third, the heater pot is made of stainless steel with associated poor heat conductivity. This undoubtedly adds to the temperature gradient problem within the gondola. A finned copper reaction pot in the heater would lower the surface temperature and possibly the temperature gradient within the gondola. Fourth, the heater is equipped with insensitive thermostats to regulate the flow of water. As a result, the lag in heating the thermostat causes the pot to accept too much water and to overheat. The exposed bimetal is susceptible to undesirable influence due to cooling in the air convected past.

To solve these difficulties and problems, the following steps were taken. The solenoid-actuated water valve was redesigned as an integral unit to maintain positive adjustment; a more efficient condensing coil was added to the water chamber; the pot was refabricated from copper and finned; and an immersion-type thermostat (Fenwal #12410) was inserted in the bottom of the reaction pot under the chemicals. In addition, a heater control was built which will add water to the chemicals at four different rates, depending upon the heat demands of the gondola. The thermostat set for the highest temperature admits water at the slowest rate. If this rate is insufficient for temperature requirements, a second thermostat operates to increase the rate of flow and similarly for the third and fourth thermostats. In this way the maximum rate of heat output is increased with an increased rate of heat loss.

E. AGENT CONTAINERS

It was decided to use five agent containers to hold the agent fill for each munition, rather than one large package. This will facilitate handling, filling and storing. The first proposed package, shown in Figure 11, was considered too fragile for this use. This package had rigid grooved plastic plates at the top and bottom. The package wall was kraft paper coated on the inside with polyethylene, folded over to contain draw strings at the top and bottom, and using a rip panel to join the ends of the paper into a tube. As in all subsequent designs, this package contained a felt filter that would permit pressure equalization but would not permit the agent to pass. When the package was filled, the draw strings on each end were secured with small pins with pull-strings tied to them. These pull-strings were joined with the free end of the wrap-around band and the line which tears the rip panel. An opening cord was tied to these lines at this point.

When the opening cord was pulled, the two pins were pulled free of the draw strings and the two end plates were released. When the wrap-around band was completely unwrapped, the rip panel was torn by its rip cord and the contents spilled. See Figure 12.

Another proposed package consisted of three molded plastic parts with gaskets at all joints. This package was to be held together by pins thru meshing metal clips fastened to the two halves. When the pins were pulled by either a static line from the gondola or a mechanical fuze, the two halves would separate, releasing the lids and the contents. This package was designed but never built, as it was felt to be too costly and too susceptible to leaks and mishandling.

The next design proposed a cylindrical body fabricated from paper fiber similar to commercial canisters. The body is provided with a flexible sleeve liner attached at the body top. At the bottom, this sleeve is secured to a rigid plate which moves up inside the container when actuated by gas pressure. This action turns the sleeve inside out and insures that all contents are emptied from the package.

The first experimental model has a carbon-dioxide cylinder on the side and is equipped with a spring-actuated device for piercing the seal on the CO_2 cylinder. The gas leaving the cylinder passes through a tube which connects to the inside of the container through a fitting in the bottom. One end of an extension spring is hooked to the lever which causes the CO_2 cylinder to be pierced. The other end is anchored to a bracket fixed to the bottom of the container. There is a compression rod passing through the spring which holds the spring extended by bearing at the upper end against the CO_2-actuating cam-arm and at the lower end against the release lever. The bottom end of the rod bears against the release lever passing across the bottom of the container. As long as the container rests on its feet this lever is held in place and keeps the rod in position, but when the container is lifted off its feet the lever pivots away from the bottom and frees the rod to permit the spring to actuate the CO_2 system.

This container was tested at Dugway Proving Ground and proved satisfactory. See Figure 13. (Report of M Division Test No. 1230).

However, it was felt necessary to move all mechanism to the underside of the package. A working model has been made and tested in the laboratory. See Figure 14. The CO_2 cylinder is pierced by a spring-driven pin held in the cocked position by two balls which protrude through the spring barrel and fit into a groove in the piercing pin block. The balls are kept in the groove by a retainer sleeve which slides on the spring barrel. This retainer sleeve is connected to two levers in such a way that when the container is raised off its support, the levers swing out away from the bottom of the container to slide the sleeve off the balls. The balls

[redacted]

CONFIDENTIAL

then move out to free the piercing pin block which is driven against the CO_2 cylinder by the spring. This latest model is the same in principle as the unit tested at Dugway and is the proposed final design.

F. NEUTRALIZING SYSTEM

In the discussion of the instrumentation, three features were described which initiate a neutralizing action to render the agent innocuous in the event of malfunctioning of the munition. At first formaldehyde was considered for the neutralizing agent, but was abandoned in favor of sulfur dioxide, as SO_2 kills much more quickly. Preliminary work was done at General Mills, Inc. on an SO_2-dispersing arrangement within the package. Four types of arrangements were utilized in a shredded paper container. Seven tubes were led into the package from the top, then four tubes, and finally two single tubes of varying length. The seven-tube arrangement was the most efficient. However, the long single tube was efficient enough and was selected because of its simple design. A working model of this unit is being tested at this time by M Division. (Request for Test No. 1295). Preliminary test data show 100 percent kill using 40 grams of SO_2 and 5-minute exposure time.

This unit consists of the SO_2 cylinder (See Figure 15), the mounting block, and the dispersing tube. The mounting block houses a squib and a hollow piercing pin. When the squib is fired, the hollow pin pierces the SO_2 cylinder and vents it into the dispersing tube. This tube has small holes along its entire length for dispersing the gas within the container.

The unit is mounted on the cover of the agent container so that the mounting block and gas cylinder are outside and the tube extends thru a seal in the cover into the container.

G. IMPORTANT TESTS

In the test mentioned above (No. 1230), five drops were made with five gondolas utilizing dummy agent-containers and instrumentation necessary for air bursts. These tests demonstrated release of the munition from the vehicle, terminal velocity (dragchute performance), opening of the munition, and showed that the tested part of the design was feasible.

Test No. 1295, mentioned earlier, is in progress to determine the effectiveness of SO_2 in killing the agent. Preliminary results indicate that the unit as designed obtains 100 percent kills of the agent. This test will also study the feasibility of smaller SO_2 quantities and a simpler dispersing system.

[redacted]

Test No. 1311 is in progress to determine the compatibility for viability of the agent with brass, aluminum, stainless steel, polyethylene, and Micarta. Results are not yet available.

III. FUTURE PLANS

A. CHANGES AND FUTURE TESTS

There are no changes contemplated in the design of this munition at this time. However, it is reasonable to assume that changes will be necessary as a result of the final engineering test data.

An amended scope to the original contract with General Mills, Inc. is now in the final stages. This amended scope calls for, among other things, an accelerated attack on the heater problem. The contractor proposed to bring in University of Minnesota consultants, make a check of the solution of similar problems by others, and to develop a parallel heater as a "buffer" in case the present one proves inadequate. The Chemical Corps requested that the contractor have a heater ready by July; however, it appears that this request cannot be filled before September.

In this amended scope, General Mills has been asked to supply items for and to conduct all final engineering tests (except those involving agent) by 31 December 1953. It was hoped that by 1 September several of the important tests would be completed, such as altitude chamber tests involving the agent and actual drops at Dugway Proving Ground involving agent for determining dissemination density (using inactive agent). It appears now that these tests will be postponed until August and September because of delays in procuring commercial items for the test munitions.

The developing and testing of the packaging for the munition will follow these tests on into November.

[redacted]

REFERENCES

R. E. Stine, Project Officer, and Majors John W. Lakin and R. W. Motis, USAF, have been responsible for development of the E77 at Biological Laboratories. General Mills employees identified most closely with this project include Frank B. Jewett, Dr. Cledo Brunetti, G. O. Haglund, D. J. Owen, Raymond I. Hakomaki, and Marvin A. Sandgren, Project Engineer.

[redacted]

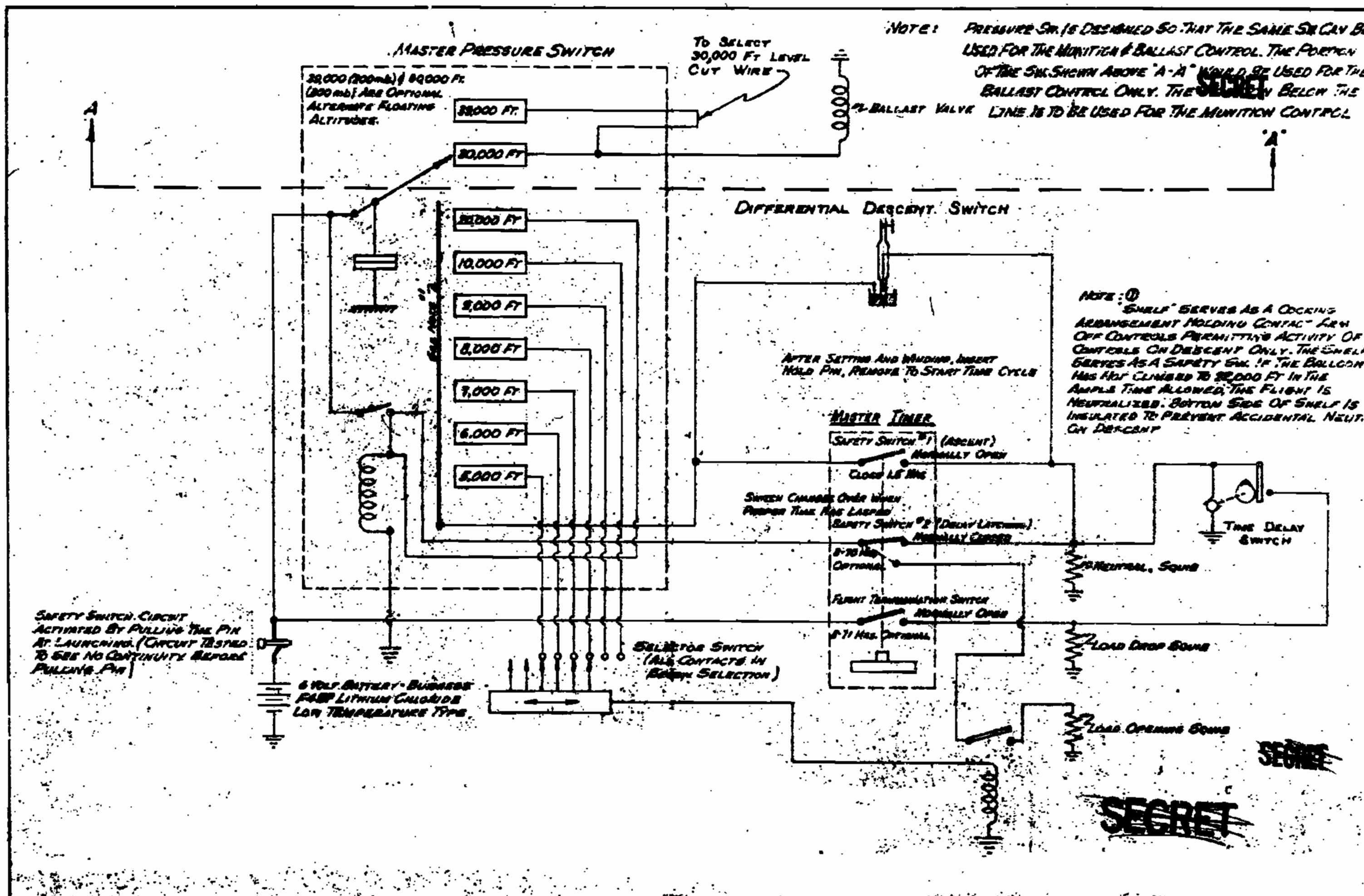


Fig. 1. - Schematic Diagram of Control Circuit.

CONFIDENTIAL

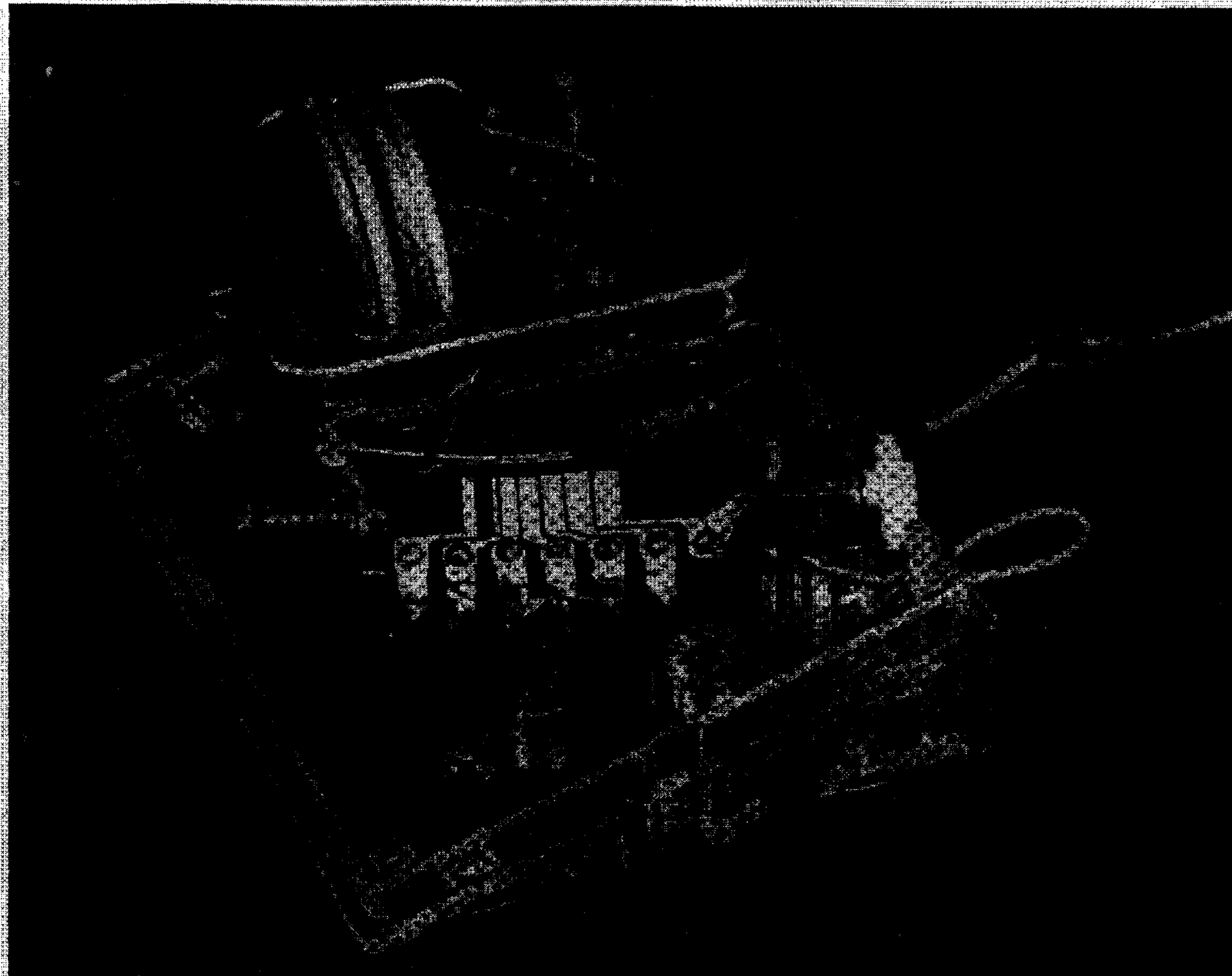


Figure 2. Pressure Switch

[redacted]

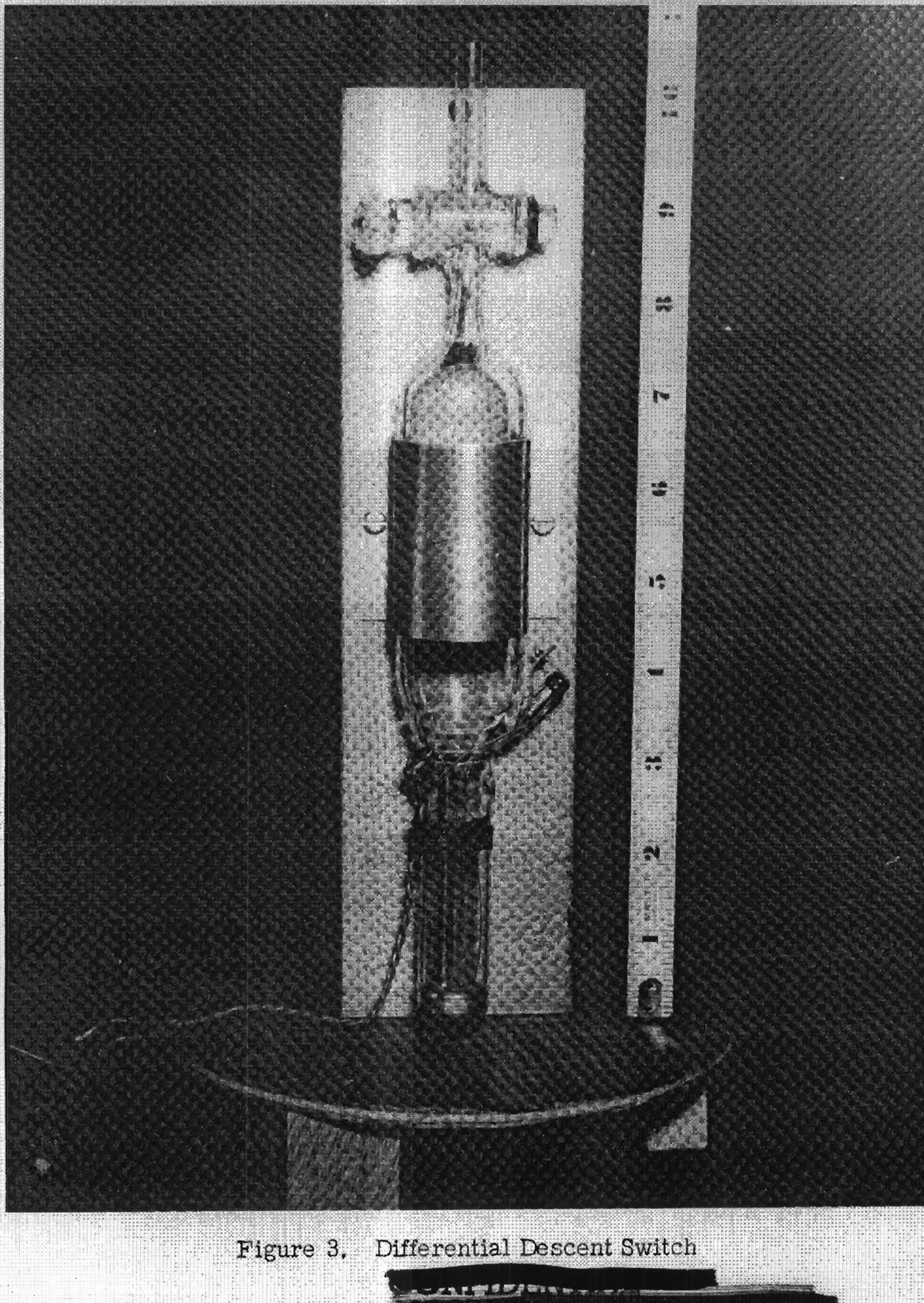


Figure 3. Differential Descent Switch

[redacted]

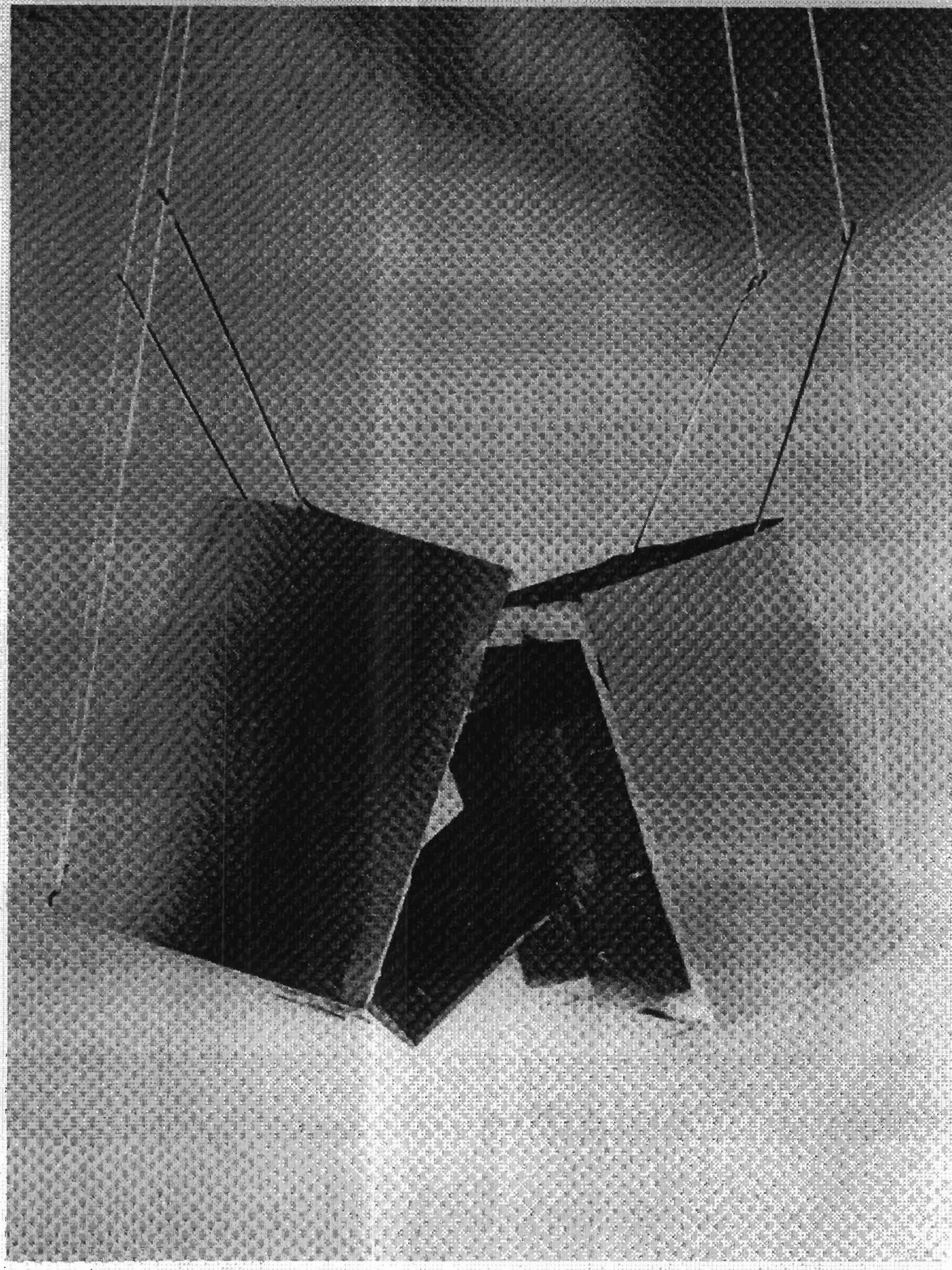


Figure 4. Munition Opening

[redacted]

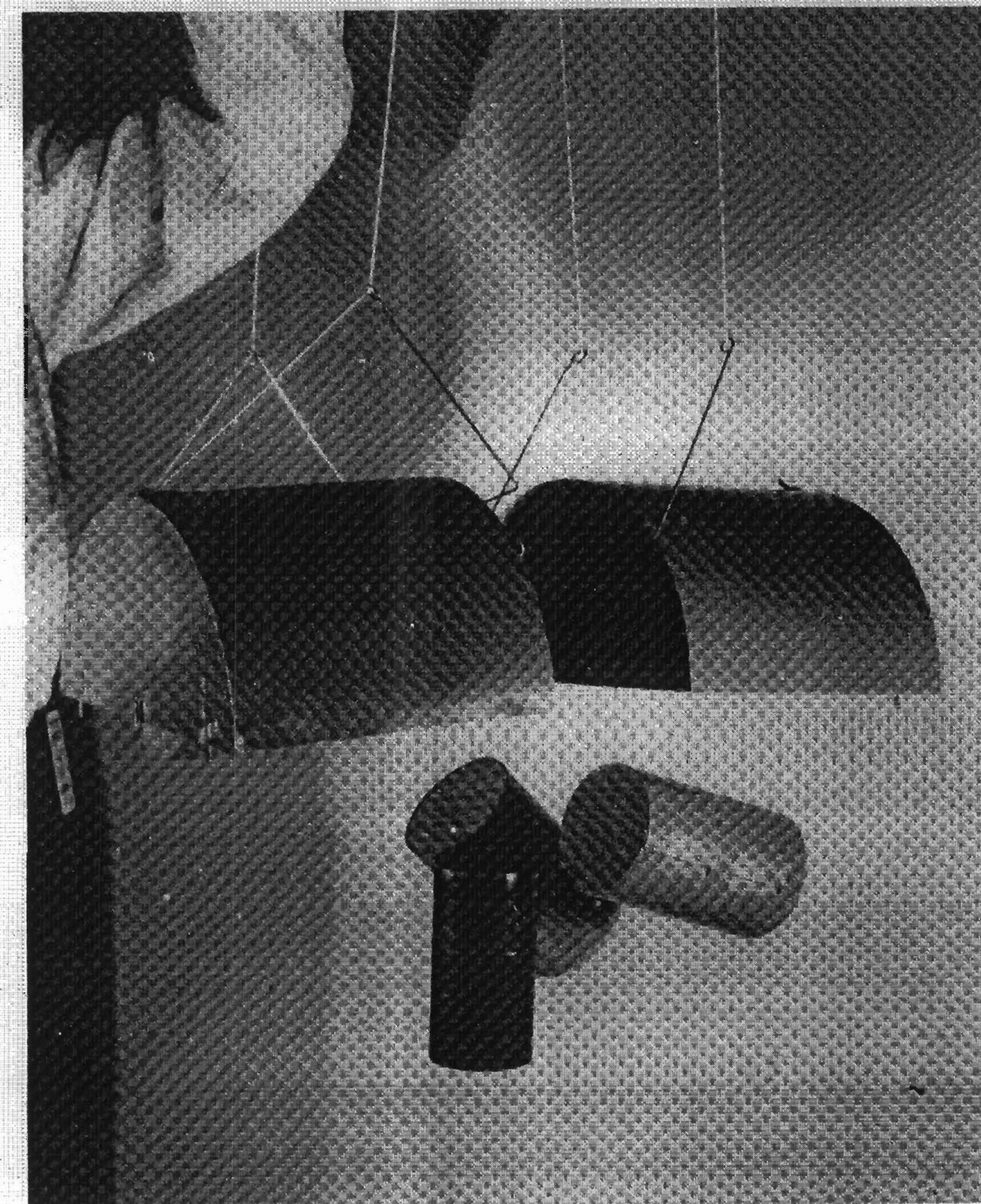


Figure 5. Munition Dropping Contents

~~CONFIDENTIAL~~

[redacted]

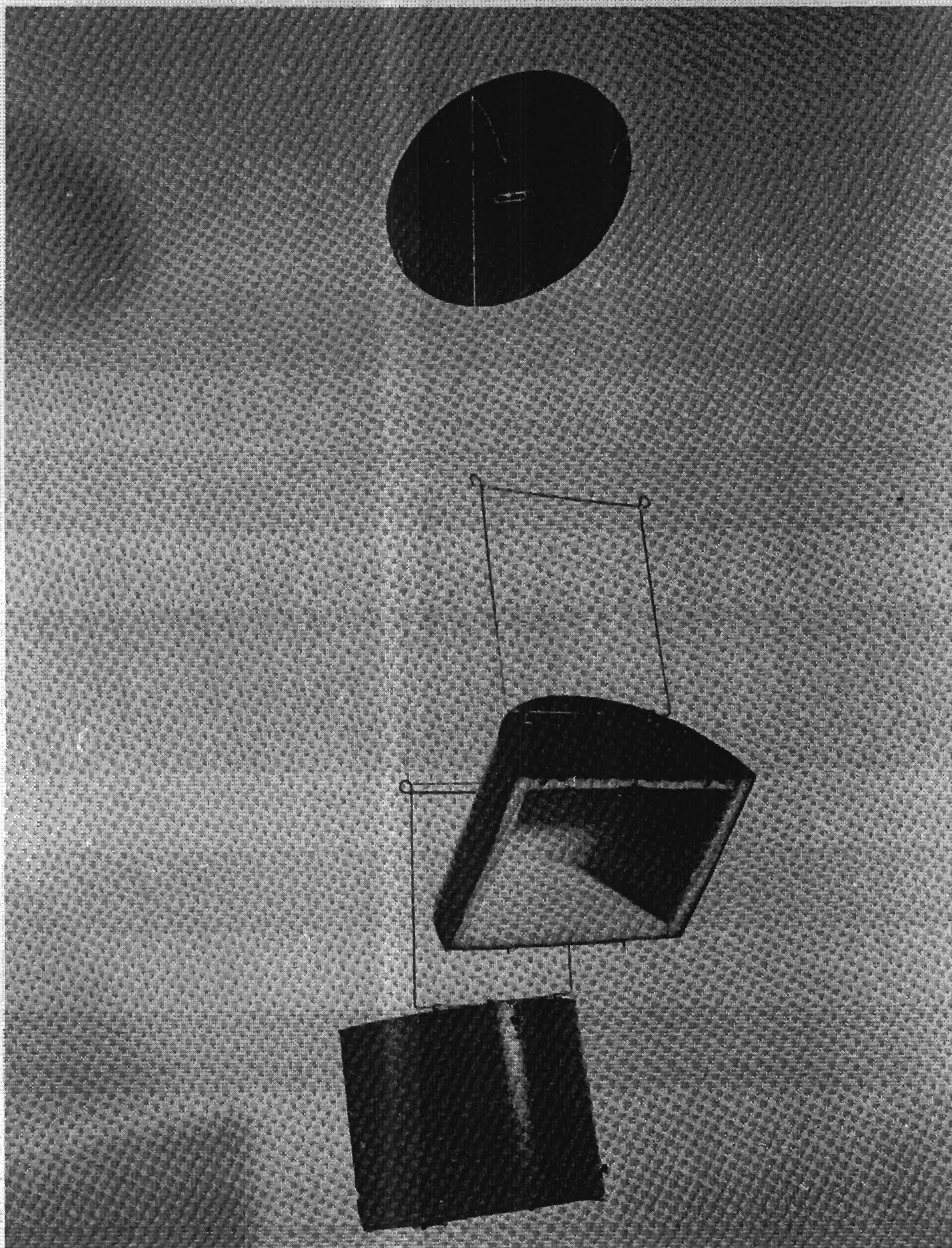


Figure 6. Munition Separated

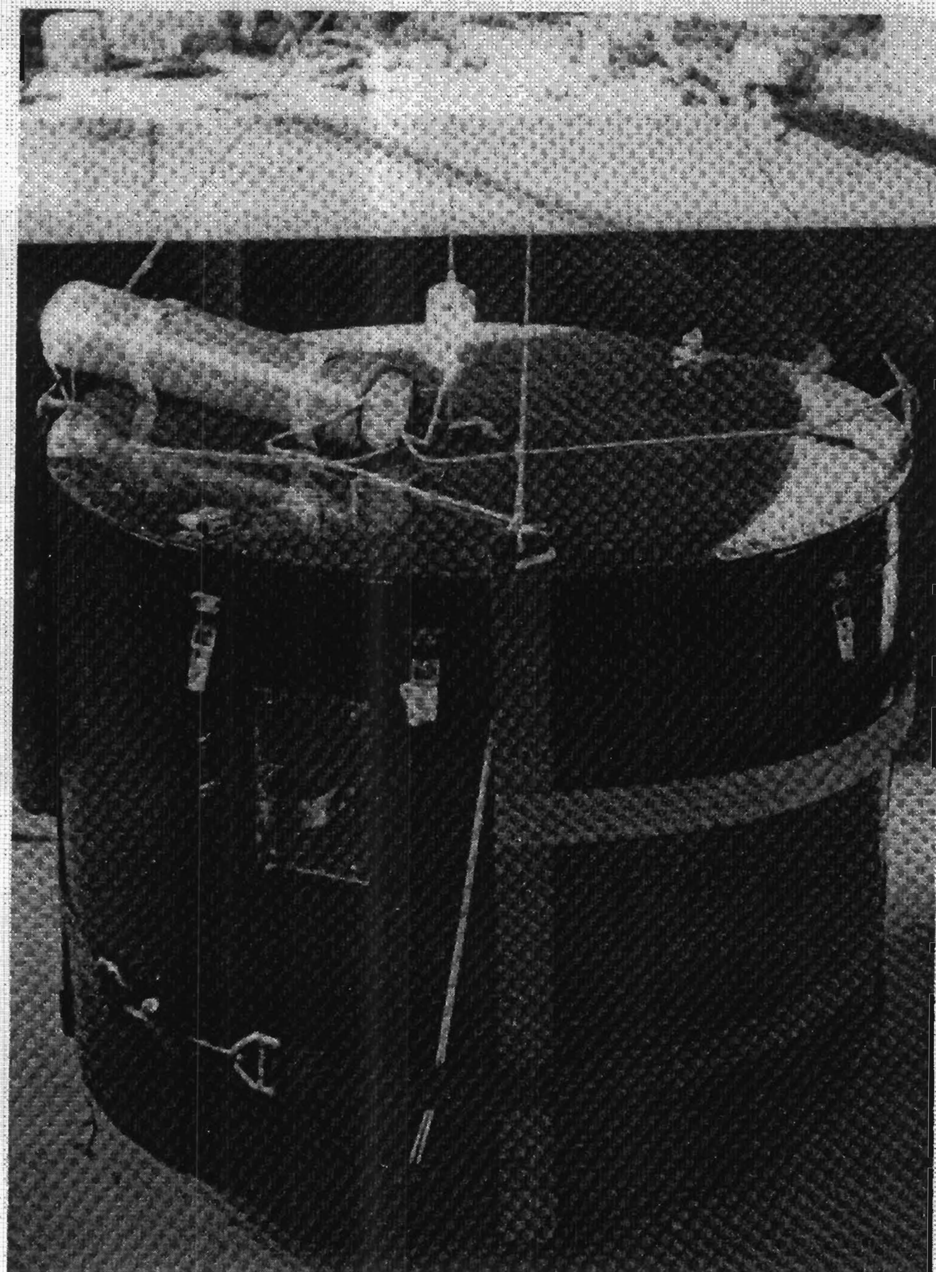


Figure 7. Full-sized Munition

[redacted]

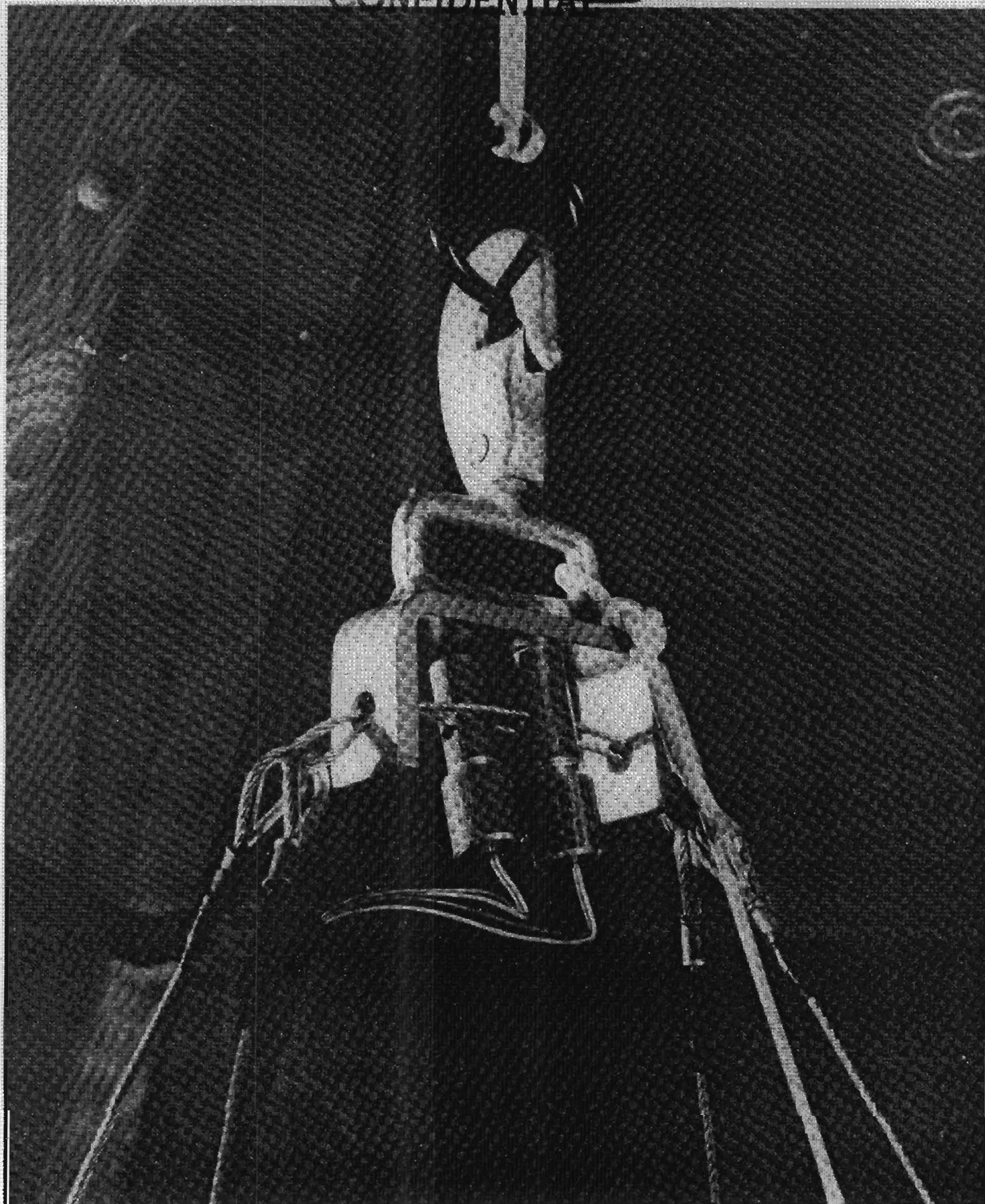


Figure 8. Load Hangar

[redacted]

[redacted]

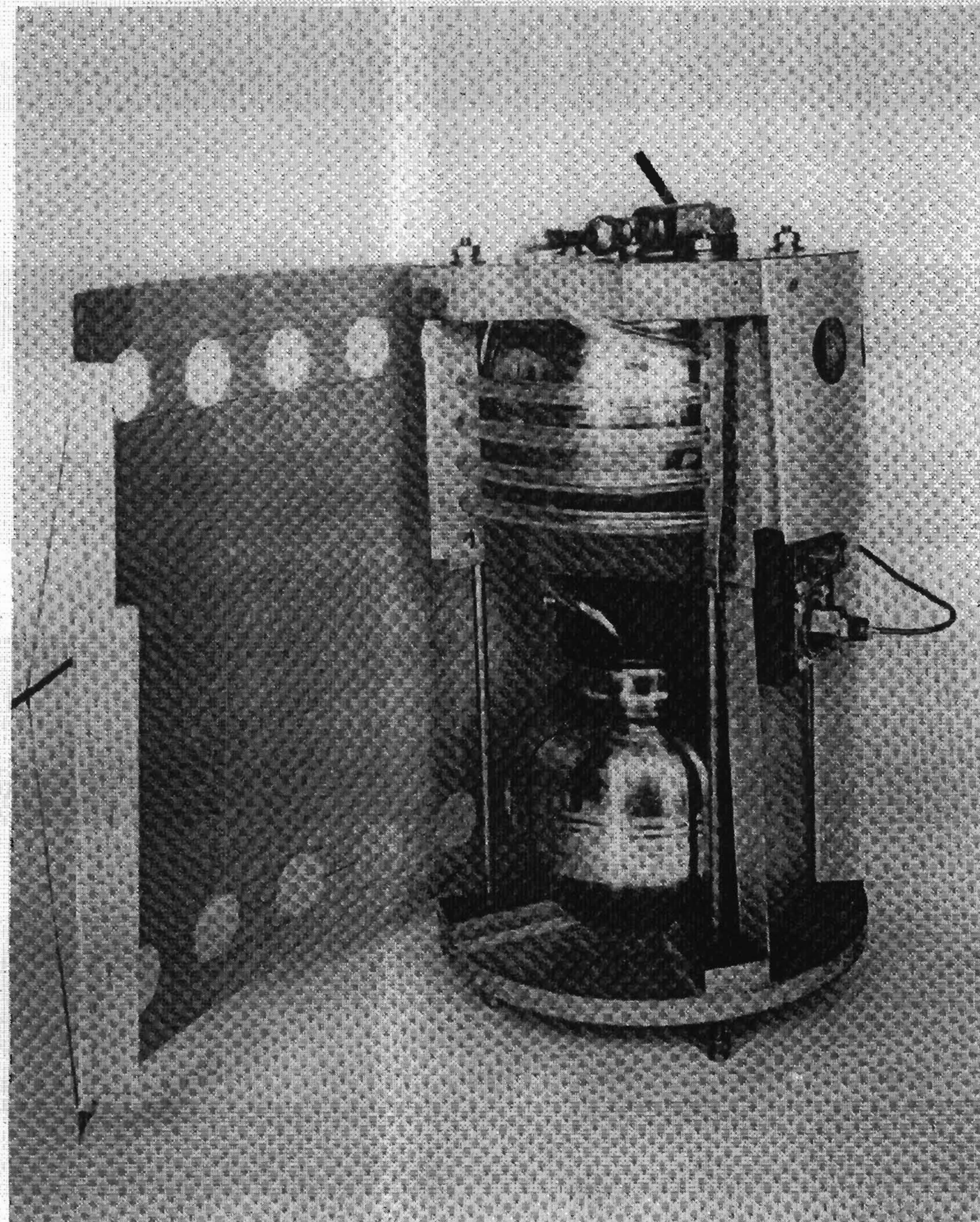


Figure 9. Heater with Cover Opened

CONFIDENTIAL

[redacted]

CONFIDENTIAL

[redacted]

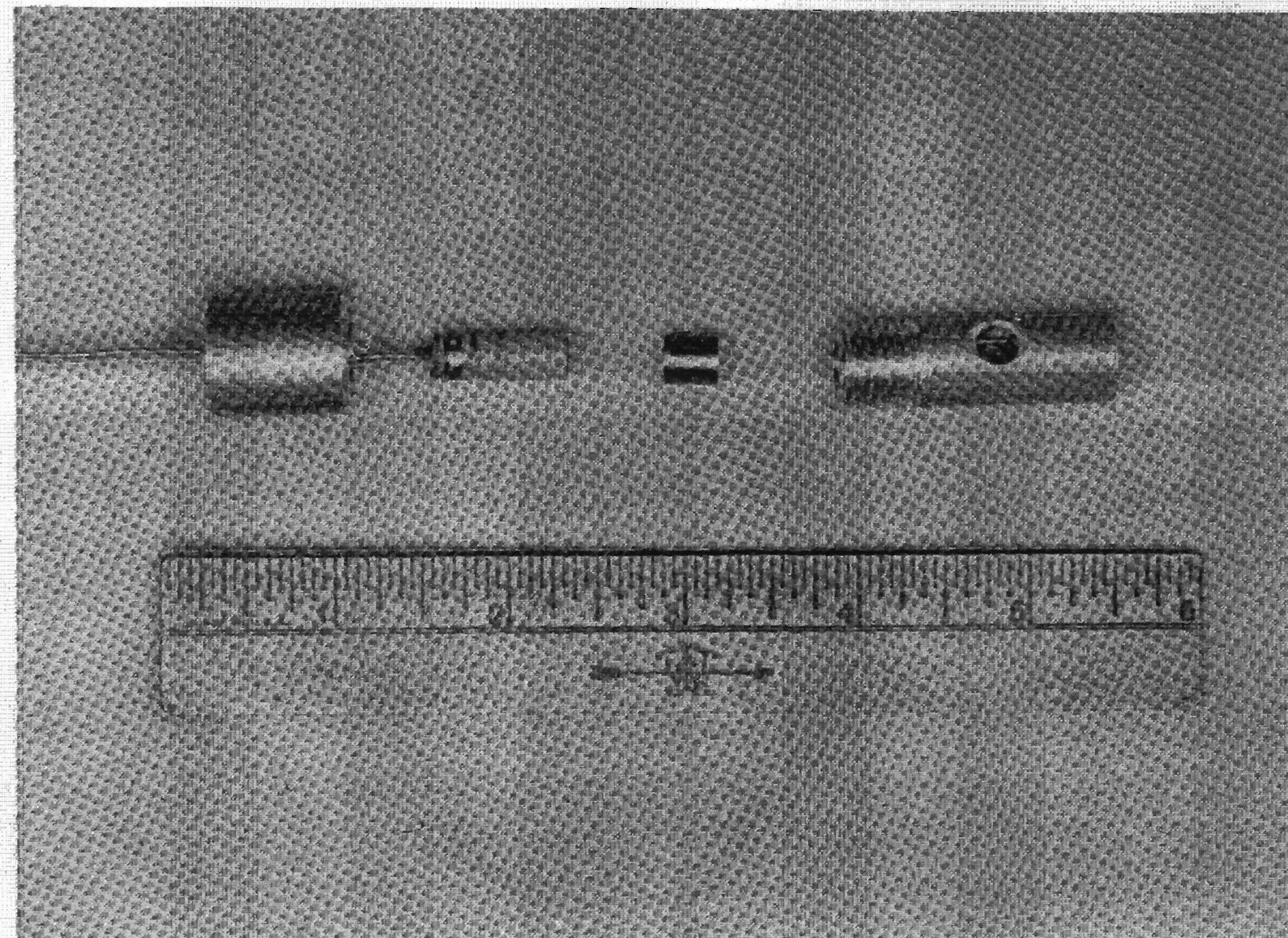


Figure 10. Squib-fired Line-cutting Cannon

[redacted]

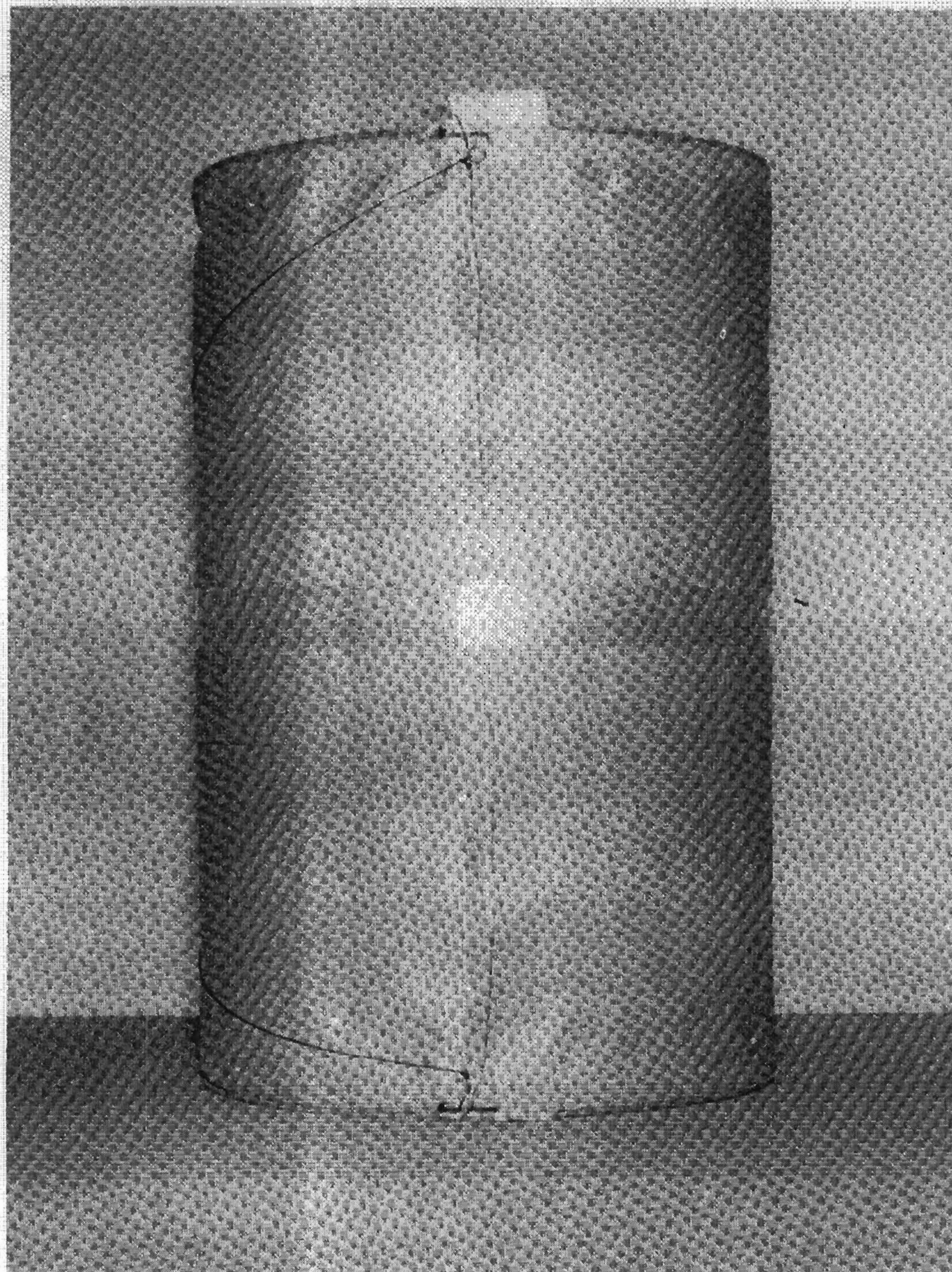


Figure 11. Early Agent Package

Figure 12. Early Agent Package opened

[redacted]

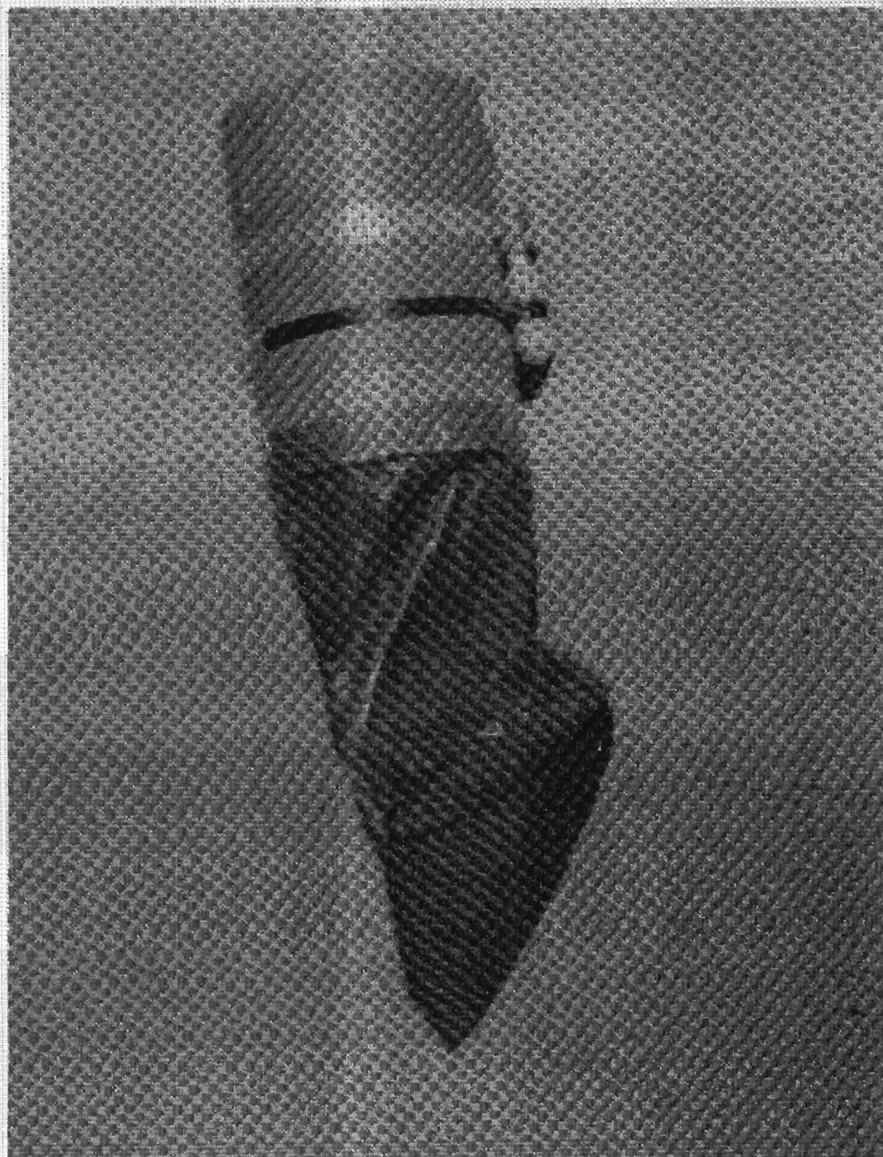


Figure 13. Container after functioning

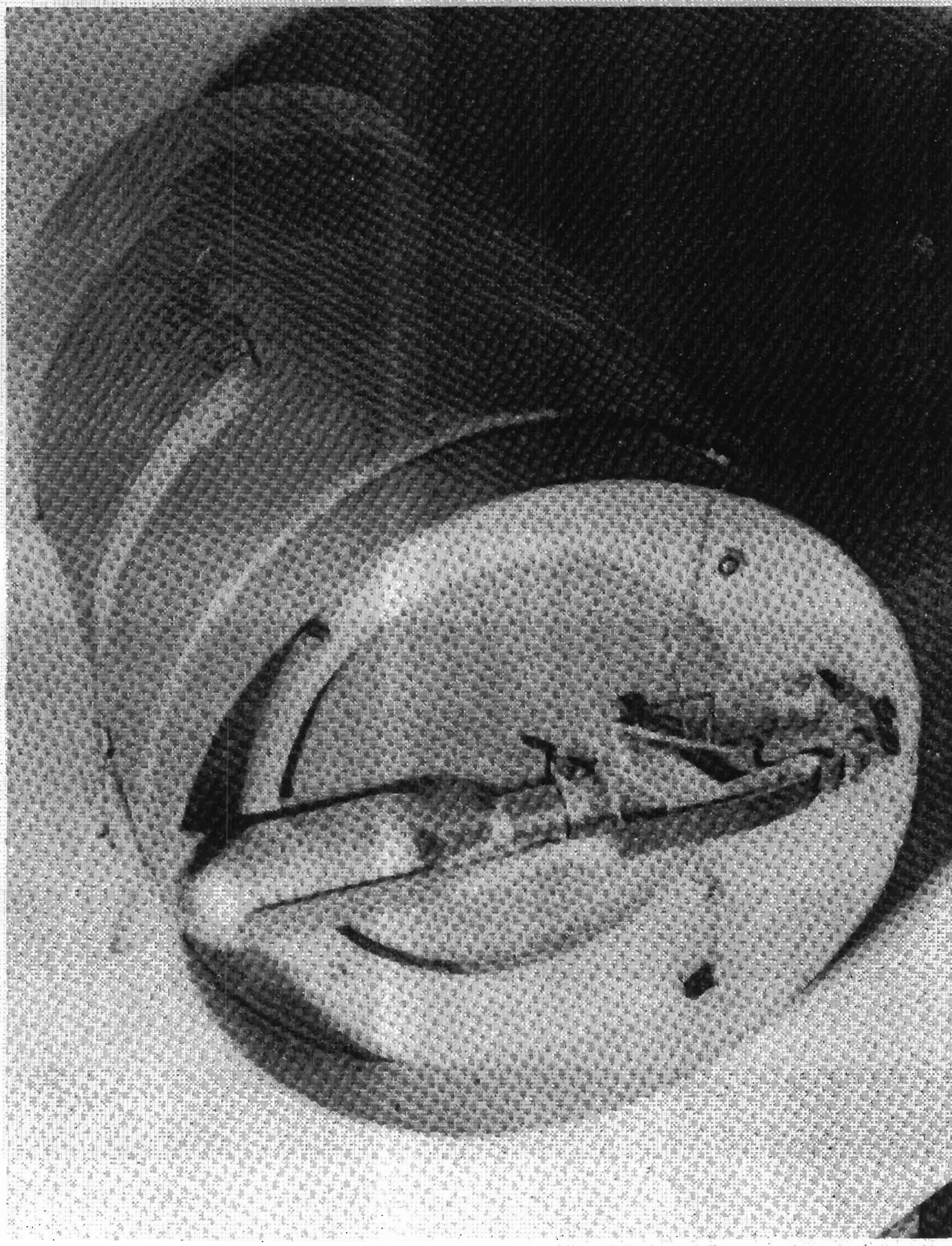


Figure 14. CO_2 Unit on Container Bottom

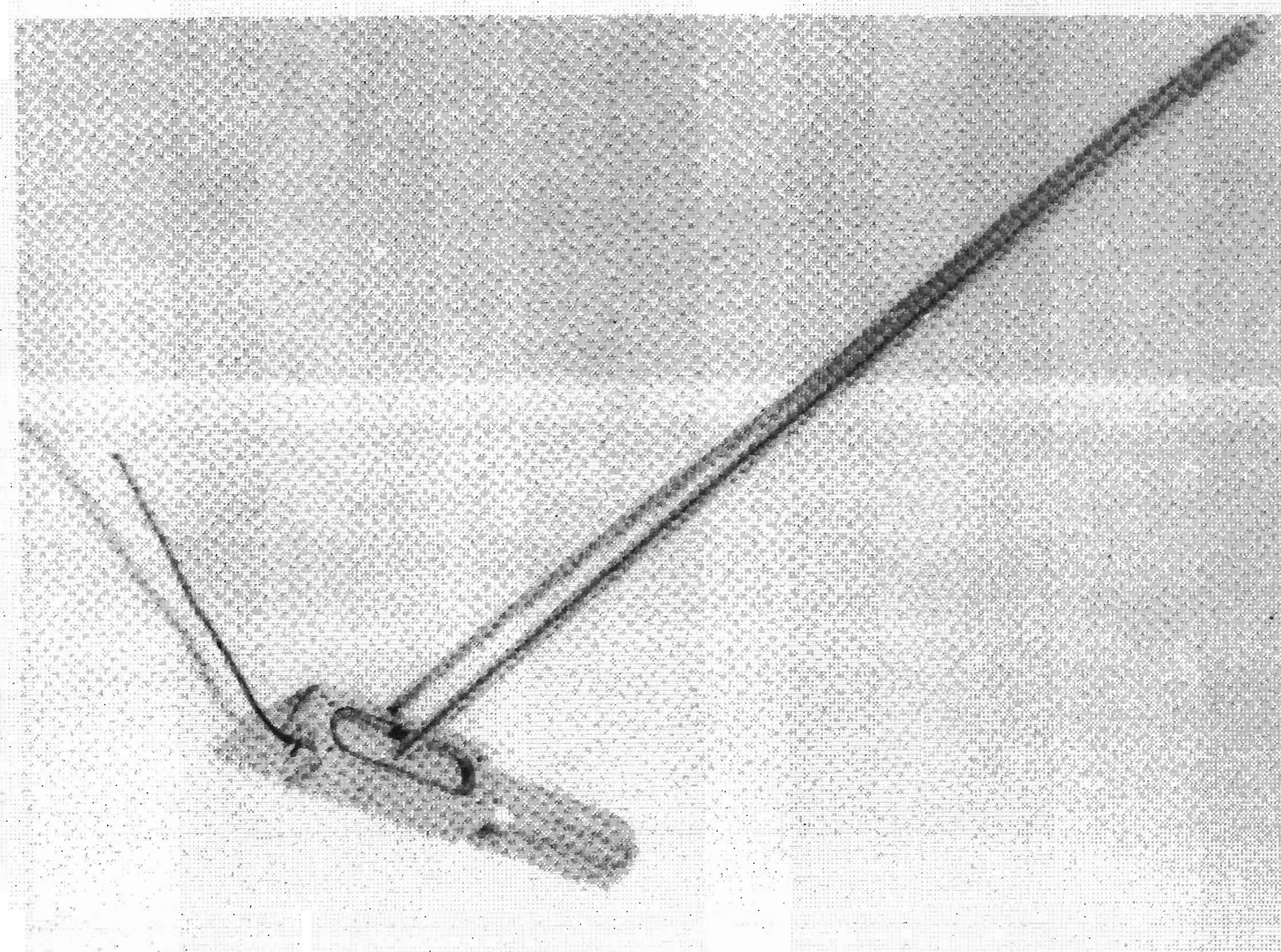


Figure 15. SO_2 Unit

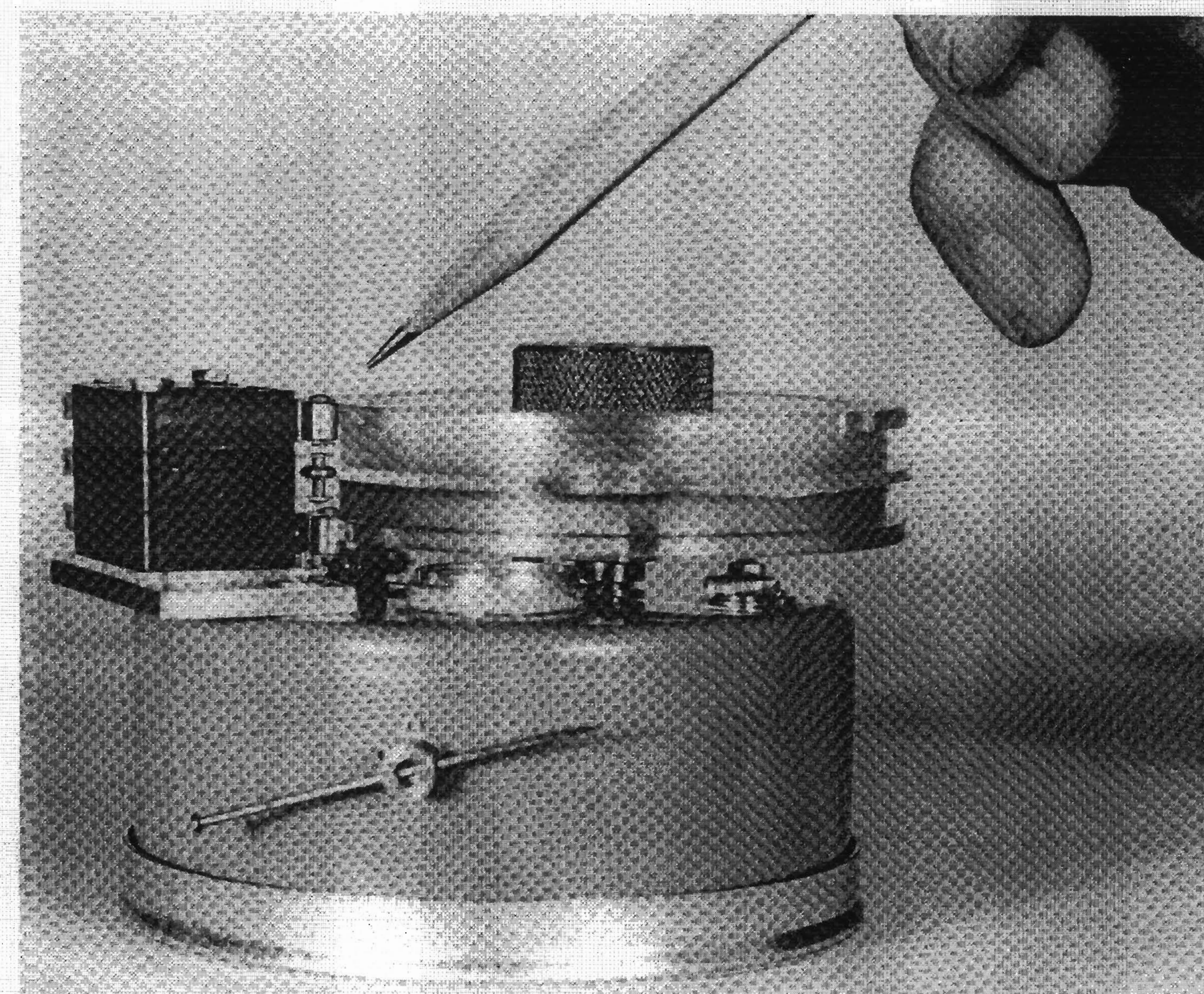


Figure 16. Final Mastertimer

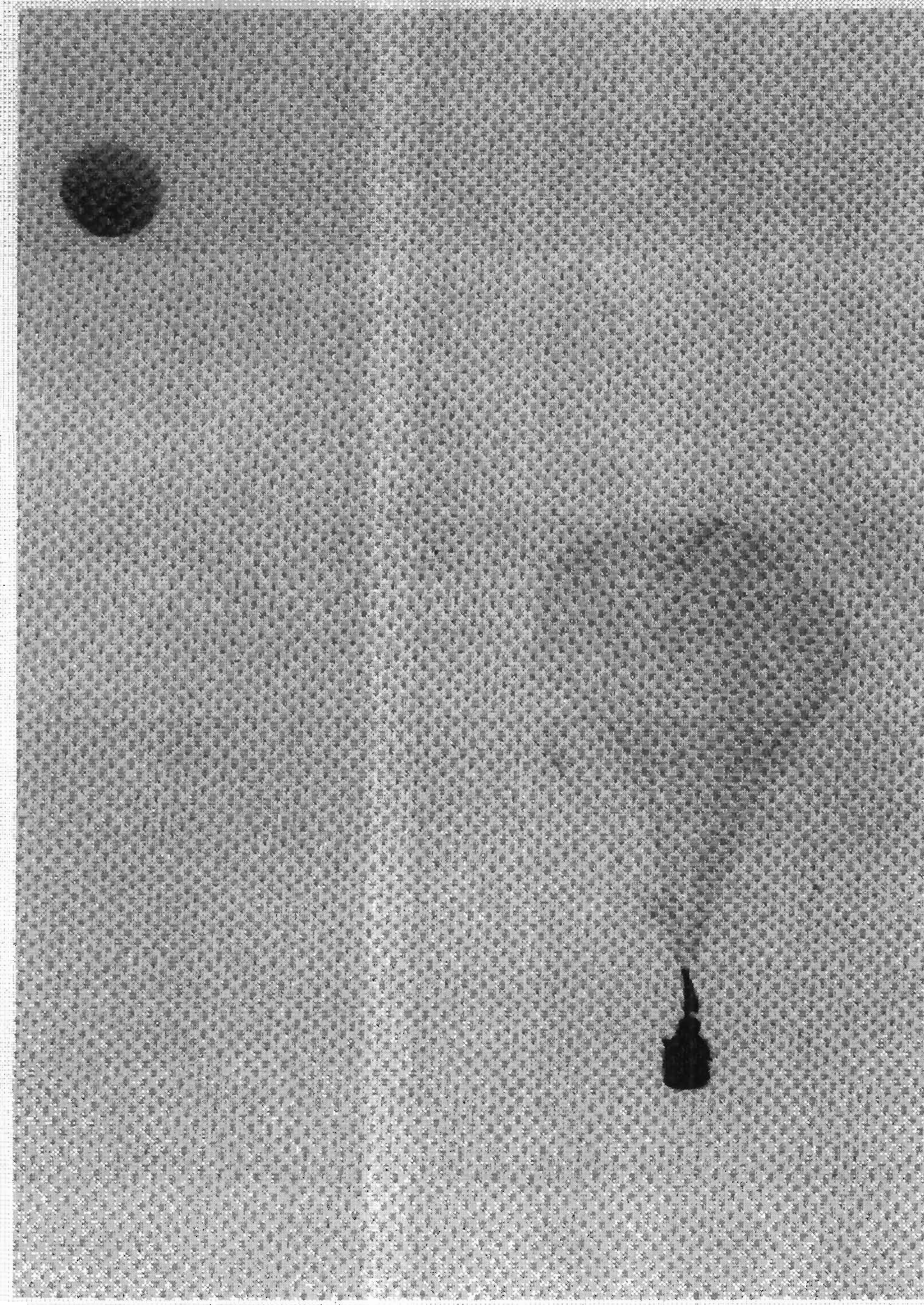
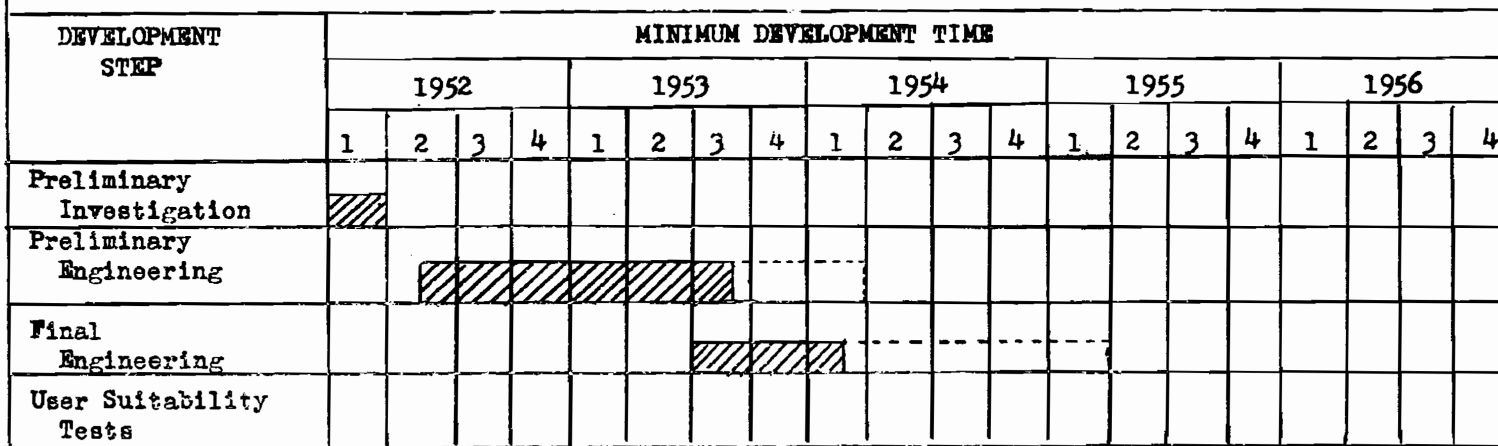


Figure 17. Launched Munition

[redacted]

[redacted]

ITEM : Bomb, Biological, 80-lb
DESIGNATION: E77
PROJECT NO : (Cml C) 4-04-14-011



DEVELOPMENT STEP	Total Manpower Effort Req.	Proj. Engr. Manpower Effort Req.	Proj. Engr. Manpower Effort Avail.	Proj. Engr. Staffed	Probable Completion Date	Number of Items Required	Estimated Cost Per Item
	Man/Mo	Man/Mo	Man/Mo	%		ea	$
Preliminary Investigation	3 1/2	3 1/2	3 1/2	100			
Preliminary Engineering	16 7/8	16 7/8	12 3/4	75	Feb 54	6	300.00 w/o Balloon
Final Engineering	12 5/8	12 5/8	6	47	Jan 55	50	1000.00 w/o Balloon
User Suitability Tests							

Figure 18. Development Schedule

[redacted] CLASSIFIED

[redacted]

UNCLASSIFIED

DISTRIBUTION LIST

Copy No.	Addressee
1	Director, Cml C Bio Labs
2	CCBL Retirement Copy
3,4,5	Technical Library Cml C Bio Labs
6	Assistant to the Chief Chemical Officer for BW ATTN: Technical Advisor
7	Assistant Director for WD Cml C Bio Labs
8-12	Chief, M Division (for Chief, M Div; Project Engineer; and D&D Branch)
13,14	Air Force Development Field Office Camp Detrick (for Liaison Office and WADC)
15-25	Chief, Editorial Branch Cml C Bio Labs

REGRADED UNCLASSIFIED JOD, DPG

UNCLASSIFIED

[redacted]

2-1-67

BRL R 1327

BRL

REPORT NO. 1327

REVIEW OF THE HIGH ALTITUDE RESEARCH PROGRAM (HARP)

by

C. H. Murphy
G. V. Bull

July 1966

U. S. ARMY MATERIEL COMMAND
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

DISCLAIMER NOTICE

This document may contain pages which do not reproduce legibly. Inconsistent page numbers are due to omittance of blank pages.

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

REPORT NO. 1327

JULY 1966

REVIEW OF THE HIGH ALTITUDE RESEARCH PROGRAM (HARP)

C. H. Murphy

Ballistic Research Laboratories

G. V. Bull

Space Research Institute, McGill University
Montreal, P. Q., Canada

RDT&E Project No. 1A011001B021

A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

REPORT NO. 1327

CHMurphy/GVBull/cr
Aberdeen Proving Ground, Md.
July 1966

REVIEW OF THE HIGH ALTITUDE RESEARCH PROGRAM (HARP)

ABSTRACT

Project High Altitude Research Program (HARP) is directed toward the use of guns for scientific probing of the upper atmosphere. The attractive features of guns for this purpose are the basic economy of such a system and the high inherent accuracy of guns for placement at altitude as well as accuracy in ground impact. The basic liability for such an approach lies in the very high accelerations experienced by gun-launched payloads.

The guns used in Project HARP vary in size from 5-inch and 7-inch extended guns on mobile mounts to transportable fixed 16-inch guns. Altitude performance varies from 20 pound, 5-inch projectiles reaching 240,000 feet to 185-pound, 16-inch projectiles reaching 470,000 feet. Single and multiple stage rockets launched from the 16-inch gun have very promising predicted performance and are under development.

Scientific results to date are primarily wind profiles measured by radar chaff, aluminized balloons and parachutes, and tri-methyl-aluminum trails, although a number of successful 250 MHz and 1750 MHz telemetry flights have been made. Sun sensors, magnetometers, and temperature sensors have been flown and an electron density sensor was fired in early June. Development of other active sensors is continuing.

TABLE OF CONTENTS

TABLE OF CONTENTS (Contd)

LIST OF FIGURES

LIST OF FIGURES (Contd)

1. INTRODUCTION

Project High Altitude Research Program (HARP) is a program of engineering and scientific research sponsored by the United States Army and the Canadian Department of Defence Production. The engineering objective of the program is the development of the gun launching system (guns, vehicles and payloads) to realize the maximum payload/mission potential. This ranges from the development of non-assisted, non-guided vehicles for probing to apogees in the order of 100 miles, to the development of multi-stage, gun-launched rockets with guidance and control in the upper stages such that in addition to specific re-entry placement capabilities, the system possesses significant orbital capability. The scientific portion of the program makes use of developed payload capability to conduct synoptic studies of the ionosphere as well as the usual meteorological measurements in the lower mesosphere.

The Army program is centered at the Ballistic Research Laboratories (BRL), Aberdeen Proving Ground, with participation of many other agencies in the various phases of the program. The joint Army/Canadian portion of the program is centered in the Space Research Institute of McGill University, and is monitored by the Joint International Steering Committee consisting of members of the Army Research Office, Army Materiel Command, Ballistic Research Laboratories, and the Canadian Department of Defence Production. The Space Research Institute of McGill University, working closely with the staff of the BRL, has developed and operates 16-inch gun systems in Barbados, W. I. and Highwater, Quebec, and has engineered the installation at the Yuma Proving Ground, Arizona. In addition, numerous vehicle systems have been or are under development along with appropriate payloads. The Institute organizes and coordinates the numerous 16-inch firing series which take place both for engineering test development purposes and for the gathering of scientific data.

2. MAJOR FEATURES OF THE GUN SYSTEM

The gun barrel, in addition to acting as a first stage re-usable booster, also acts as a guidance and control system. On emergence from the barrel, the vehicle is at a high velocity on a pre-determined flight path and is not significantly affected by surface winds. Thus, vehicle dispersion (in the case where there is no in-flight rocket-boost) can be closely controlled to both a predicted point in space, as well as impact into a relatively confined area. The gun-launch system from a dispersion point of view more closely approaches anti-aircraft gun fire than conventional rocket launches. In addition to the lower dispersion of a gun system compared to an unguided rocket, the re-usable booster characteristic of the gun barrel can lead to significant cost advantage over rocket systems.

The gun-launch technique takes on two different tasks in the HARP program. It may act simply as the first stage of a multi-stage rocket system with subsequent trajectory characteristics controlled by the performance and selected ignition times of the rocket stages, or may be the sole propulsive force applied to the vehicle. When it acts as the sole boosting stage, it then becomes necessary to achieve a ballistic coefficient larger than that of a conventional shell, and at the same time, double the muzzle velocity of conventional guns.[1,2*] The relation between launch ballistic coefficient, muzzle velocity and apogee is shown here in Figure 1. It may be noted from this figure that below a ballistic coefficient of 2000 pounds per square foot, apogee is controlled largely by the ballistic coefficient, while beyond this, apogee is controlled largely by muzzle velocity.

**Superscript numbers denote references which may be found on page 35.*

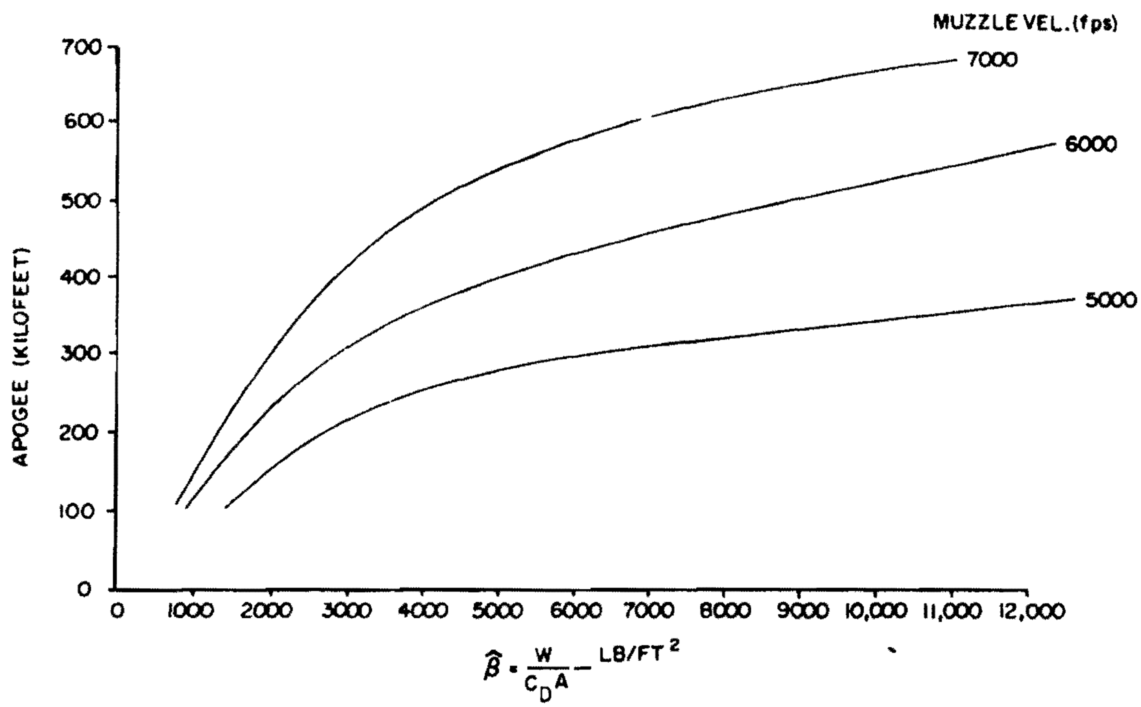


Fig. 1 APOGEE AS A FUNCTION OF BALLISTIC COEFFICIENT AND MUZZLE VELOCITY

Thus, in order to glide to apogees of interest, it is necessary to use sabot launched, sub-caliber vehicles (Figures 2-3). The vehicle launch ballistic coefficient can be kept large, while the all-up shot weight can be kept small. For example, the service 16-inch gun fires a 3000-pound shell at muzzle velocities of 2800 feet per second. The vehicle/sabot combination shown in Figure 2 has an overall weight of a nominal 400 pounds and has been launched at muzzle velocities of over 6000 feet per second. The pusher plate converts the gun pressure to a total thrust on the vehicle, while the petal arms keep the vehicle aligned during bore travel. A much lighter sabot system is shown in Figure 3; this supports the vehicle near its center of gravity, and lets the afterbody trail in the gun gases.

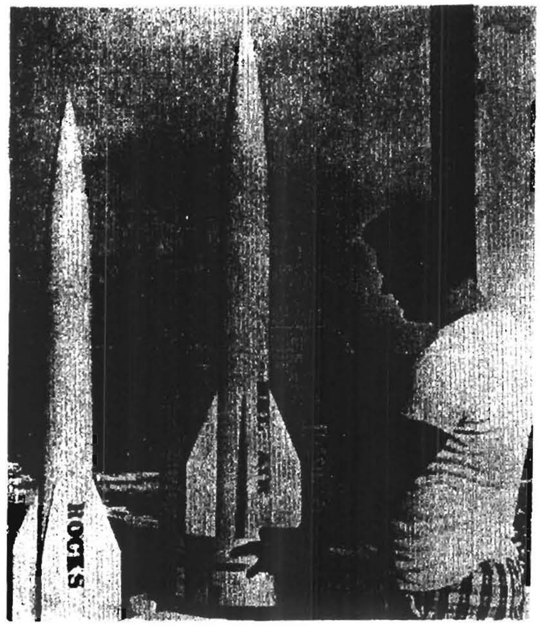


Fig. 2 16-Inch projectile with and without base pusher sabot.

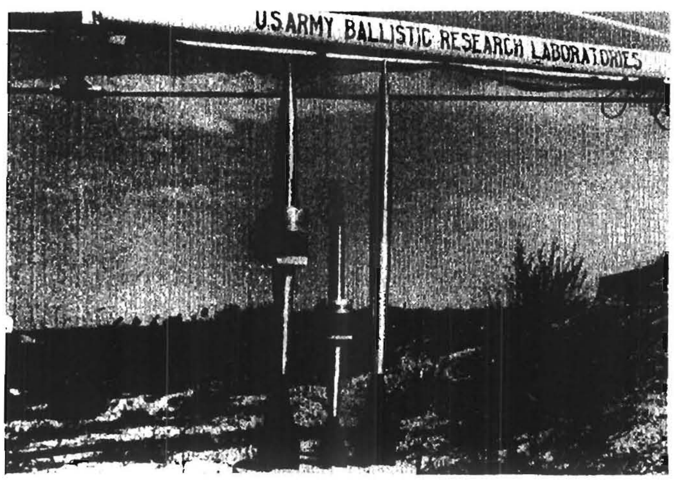


Fig. 3 5-inch and 7-inch projectiles with center sabots and 7-inch projectile without sabot.

In order to achieve optimum gun performance with these lightweight shots, it is necessary to increase the barrel length to between 75 to 100 calibers (approximately double the normal barrel length) and to tailor a suitable propellant web. The muzzle velocity is further increased as much as 200 feet per second by sealing the muzzle with a thin plastic sheet and evacuating the barrel of air. The current peak performance for HARP guns is given in the following table.

PEAK PERFORMANCE FOR HARP GUNS

Gun	Gun Length	In gun Weight	Flight Weight	Muzzle Velocity	Apogee
175 mm	34'	130 lbs	130 lbs	3150 ft/sec	81,000
5"	33'	25 lbs	20 lbs	5200 ft/sec	240,000
7"	50'	75 lbs	60 lbs	5400 ft/sec	300,000
7"	50'	47 lbs	27 lbs	5800 ft/sec	330,000
16"	119'	410 lbs	185 lbs	*6300 ft/sec	*468,000

All tubes are smoothbores except for the standard 175 mm. Usual payload weights are between 10% and 20% of flight weights.

*In November 1966 an improved ignition system allowed the Yuma gun to achieve a velocity of 7100 ft/sec and an apogee of 590,000 ft with this projectile.

Vehicles are subjected to acceleration loads that decrease in inverse ratio to the gun size (i.e., doubling the barrel diameter halves the peak g load). For the 7-inch gun, peak accelerations are in the 35,000 g range, for the light shot weights, while equivalent accelerations in the 16-inch gun are of the order of 15,000 g's. For the large rocket systems under development for the 16-inch gun, peak accelerations are in the 5,000 g range. A natural handicap of high-g gun launch is the special development of telemetry units and sophisticated sensors. The work to date indicates that this liability can be overcome in a number of applications.[3-5]

3. FIVE-INCH SYSTEM

3.1 Gun-Projectile Properties

The first HARP vertical firings were made in June 1961 from the Edgewood peninsula, 10 miles outside of the Baltimore city limit. These flights were made with a smoothbored 120 mm T-123 barrel and a center-sabot stabilized vehicle. The vehicles were constructed from excess parts of a defunct developmental missile. This non-optimum design reached an altitude of 130,000 feet and chaff was deployed.[6]

The next year, a 10-foot extension was added to the gun and an optimum design for the vehicle established. The present gun is shown on the right of Figure 4 and the 5-inch missile is the center missile in Figure 3. The 45-inch long missile (HARP 5.1) weighs 20 pounds with a 5-pound center sabot. The maximum body diameter is 2.6 inches and the fins are slightly smaller than the bore diameter. The center sabot consists of a four-piece aluminum section backed up by plastic quarters. The aluminum parts are locked to the missile by buttress threads and the plastic quarters seal the gun tube and supply most of the bore riding surface. The plastic part of the sabot is made slightly oversize and the projectile-sabot combination is rammed into the tube by a hydraulic jack.

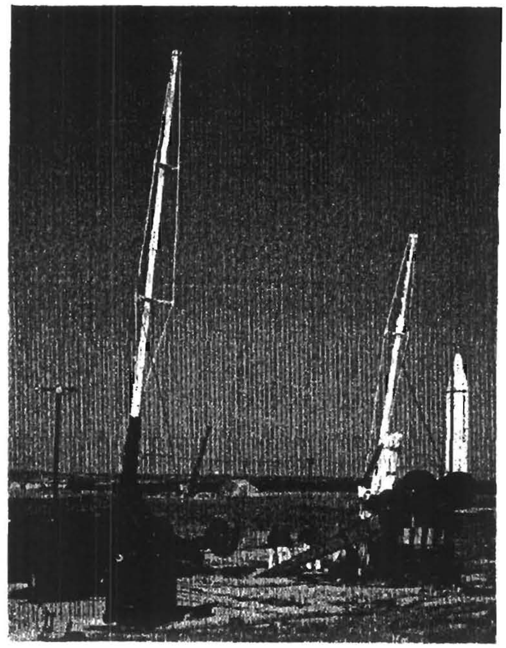
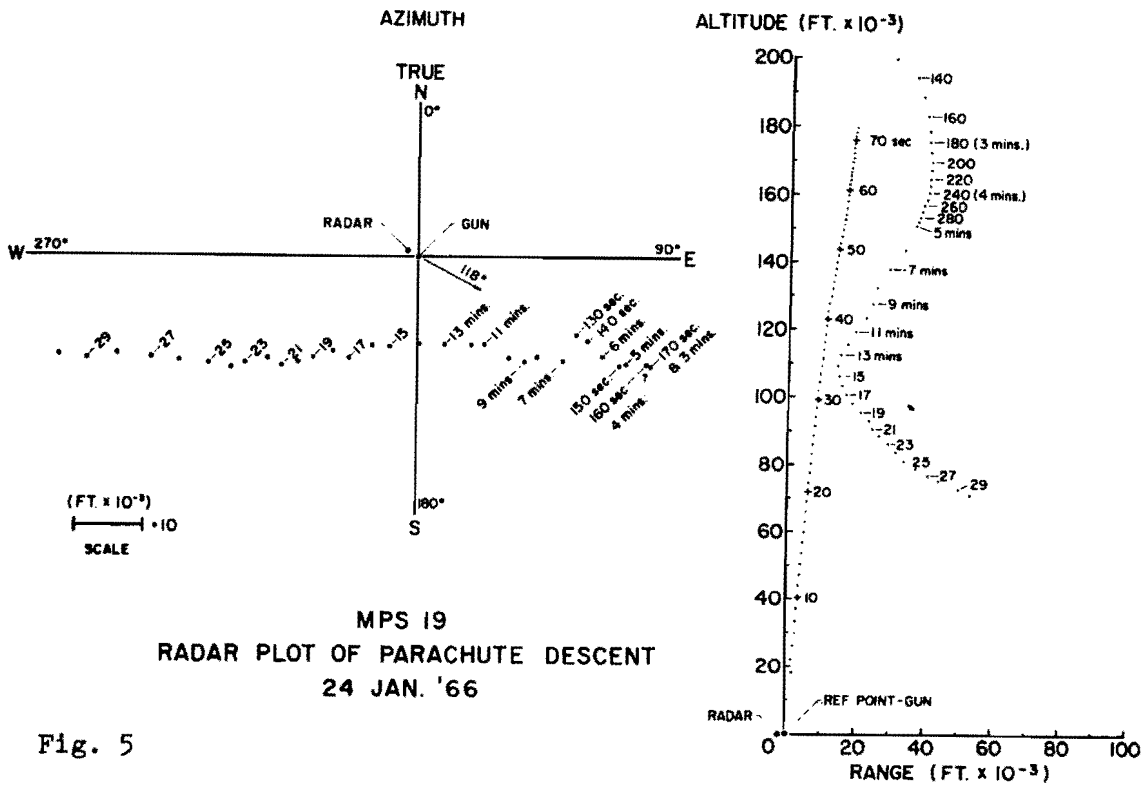


Fig. 4 5-inch and 7-inch extended smoothbore guns at Wallops Island, Va.

A 35-pound triple web mixture of M-17 is normally used and breech pressures range from 55,000 psi to 62,000 psi. Projectiles reach muzzle velocities of 5100-5200 ft/sec and apogees of 220-240,000 feet.[7,8] Early in the program, a significant number of apparently undamaged rounds flew to heights less than 100,000 feet, probably due to some aerodynamic difficulties. When the fins were beveled 3 degrees to induce spin, the missiles became most reliable and impact circle radii of less than one mile were routinely observed.

3.2 Payloads

The first payloads flown were radar chaff and aluminized parachutes. These are tracked by radar to give winds between 200,000 feet and 80,000 feet. Figure 5 is a sample radar plot for an aluminized six-foot square parachute flown over Barbados in January 1966.[25]



MPS 19
RADAR PLOT OF PARACHUTE DESCENT
24 JAN. '66

Fig. 5

An acoustic source payload[9] consisting of a 180-gm charge has been developed by the Atmospheric Sciences Laboratory at White Sands Missile Range and a high-g temperature sensor for use with 250 MHz transmitter and parachute deployment is under development. 1680 MHz transmitters are also under development. Over 75 observations of winds have been made by 5-inch HARP projectiles at various locations and these are being published in the Meteorological Rocket Network[10] (MRN) Data Reports.*

**The first report to contain this data is Volume XLVIII for August 1965.*

In addition to meteorological measurements, telemetry payloads with accelerometers and sun sensors have been successfully flown to measure missile dynamics.[11]

3.3 Sites

The first vertical firings of the 5-inch HARP gun were made on the Edgewood peninsula of the Aberdeen Proving Ground. Most of the later developmental work has taken place at National Aeronautics and Space Administration (NASA) Wallops Island, Virginia facility where excellent radars are available which can skin track all projectiles to apogee. During the final stages of development, a second gun was located at White Sands Missile Range, New Mexico to initiate the MRN wind measurement program. When development of the vehicle and parachute ejection package was complete, two more guns were deployed to the HARP Barbados range and U.S. Army's test facility at Fort Greeley, Alaska. Thus three sites are now involved in a routine MRN network wind measurement program. Additional guns are planned for Johnson Island, Yuma Proving Ground, Arizona; and the HARP Highwater range. By May 1966, 162 flights were made at Wallops Island, 47 at White Sands Missile Range, 30 at Barbados, and 24 at Fort Greeley.

3.4 Balloon Altitude Measurements from Rifled Tubes

The primary meteorological data required by the field Army are current winds and temperatures up to 100,000 feet. Although balloons can obtain this data, balloons require moderate ground winds for launching, take over an hour to reach altitude, and can only sample points downwind of the launch point. As a result of the success of the 5-inch HARP gun, the use of presently available rifled tubes for meteorological sounding was suggested. A feasibility test of this concept was made with a standard 177 mm rifled tube mounted on an 8-inch mount[12] (Figure 6). A 3-foot square aluminized parachute with ejection fuze was placed in a standard shell and four shots fired at Wallops Island. Flights to between 79,000 feet and 81,000 feet were made and all parachutes were successfully tracked to provide wind data.

Fig. 6 175mm rifled tube set up for vertical fire.

4. SEVEN-INCH SYSTEM

4.1 Gun-Projectile Properties

The 7-inch system is essentially a scaled up version of the 5-inch system with three times the payload and an altitude capacity of 350,000 feet. The modern 175 mm M113 gun was smoothbored, extended by 26 feet,[13] and placed in a modified T-76 mount.* (The extended 7-inch gun is on the left in Figure 4.) The basic vehicle (HARP 7.1) is 64-inches long, has a 3.6-inch diameter and weighs 60 pounds. Seven-inch missiles with and without center sabots were shown in Figure 3.

The 7-inch vehicle plastic sabot is also made oversize and must be forced into the gun by a hydraulic jack. The charge is M17 bagged .114 web powder weighing up to 110 pounds. With this charge and a gun

**Since there are only two T-76 mounts available, the 8-inch gun field mount has been modified for use with this system.*[14]

pressure of 56,000 psi, a muzzle velocity of 5400 feet per second and apogee of 300,000 feet has been obtained for the 60-pound missile.

A smaller higher performance missile (HARP 7.2) is under development to reach 400,000 feet with a much smaller payload. This missile is 55-inches long, has a diameter of 3 inches and weighs 40 pounds. A preliminary version of this missile weighing 27 pounds has been placed at 330,000 feet.

4.2 Payloads

The usual wind sensor, chaff and aluminized parachutes have been successfully ejected from 7-inch missiles with particular interest associated with the ability of high altitude chaff to measure winds above 210,000 feet. The available payload volumes of over 125 cubic inches allows the use of chemical payloads of the type flown in Project Firefly.[15] A 10 to 12-pound mixture of cesium nitrate and high explosive is being developed for the generation of electrons at 330,000 feet. This payload has already been successfully deployed from a 16-inch missile and created an observable cloud of electrons over Barbados in late 1965.

The ability of this vehicle to reach through the D layer into the lower E layer of the ionosphere has lead to the development of a Langmuir probe with associated telemetry to make direct measurements of electron density. Early versions of this device have been successfully flown from both the 7-inch gun and the 16-inch gun.

4.3 Gun-boosted Rockets

The use of gun-boosted rockets should retain the accuracy and economy of a gun system and provide markedly increased payload and altitude capability. The accuracy advantage of a gun over an unguided rocket is based on the gun's high launch velocity and this advantage would also apply to a gun-boosted rocket. If we consider the gun-boosted rocket to be a two-stage system with a reusable first stage, a significant economy should be realizable. For these reasons, a full bore 7-inch rocket is under development as part of the HARP program.

The current concept for this development is a 125-pound full bore, fiber glass case, solid propellant rocket with pop-out fins which can be launched at muzzle velocities exceeding 4000 feet per second. This rocket should be able to exceed 500,000 feet with a 20-pound payload for a very modest cost. Full bore rocket grains in fiber glass cases have been successfully launched at 10,000 g's from a 6-inch gun. These are being scaled up to the 7-inch system and the pop-out fins are being flight tested. Vertical flights of this system are planned for late in 1966.

4.4 Sites

Although numerous horizontal tests of the 7-inch system and some vertical flights of high drag slugs have been made at Aberdeen Proving Ground, all vertical high performance flights of the 7-inch system have been made at NASA's Wallops Island facility. A second gun has been emplaced at White Sands Missile Range for tests in early summer, 1966, and guns are tentatively planned for Barbados and Johnson Island. Firm plans on additional sites depend on completion of a fully developed 7-inch system. By May 1966, thirty-four 7-inch vehicles had been fired at Wallops Island.

5. SIXTEEN-INCH SYSTEM

5.1 Gun-Projectile Properties

Late in 1962, McGill University obtained two U.S. Navy surplus 16-inch barrels and one complete mount. These barrels were smoothbored in the Spring of 1962 and transported to Barbados, West Indies in the summer by the U.S. Army Transportation Corps on the B.D.L. LTC John D. Page. These two 140-ton barrels with 90 tons of mount parts were landed on the beach at Foul Bay and railroaded overland 2.2 miles to the current launch site. In January 1963, the first vertical firings were made to proof test the gun installation. In June 1963, a 185-pound projectile was fired to 340,000 feet.[16] A 51-foot muzzle extension was attached in March 1964 and a 185-pound projectile was fired to 430,000 feet.[17] With sabot and powder modifications and bore evacuation, the peak altitude was increased to 468,000 feet in November 1966.

The current Barbados 16-inch gun is shown in Figure 7. To stiffen this 119 foot 5-inch long barrel, 30 tons of 1-1/2-inch thick longitudinal steel gussets and 2-inch thick radial webs were welded in place. Eight tie rods were also added to reduce droop to acceptable limits in the elevated position. The stiffened extended barrel has a total weight of approximately 200 tons and can be elevated to 85 degrees in less than 8 minutes.

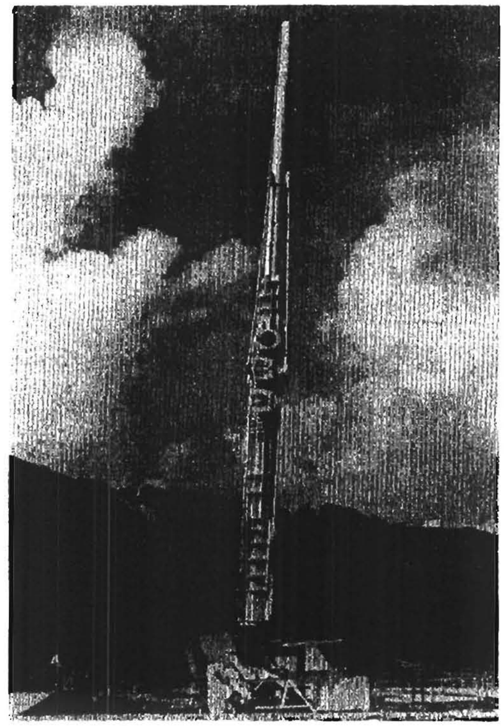


Fig. 7 16-inch extended smoothbore gun at Barbados, W.I.

The 16-inch projectile (Martlet 2C) is a 54-inch long fin-stabilized missile with a maximum body diameter of 5.4 inches and weighing 185 pounds. Its four fins have a total span of 11.4 inches and are canted 1/4 degree to produce a slow roll (shown in Figure 2). The missile is held in the gun by a 225-pound base pusher sabot consisting of an aluminum and steel base with four wooden 28-inch long arms. This sabot is also made oversize and must be forced into the gun by a hydraulic jack. A more efficient, but more sophisticated center sabot missile similar to the 5 and 7-inch missiles is under development as well as base pusher saboted vehicles with greater payload capacities.

The powder consists of bagged .225-inch web modified M8 propellant with a total weight of 780 pounds. A different web M8 powder has been used with a charge weight as high as 980 pounds. This charge is designed to yield 48,000 psi and a muzzle velocity in excess of 6100 feet per second. To increase the muzzle velocity further, the muzzle was sealed with a mylar sheet and the bore evacuated to a tenth of an atmosphere, thereby adding about 150 feet per second to the velocity and 20,000 feet to the apogee.

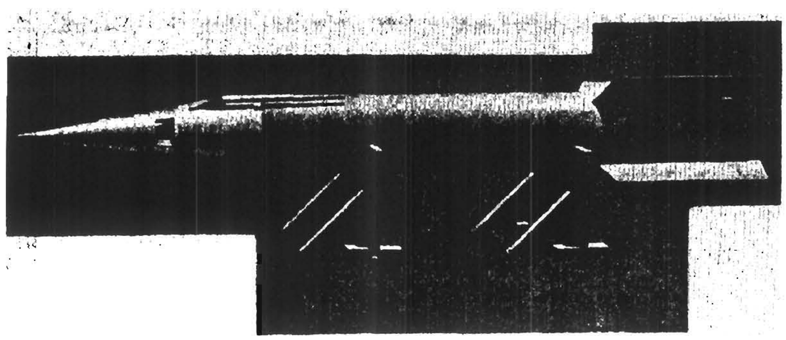
5.2 Payloads

The usual ejection payloads of chaff and aluminized parachutes have been flown from the 16-inch gun but all of these flights were limited to a maximum apogee of 250,000 to 300,000 feet for proper deployment, thus these payloads can, in most cases, be launched from smaller caliber guns. The placement of chemical payloads[15] above 330,000 feet is, however, a 16-inch gun mission. Liquid tri-methyl-aluminum has been used to produce luminous nighttime trails from 300,000 to 460,000 feet to measure ionospheric winds and a cesium compound has been exploded at 330,000 feet to produce an artificial cloud of electrons which was observed by a ground-based ionosonde for over 15 minutes.

Active payloads using both 250 MHz and 1750 MHz telemetry have been carried on a number of 16-inch flights. Onboard sensors have included magnetometers, sun sensors, pressure gages, and Langmuir probes. Although most of these devices have functioned successfully, they must still be considered as under development. Two Langmuir probe flights made direct measurements of electron densities in June 1965 and will be described in more detail later. 135 Martlet 2's have been fired in Barbados.

5.3 Gun-boosted Rocket Properties

The first gun-boosted rocket to be successfully flown from a HARP gun was a 5-inch aluminum body, fixed fin, subcaliber, solid propellant rocket fired from the Barbados 16-inch gun in September 1963, (Martlet 3A). This was followed in July 1964 by flights of a 9-inch steel body Martlet 3B at muzzle velocities up to 3200 feet per second and an acceleration level of 8000 g's. Figure 8 shows a Martlet 3B with a sun sensor slot and an antenna for 250 MHz telemetry. These tests[18] showed, however, that higher muzzle velocities and higher accelerations were not feasible for these unsupported center hole grains since the grains break up and ignition and explosion failure ensue. Hence, an engineering development was indicated.



MARTLET-3B

Fig. 8 16-inch subcaliber gun-boosted rocket.

Since July 1964, the gun was lengthened and a steel Martlet 3B was successfully fired[17] at 8000 g's and attained a muzzle velocity of 5200 feet per second. The low mass fraction associated with the metal bodies has been raised by introducing the use of fiber glass bodies. The first fiber glass versions were successfully fired at 3800 feet per second and improved versions are being developed. The peak performance of a developed subcaliber gun-boosted rocket is 800,000 feet with 35 pounds of payload. Eleven Martlet 3A's and twenty-five Martlet 3B's have been fired at Barbados. Ignition was attempted on all flights but the last 15 Martlet 3B's which were primarily structural tests.

The flight performance and economy of subcaliber rockets suffers severely in comparison with that of full-bore rockets which can carry 600 pounds to 400 miles at much lower cost per pound. The developmental problems of pop-out fins and 1000 to 1500 pound rocket motors seem to be well worth the effort, and the developmental effort is being shifted to work on the full-bore rocket. Several full-bore grains have been successfully launched horizontally at a muzzle velocity of 2200 feet per second and a number of pop-out fin tests have been made. Vertical flights of a 16-inch full-bore rocket are planned for late 1966.

5.4 Sites

In addition to the 119-foot long Barbados gun, a second 119-foot long gun is located at Yuma Proving Ground, Arizona (Figure 9), and a 104-foot long horizontal fire gun is located at Highwater, Quebec. The Yuma gun is limited by a 35-mile range restriction but possesses the important advantages of ground recovery and near geographical location to the West Coast rocket manufacturers. In addition to scientific soundings with Martlet 2's, this gun will be used for flight tests of attitude control and telemetry components requiring ground recovery and short duration rocket flights as well as other engineering tests appropriate to this location. The Highwater gun is used primarily for missile-sabot structural integrity tests, charge development, and rocket grain tests (see Section 7.2).

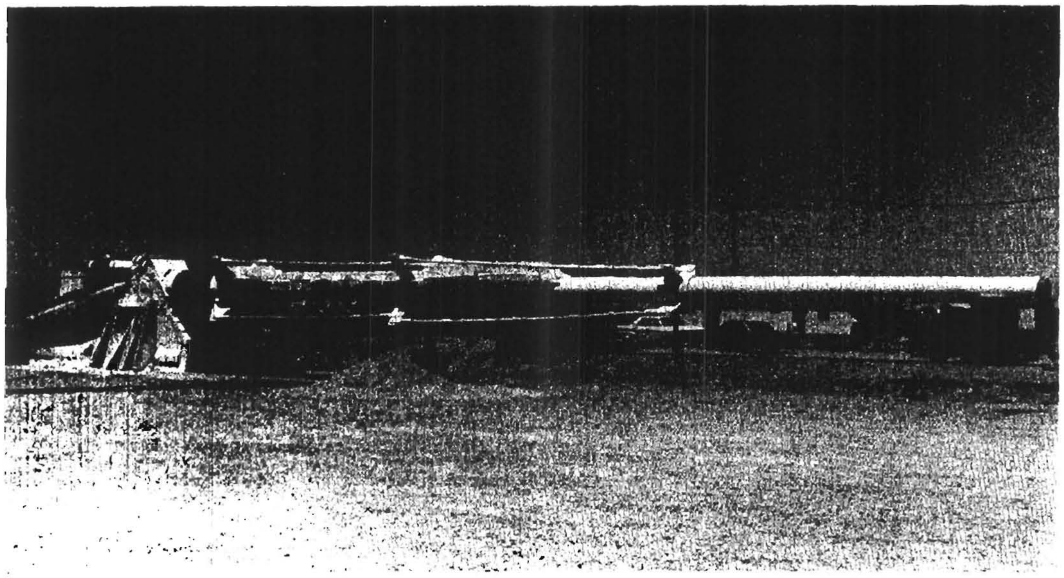


Fig. 9 16-inch extended smoothbore gun at Yuma Proving Ground, Arizona.

6. MULTI-STAGE GUN-BOOSTED ROCKETS

The full potential of the large caliber gun launch concept can only be realized by multi-stage gun-boosted rockets. Computer studies show that a three stage gun-boosted rocket can reach ICBM reentry velocities[19] or can generate sufficient velocity to establish an orbit.[20,21] In these studies, the three stage solid propellant rocket weighs 2000 pounds and is launched at 4500 feet per second by the extended 16-inch gun. Thus, the gun acts as a fairly large reusable first stage booster and, thereby, provides a low cost system for reentry studies or small satellite launches. The use of liquid propellant upper stages or larger caliber guns significantly increases payloads and reduces the cost per pound. A 32-inch gun, for example, will provide ten times the payload of the 16-inch gun for either mission.

Preliminary computer studies for the reentry mission have made use of two vacuum specific impulses, 250 second and 300 second, with corresponding payload weights of 50 pounds and 100 pounds. For both cases, stage mass fractions of 0.8 were assumed. Stage weights of

1200, 550, and 250 were assumed for the 50-pound payload and 1200, 500, and 300 for the 100-pound payload. A sample 50-pound payload trajectory calls for gun launch at 60 degrees elevation, first state ignition 35 seconds after launch with burnout velocity of 8260 feet per second, second stage ignition immediately following with burnout velocity of 14,300 feet per second, and a coast phase of 600 seconds before third stage ignition. With this program, the 50-pound payload is placed 1260 n.m. downrange with a velocity of 21,800 feet per second at 230,000 feet altitude and a reentry angle of -22 degrees. A possible orbit mission is shown in Figure 10.

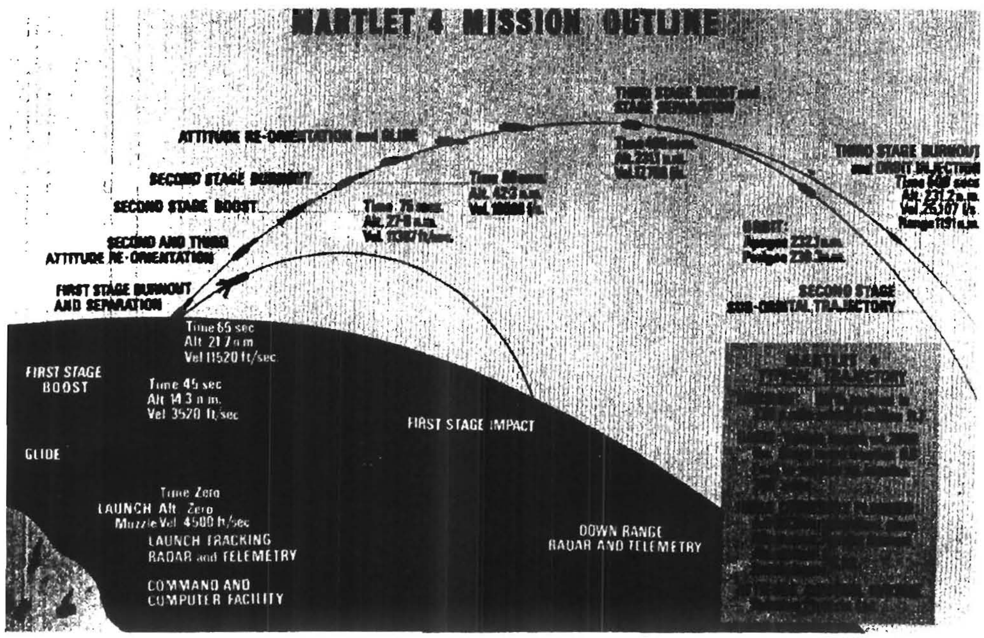


Fig. 10

The key engineering needs for either mission are development of a large first stage rocket and an acceleration resistant attitude control system. Since the full-bore 16-inch rocket has already been discussed, we will examine here the question of the attitude control system.

The primary components of attitude control systems are a spin rate sensor, a sun sensor, an infra-red horizon sensor, a computer and cold gas reaction jets (Figure 11). The combination of sun sensor and horizon sensors can be used to determine the missile's attitude with respect to the sun and a normal to the earth.[22] The computer can then be used to properly position the upper stages during burning by means of the reaction jets. A breadboard version of this system has been assembled and successfully operated. All components have been launched at 10,000 g's from a 6-inch gun, recovered, and shown to be undamaged. First flight tests of the complete system are planned for late 1966.

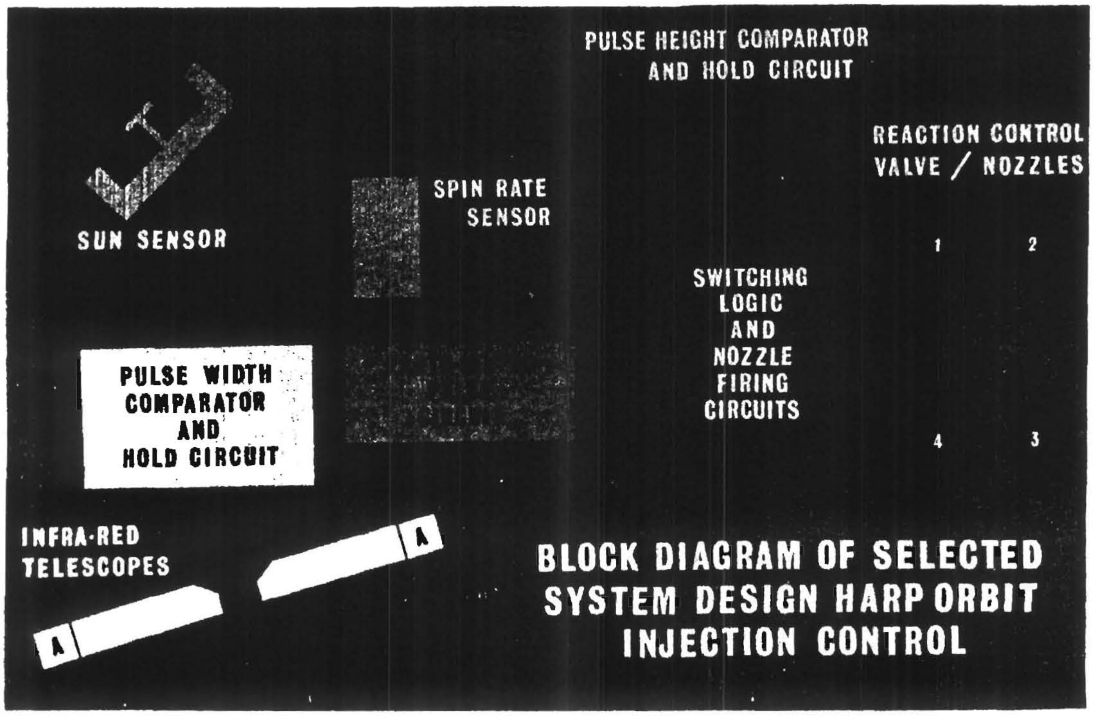


Fig. 11

7. HARP RANGES

7.1 Barbados Range (57.5° W; 13.1° N)

The Barbados range combines the advantage of a tropic location with the advantages of very long flights over water and nearness of various Eastern Test Range facilities. Its major disadvantage is remoteness from the industrial centers of North America.

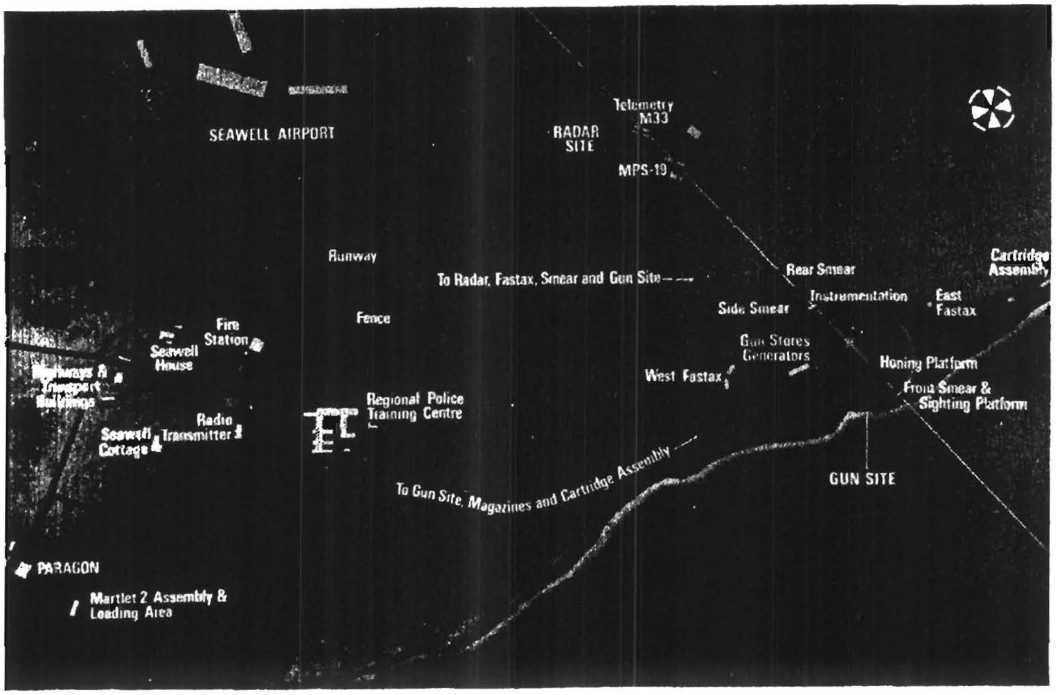


Fig. 12

The 16-inch gun* is located near the East end of the main runway for Seawell Airfield and fires on an asimuth of 119 degrees (Figure 12). On the cliff behind the gun, there are four camera locations (East Fastax Rear Smear, Side Smear, and West Fastax) and in front of the gun on a 50-foot tower a fifth location (Front Smear). Two thousand feet behind the gun are located the radars (M33 and MPS-19) and a telemetry receiving station (Figures 13 and 14). The MPS-19 can skin-track the Martlet 2 to 350,000 feet and the 5-inch projectile all the way, while the M33 is used for area surveillance. Almost 2 miles down the coast is the Range headquarters at Paragon House. This building houses the Launch Control Center, radio communications center, another telemetry receiving station, machine shop, and other supporting administrative activities. In view of the gun-runway location, all flights are cleared with the Seawell Control tower in addition to advising the Eastern Test Range (Cape Kennedy) as to firing schedule and results.

**The 5-inch gun is located directly in front of the 16-inch gun and fires on the same azimuth.*

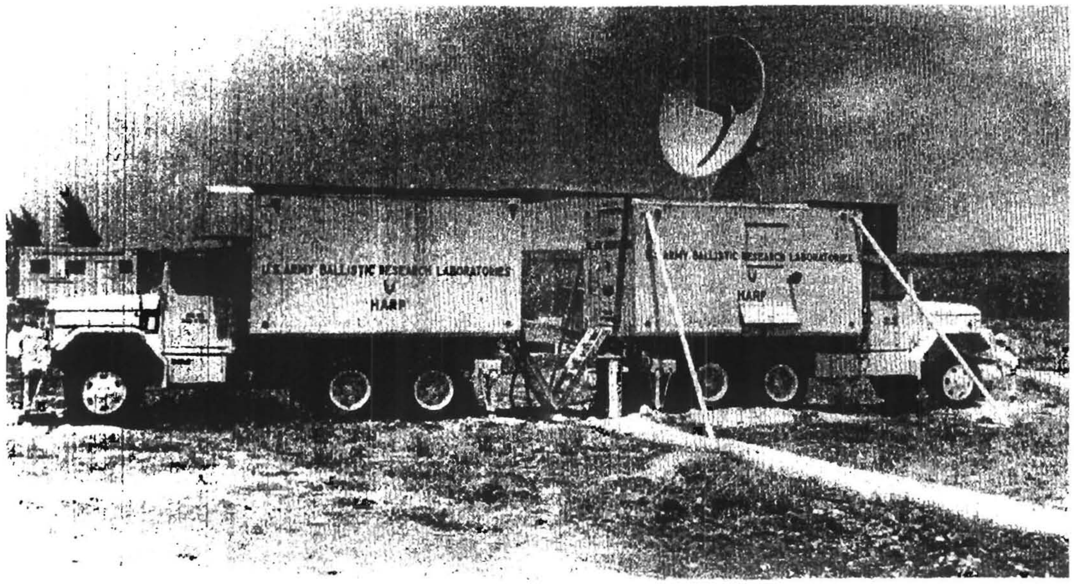


Fig. 13 HARP-Barbados MPS-19 radar.

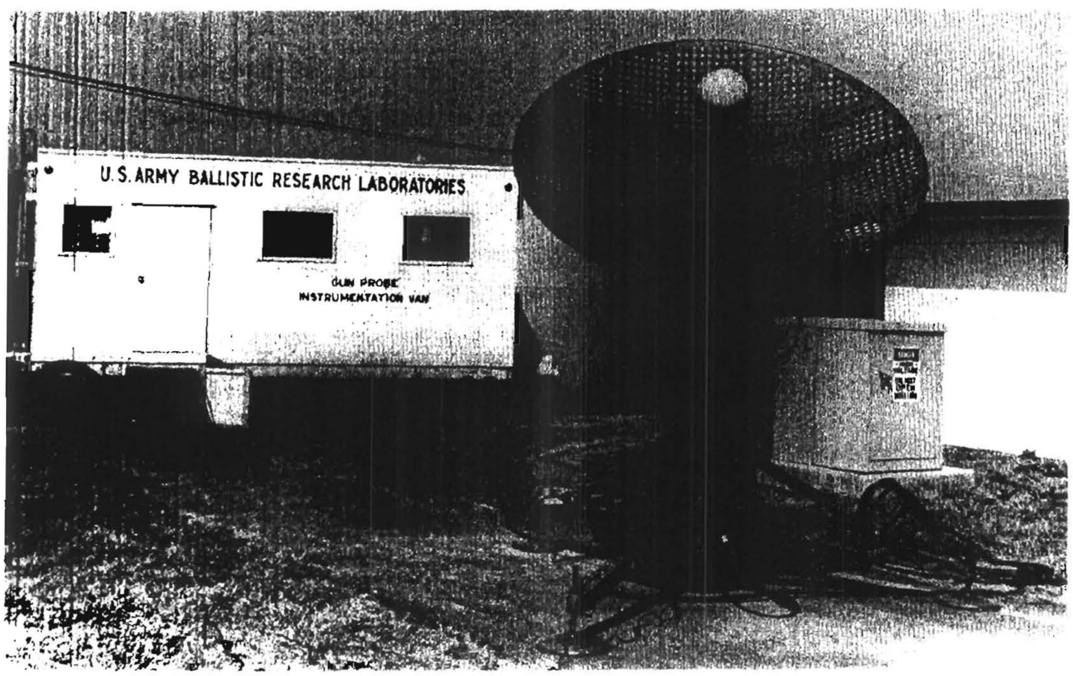


Fig. 14 1750 MHz receiving station and tracking antenna (modified GMD-1).

For proper coverage of the nighttime TMA trails, K-24 camera stations are operated on the islands of St. Vincent, Grenada, and Tobago, as well as on Barbados itself (Figure 15). All photographic stations are in radio communication with the HARP Launch Control Center. When they are available, additional radar support is supplied by the Eastern Test Range's radar on Trinidad as well as the ETR radar ship Twin Falls. The Trinidad radar has no difficulty in skin-tracking both the Martlet 2 and the 5-inch projectile from a range of over 200 miles.

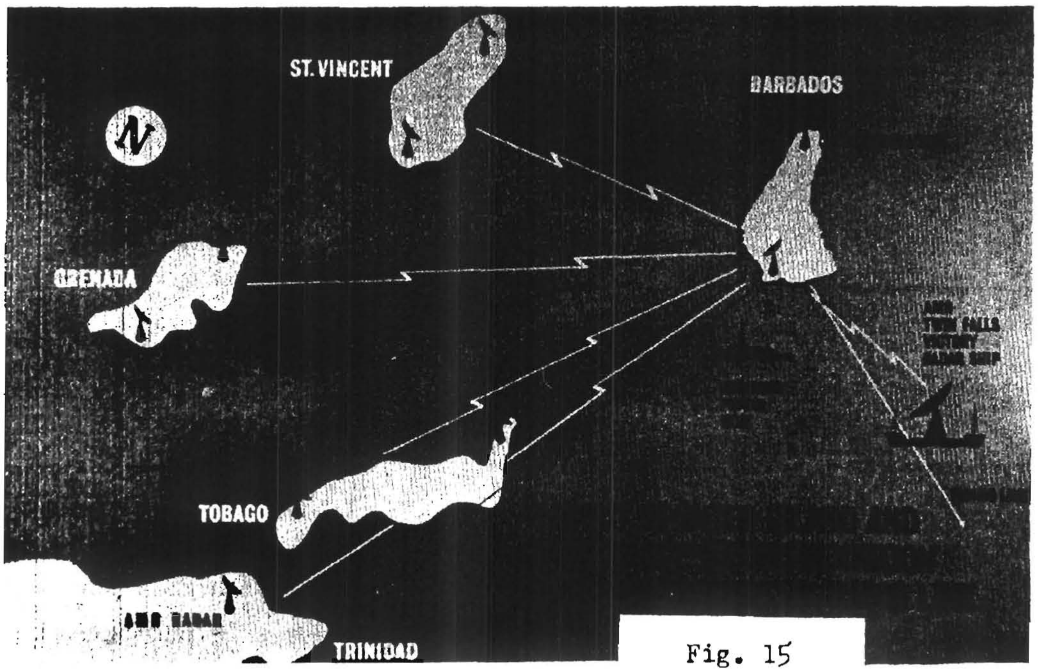


Fig. 15

7.2 Highwater Range (73^{o} 31' W; 45^{o} 2' N)

The Highwater Range is located in the Province of Quebec about 2 miles north of the Vermont border in the Green Mountains. It is in a natural valley which allows a restricted line of fire to the southwest (Figure 16). The range has been designed for large rocket flights with earth butts bulldozed at regular distances to destroy the vehicle should it deviate from the normal flight path which passes through a series of concrete tunnels. The natural valley also contributes to the overall safety of the range. Impact butts are located at 500 feet and 3000 feet (Stages 1 and 2) and a third butt can be located further down range to allow a flight of 10,000 feet (Stage 3). The particular impact point can be selected by adjusting the gun elevation.

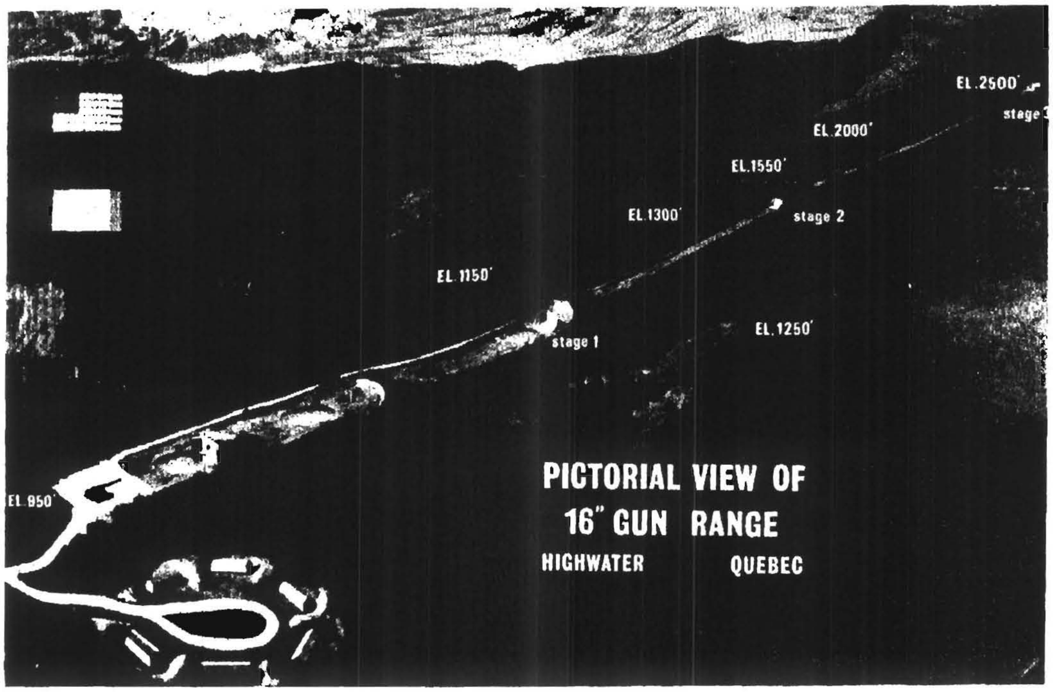


Fig. 16

The 16-inch gun* is elevated by means of a steel structure located near its center of gravity (Figure 17). A number of both full bore and subcaliber rockets have been successfully fired here with photographic coverage to determine structural integrity. In addition to structural tests of rocket grains and new sabot designs, interest is growing in using this gun to launch large configurations at hypersonic Mach numbers to measure various aerodynamic quantities such as heat transfer, surface pressures, and dynamic stability by means of onboard sensors and telemetry units.

A 6-inch gun is also located here for component tests and development of the 7-inch gun-boosted rocket.

Fig. 17 16-inch horizontal fire gun at Highwater, P.Q., Canada.

8. TWO HARP EXPERIMENTS

8.1 D-Layer Electron Density

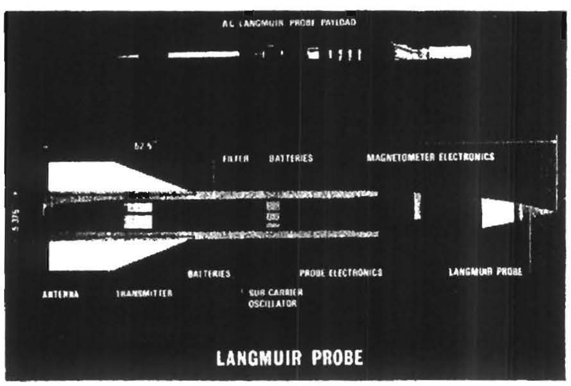


Fig. 18

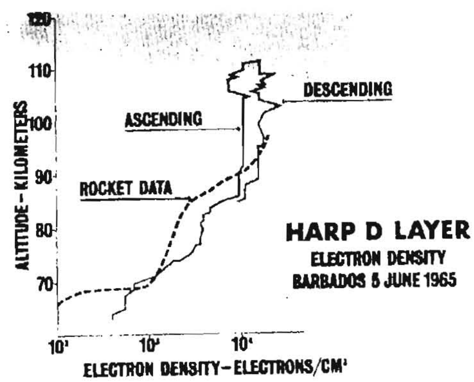


Fig. 19

The most sophisticated HARP experiment that has been carried out is the measurement of electron densities and temperatures by means of Langmuir probes.[23] The basic Langmuir payload has been hardened to 30,000 g's for launch from both the 7-inch gun as well as the 16-inch gun.

(Figure 18 shows the probe packaged for the Martlet 2.) The first successful flight of this probe was made in June of 1965 from the Barbados gun, using 1750 MHz telemetry (Figure 19). A number of additional flights of the Langmuir probe are planned for both guns in the summer of 1966.

8.2 Ionospheric Winds

The most detailed HARP experiment has been the measurement of ionospheric winds[24] by means of luminous TMA trails released from a Martlet 2 (Figure 20). The luminous trail which can be seen for over 200 miles and persists for over 15 minutes is photographed by the K-24 camera stations (Figure 21). The resulting photograph can be analyzed to yield wind profiles from 90 to 140 km (Figure 22). Records are concurrently

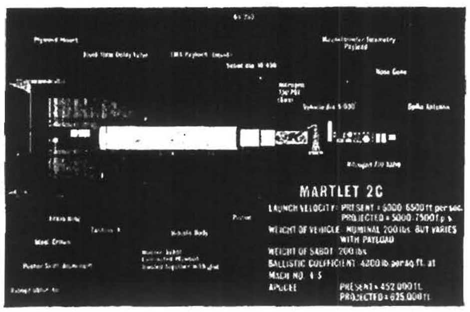


Fig. 20

Fig. 21 TMA trail over Barbados, W.I.

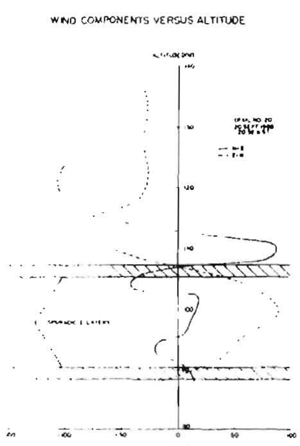


Fig. 22

taken by a ground-based ionosonde and correlations between location of sporadic E layers and high EW wind shear layers are studied. Fifty trails have been successfully photographed over Barbados and more are planned both at Barbados and at Yuma. With these synoptic studies in progress, an understanding of air circulation above 90 km and its effect on weather and communications seems to be realizable. The rapid variation of ionospheric wind throughout a night can be graphically shown by contour plots based on six HARP trails made in September 1965 (Figures 23 and 24).

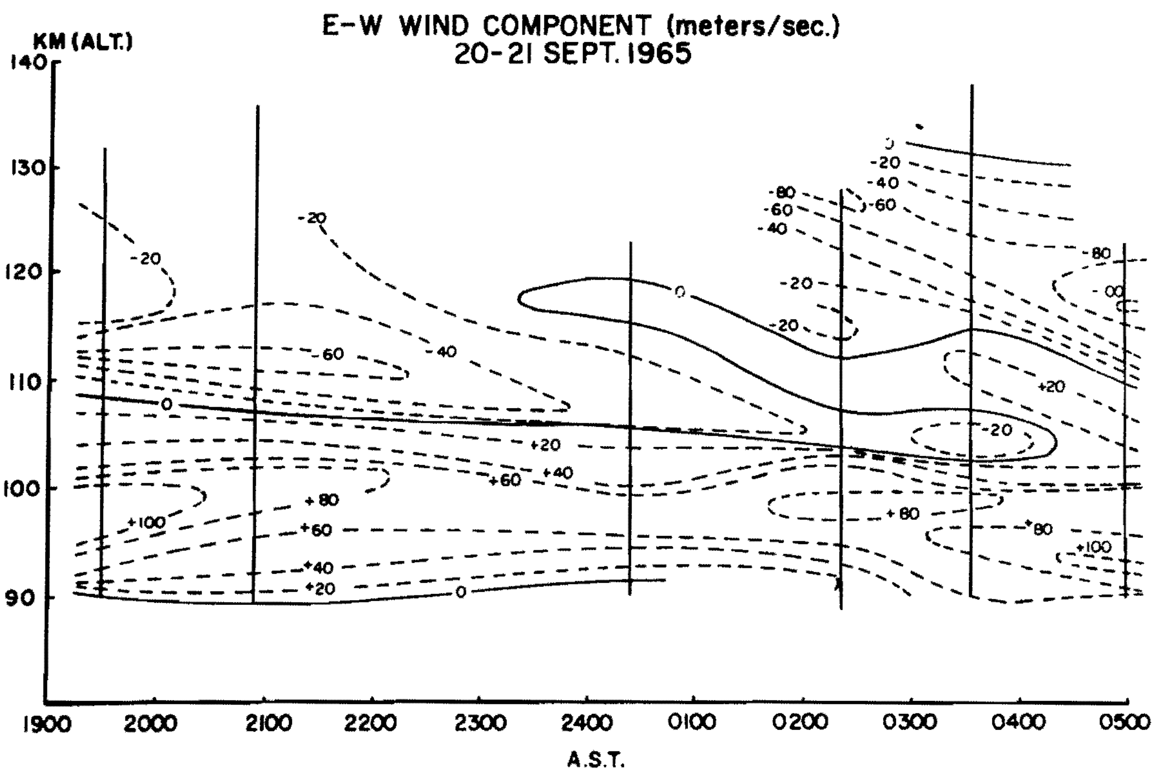


Fig. 23

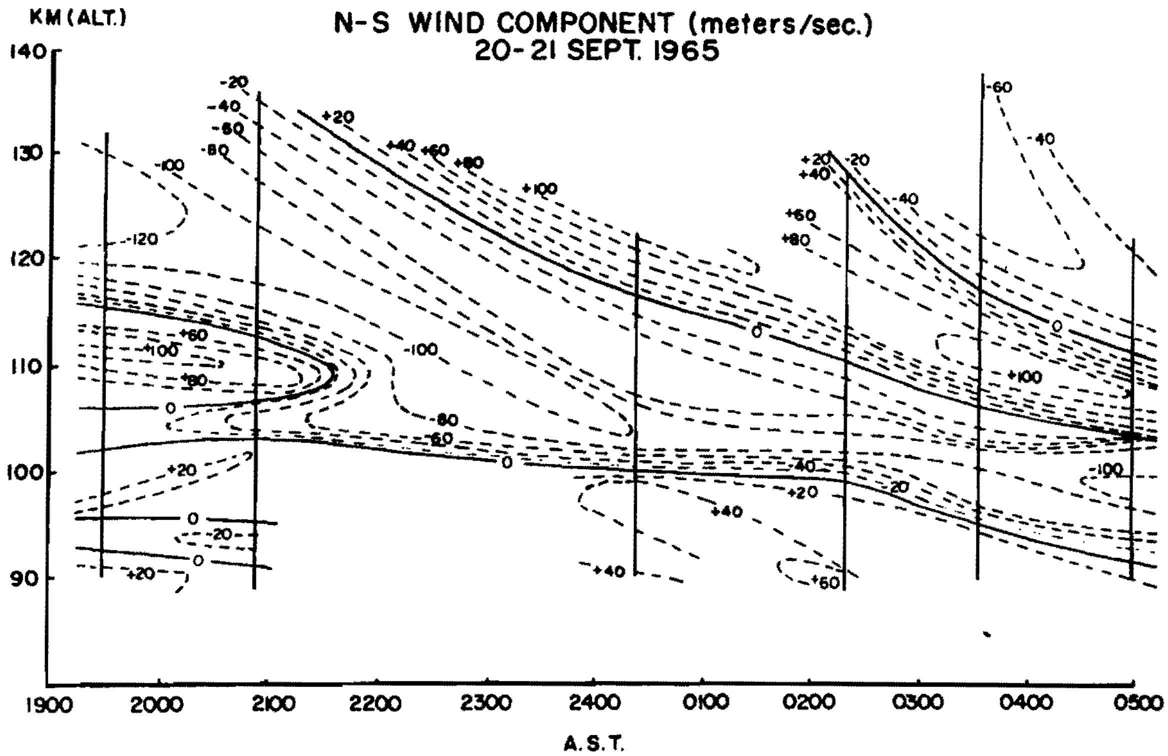


Fig. 24

9. SUMMARY

a. HARP gun-launched projectiles have reached an operational condition of routine synoptic sounding to 140 km at low unit costs.

b. HARP full-bore gun-launched rockets promise much greater performance but retain the ecomony of the gun system.

c. Full-bore multi-stage gun-boosted rockets have tremendous performance potentialities and the key problem areas of the rocket motor and attitude control units are under intensive study.

C. H. MURPHY G. V. BULL

REFERENCES

1. MacAllister, L. C. and Bradley, J. W. Comments on the Use of Guns to Launch High Altitude Probes. Ballistic Research Laboratories Memorandum Report 1252, March 1960.

2. Bull, G. V. and Murphy, C. H. Gun Launched Missiles for Upper Atmosphere Research. AIAA Preprint No. 64-18, January 1964. (See also: Bull, G. V. Development of Gun Launched Vertical Probes for Upper Atmosphere Studies, CAS Journal, Volume 10, pp. 236-243, October 1964.)

3. Mermagen, W. H. HARP 250mc Telemetry Experiments, June-October 1964. Ballistic Research Laboratories Memorandum Report 1614, December 1964.

4. Cruickshank, W. J. A Feasibility Test of a 1750 mc/s Telemetry and Tracking System for Five-Inch HARP Projectiles. Ballistic Research Laboratories Memorandum Report 1651, May 1965.

5. Mermagen, W. H.; Cruickshank, W. J. and Vrataric F. VHF and UHF High-G Telemetry Instrumentation for HARP Vehicles. Ballistic Research Laboratories Memorandum Report 1768, May 1966.

6. Marks, S.; MacAllister, L. C.; Gehring, J. W.; Vitagliano, H. D. and Bentley, B. T. Feasibility Test of an Upper Atmosphere Gun Probe System. Ballistic Research Laboratories Memorandum Report 1368, October 1961.

7. Marks, S. and Boyer, E. D. A Second Test of an Upper Atmosphere Gun Probe System. Ballistic Research Laboratories Memorandum Report 1464, April 1963.

8. Boyer, E. D. Five-Inch HARP Tests at Wallops Island, September 1963. Ballistic Research Laboratories Memorandum Report 1532, January 1964.

9. Williamson, L. E. Gun Launched Vertical Probes at White Sands Missile Range. ECOM-5030, February 1966.

10. The Meteorological Rocket Network, Inter-Range Instrumentation Group Document 111-64, 1964.

11. Mermagen, W. H. HARP 250mc Telemetry Experiments, Wallops Island, March 1965. Ballistic Research Laboratories Memorandum Report 1694, September 1965.

12. Brown, J. A. and Marks, S. T. Feasibility Test of a Potential Meteorological Shell for the Standard 175 mm Gun. Ballistic Research Laboratories Technical Note 1584, February 1966.

REFERENCES (Contd)

13. Boyer, E. D. and MacAllister, L. C. Seven-Inch HARP Gun-Launched Vertical Probe System: Initial Development. Ballistic Research Laboratories Memorandum Report 1770, July 1966.

14. Lorimor, G. Analysis of Carriages Suitable for 7-Inch HARP Gun. Rock Island Arsenal Report 3-65, January 1965.

15. Rosenberg, N. W. Chemical Releases in the Upper Atmosphere (Project Firefly). A Summary Report, Journal of Geophysical Research, Volume 68, Number 10, pp. 3057-3063, May 15, 1963.

16. Staff, Department of Mechamical Engineering. Report on the First Twelve Firings and Status as of July 30, 1963. McGill University Report 63-5, November 1963.

17. Bull, G. V. and Luckert, H. J. Report of the March 1965 Test Firing Series, Project HARP. Space Research Institute, McGill University H-R-9, July 1965.

18. Groundwater, F. M. Report on the Martlet 3B Series of Firings. Space Research Institute, McGill University H-R-7, September 1964.

19. Bull, G. V. and Eacott, K. Proposal for Using Gun-Launched Rockets for Target Placement. McGill University, S.R.I. Proposal, July 1965.

20. McKee, R. M. A Parametrics Study of Multi-Stage Gun Launched Rockets. McGill University, SRI-H-R-2, March 1965.

21. McKee, R. M. Continuation of Gun-Launched Rocket Parameter Study. McGill University, SRI-H-R-5, May 1965.

22. Raymond, H. Orbit Injection Control for the Martlet 4 Vehicle. Aviation Electric Limited. Montreal, AETR 13541, March 1965. (See also Canadian Aeronautics and Space Journal Volume 11, No. 5, pp. 153-159, May 1965.)

23. Block, A. V.; Kodis, A. L. and Smith L. C. High Altitude Gun Probes (Development of Langmuir Probes). G.C.A. Technical Report 65-15-G, September 1965.

24. Murphy, C. H.; Bull, G. V. and Edwards, H. D. Ionospheric Winds Measured by Gun Launched Projectiles. Journal Geo. Res. 71, pp. 4535-4545, October 1966. (See also Ballistic Research Laboratories Memorandum Report 1747, May 1966.)

25. Boyer, E. D. Five-Inch HARP Tests at Barbados, West Indies January-February 1966. Ballistic Research Laboratories Memorandum Report 1771, July 1966.

DISTRIBUTION LIST

No. of Copies	Organization
20	Commander Defense Documentation Center ATTN: TIPCR Cameron Station Alexandria, Virginia 22314
1	Director of Defense Research & Engineering (OSD) ATTN: Tech Lib Washington, D.C. 20301
2	Director Advanced Research Projects Agency ATTN: MAJ G. Sherwood Department of Defense Washington, D.C. 20301
1	Director Weapons Systems Evaluation Group Washington, D.C. 20305
1	Director Institute for Defense Analyses ATTN: Mr. J. Sherman 400 Army-Navy Drive Arlington, Virginia 22202
6	Headquarters Defense Atomic Support Agency ATTN: STRA, Mr. Haas STRA-RAEL, LTC J. Brown Dr. Blank Docu Lib (3 cys) Washington, D.C. 20301
1	DASA Data Center TEMPO, General Electric Company 735 State Street Santa Barbara, California 93101
1	Director Defense Intelligence Agency Washington, D.C. 20301
1	Commander Defense Supply Agency ATTN: Value Engr Svc Ofc DSA-DVEO, Mr. MacKechnie Cameron Station Alexandria, Virginia 22314
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-RP-B Washington, D.C. 20315
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-DE Washington, D.C. 20315
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-DN, Mr. Stulman Washington, D.C. 20315
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-RV-A Washington, D.C. 20315
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-RV-E, Mr. Philippe Washington, D.C. 20315
1	Commanding General U.S. Army Materiel Command ATTN: AMCRD-SS-R Washington, D.C. 20315
4	Commanding General U.S. Army Electronics Command ATTN: AMSEL-RD, Dr. W. McAfee AMSEL-RD-PFM, Mr. I. Chase AMSEL-RD AMSEL-EW Fort Monmouth, New Jersey 07703

DISTRIBUTION LIST

No. of Copies	Organization
4	Commanding General U.S. Army Electronics Command ATTN: AMSEL-BL-D Atm Phys Div Atm Sc Rsch Div Atm Sc Ofc Fort Monmouth, New Jersey 07703
3	Commanding General U.S. Army Electronics Command ATTN: AMSEL-WL-C, Mr. B. Flood AMSEL-WL-N, Mr. S. Davis Tech Lib Fort Monmouth, New Jersey 07703
2	Commanding Officer U.S. Army Electronics Research and Development Activity ATTN: Met Dept Fort Huachuca, Arizona 85613
7	Commanding Officer U.S. Army Electronics Research and Development Activity ATTN: Envir Sc Dir (2 cys) Mr. W. L. Webb Msl Met Div (2 cys) SELWS-MR, Mr. J. Mason SELWS-EE, Mr. G. Bigelow White Sands Missile Range New Mexico 88002
3	Commanding General U.S. Army Missile Command ATTN: AMSMI-XG AMSMI-RR AMSMI-RRA Redstone Arsenal, Alabama 35809
3	Commanding General U.S. Army Missile Command ATTN: AMSMI-RP AMSMI-RH AMSMI-AML Redstone Arsenal, Alabama 35809
1	Director Redstone Scientific Information Center ATTN: Ch, Docu Sec U.S. Army Missile Command Redstone Arsenal, Alabama 35809
1	Chief, Army Field Office USAF National Range Division Eastern Test Range Patrick AFB, Florida 32925
2	Commanding General U.S. Army Mobility Command ATTN: AMSMO-RD-R Warren, Michigan 48090
1	Commanding Officer U.S. Army Aviation Materiel Laboratories Fort Eustis, Virginia 23604
1	Commanding Officer U.S. Army Engineer Research and Development Laboratories ATTN: STINFO Div Fort Belvoir, Virginia 22060
3	Commanding General U.S. Army Munitions Command ATTN: Tech Lib AMSMU-RC AMSMU-RE-R Dover, New Jersey 07801

DISTRIBUTION LIST

No. of Copies	Organization
1	Director U.S. Army MUCOM Operations Research Group Edgewood Arsenal, Maryland 21010
3	Commanding Officer U.S. Army Biological Laboratories ATTN: Prog Coord Ofc Tech Lib SMUFD-12-TI Frederick, Maryland 21701
1	Commanding Officer U.S. Army Edgewood Arsenal ATTN: SMUEA-TSTI Edgewood Arsenal, Maryland 21010
2	Commanding Officer U.S. Army Frankford Arsenal ATTN: N3000 SMUFA-1140 Philadelphia, Pa. 19137
3	Commanding Officer U.S. Army Picatinny Arsenal ATTN: SMUPA-TV-3 Sp Wpn Gp SMUPA-V, Mr. A. White Dover, New Jersey 07801
1	Commanding Officer U.S. Army Arctic Test Center APO Seattle 98733
1	President U.S. Army Artillery Board Fort Sill, Oklahoma 73504
1	Commanding Officer U.S. Army Dugway Proving Ground ATTN: Met Div Dugway, Utah 84022
3	Commanding Officer U.S. Army Electronic Proving Ground ATTN: Tech Lib (2 cys) Fld Test Dept Fort Huachuca, Arizona 85613
1	Commanding Officer U.S. Army Yuma Proving Ground Yuma, Arizona 85364
1	Commanding Officer U.S. Army Watervliet Arsenal ATTN: Mr. P. Netzer Watervliet, New York 12189
2	Commanding Officer U.S. Army Cold Regions Research & Engineering Laboratory ATTN: Envir Rsch Br Hanover, New Hampshire 03755
2	Commanding General U.S. Army Deseret Test Center ATTN: Design & Anal Div (1 cy) Fort Douglas, Utah 84113
8	Commanding Officer U.S. Army Harry Diamond Laboratories ATTN: Sec 210, Mr. Wilkin Sec 230, Mr. Finger Sec 530, Mr. Tuccinardi Mr. Vrateric (5 cys) Washington, D.C. 20438
1	Commanding Officer Lexington-Blue Grass Army Depot ATTN: Maint Div, Engr Br Mr. C. Tate Lexington, Kentucky 40507
2	Commanding General U.S. Army Natick Laboratories ATTN: Earth Sc Div Natick, Massachusetts 01762

DISTRIBUTION LIST

No. of Copies	Organization
2	Commanding General U.S. Army Combat Developments Command ATTN: CDCMR-E CDCRE Fort Belvoir, Virginia 22060
1	Commanding Officer U.S. Army Combat Developments Command Institute of Nuclear Studies Fort Bliss, Texas 79916
1	Commanding Officer U.S. Army Combat Developments Command Air Defense Agency Fort Bliss, Texas 79916
1	Commanding Officer U.S. Army Combat Developments Command Artillery Agency Fort Sill, Oklahoma 73504
1	Commanding Officer U.S. Army Combat Developments Command Chemical-Biological-Radiological Agency ATTN: Mr. N. W. Bush Fort McClellan, Alabama 36205
1	Commanding Officer U.S. Army Combat Developments Command Communications-Electronics Agency Fort Monmouth, New Jersey 07703
1	Director, Huachuca Office U.S. Army Combat Developments Command Communications-Electronics Agency Fort Huachuca, Arizona 85613
1	Commanding Officer U.S. Army Combat Developments Command Transportation Agency Fort Eustis, Virginia 23604
2	Commanding General U.S. Continental Army Command ATTN: ODCS/Intel, Recon Br (1 cy) Fort Monroe, Virginia 23351
1	Commandant U.S. Army Artillery & Missile School ATTN: Tgt Acq Dept Fort Sill, Oklahoma 73504
1	Commandant U.S. Army Chemical School ATTN: Micrometeorological Sec Fort McClellan, Alabama 36205
1	Commandant U.S. Army Signal Center & School ATTN: Met Dept Fort Monmouth, New Jersey 07703
1	Assistant Secretary of the Army (R&D) ATTN: Mr. C. L. Poor Washington, D.C. 20310
2	Chief of Communications-Electronics ATTN: OCCE-ES-2 Elct Sys Div Department of the Army Washington, D.C. 20315
1	Chief of Engineers Department of the Army Washington, D.C. 20315

DISTRIBUTION LIST

No. of Copies	Organization
1	Commanding Officer U.S. Army Map Service ATTN: Mr. R. Vitek Corps of Engineers 6500 Brooks Lane Washington, D.C. 20315
1	Commanding Officer U.S. Army Engineer Waterways Experiment Station ATTN: WES-FV P.O. Box 631 Vicksburg, Mississippi 39180
2	Chief of Research and Development ATTN: CRD/C Department of the Army Washington, D.C. 20310
3	Director U.S. Army Research Office ATTN: Mrs. F. Whedon Dr. H. Lemons CRD/M 3045 Columbia Pike Arlington, Virginia 22204
2	Commanding Officer U.S. Army Research Office (Durham) ATTN: Mr. J. Lane Mr. R. Mace Box CM, Duke Station Durham, North Carolina 27706
1	Assistant Chief of Staff for Force Development ATTN: CBR & Nuc Op Department of the Army Washington, D.C. 20310
1	Superintendent U.S. Army Military Academy ATTN: Lib West Point, New York 10996
1	Assistant Chief of Staff for Intelligence ATTN: ACSI-DSRSI Department of the Army Washington, D.C. 20310
4	Chief of Naval Operations ATTN: Code 427 (1 cy) Department of the Navy Washington, D.C. 20350
3	Chief of Naval Research ATTN: Code 427 Dr. F. Byrne Mr. J. Winchester Department of the Navy Washington, D.C. 20360
3	Commander U.S. Naval Air Systems Command Headquarters ATTN: AIR-604 Department of the Navy Washington, D.C. 20360
1	Commander U.S. Naval Ship Systems Command Headquarters ATTN: SHIP-031 Department of the Navy Washington, D.C. 20360
1	Commanding Officer U.S. Naval Air Development Center, Johnsville ATTN: EDE-6, Mr. S. Grillo Warminster, Pennsylvania 18974
1	Commanding Officer & Director U.S. Navy Electronics Laboratory ATTN: Code 32701 San Diego, California 92152

DISTRIBUTION LIST

No. of Copies	Organization
3	Commander U.S. Naval Ordnance Laboratory ATTN: Mr. M. Parker Dr. P. Thurston Mr. C. Kessler Silver Spring, Maryland 20910
1	Superintendent U.S. Naval Postgraduate School ATTN: Tech Rept Sec Monterey, California 93940
2	Commanding Officer U.S. Naval Propellant Plant ATTN: REDPZ, Mr. B. Kirk Mr. Jim Edwards Indian Head, Maryland 20640
3	Director U.S. Naval Research Laboratory ATTN: Astrophys & Atm Div Dr. P. Mange Tech Lib Washington, D.C. 20390
2	Commander U.S. Naval Weapons Laboratory ATTN: Dr. Kemper Mr. D. Sloan Dahlgren, Virginia 22448
1	Director U.S. Naval Weather Service Office Washington Navy Yard Washington, D.C. 20390
1	Officer in Charge U.S. Navy Weather Research Facility Naval Air Station Norfolk, Virginia 23511

No. of Copies	Organization
3	HQ USAF (AFRDC; AFRDQ; AFTAC) Washington, D.C. 20330
2	HQ USAF (AFRDQ-PO; AFNIN) Washington, D.C. 20330
2	OAR (RROSI; RRW) T-D Building Washington, D.C. 20333
1	AFOSR (SGRL/Tech Info & Intel Div) 1400 Wilson Boulevard Arlington, Virginia 22209
1	AFSC (SCW) Andrews AFB Washington, D.C. 20331
3	AEDC (VKF/Mr. Lukasiewicz, Mr. Clemens; AEOI) Arnold AFS Tennessee 37389
1	RTD (RTTR) Bolling AFB, D.C. 20332
1	APGC (PGBPS-12) Eglin AFB Florida 32542
1	APGC (PGOW) Eglin AFB Florida 32542
1	APGC (PGOZP) Eglin AFB Florida 32542
1	APGC (PGTRI) Eglin AFB Florida 32542

DISTRIBUTION LIST

No. of Copies	Organization
1	USAFTAWC (OA) Eglin AFB Florida 32542
1	RADC (EMLAL-2) Griffiss AFB New York 13442
2	AFCRL (CRU/Dr. Newman; CRMXLT) L.G. Hanscom Fld Bedford, Massachusetts 01731
2	AFCRL (CRUB/Dr. Pfister, Dr. Champion) L.G. Hanscom Fld Bedford, Massachuseets 01731
3	AFCRL (CRXL; CRT; CRTPM) L.G. Hanscom Fld Bedford, Massachusetts 01731
4	AFCRL (CRZA; CRZC; CRZW; CRZI) L.G. Hanscom Fld Bedford, Massachusetts 01731
1	ESD (ESTI) L.G. Hanscom Fld Bedford, Massachusetts 01731
1	AFMDC (MDLD) Holloman AFB New Mexico 88330
5	AFWL (WLL; WLS; WLRS/Dr. Dyal) Kirtland AFB New Mexico 87117
3	AFWL (WLRP; WLRJ; WLREH) Kirtland AFB New Mexico 87117
1	SSD (SSSD) AF Unit Post Office Los Angeles, California 90045
1	BSD (BSR) Norton AFB California 92409
1	AWS (AWSSS/TIPD) Scott AFB Illinois 62226
1	AFIT Wright-Patterson AFB Ohio 45433
1	ARL (ARD) Wright-Patterson AFB Ohio 45433
1	ASD (ASBW) Wright-Patterson AFB Ohio 45433
1	USAF Project RAND The Rand Corporation 1700 Main Street Santa Monica, California 90406
2	Director Environmental Science Services Administration ATTN: Code W533 Code R321 Mr. Ashenfelter U.S. Department of Commerce Silver Spring, Maryland 20910
4	Director Environmental Science Services Administration ATTN: Code R4.2, Dr. Shapley Code R413, Mr. Gautier Code R445, Dr. Ferguson U.S. Department of Commerce Boulder, Colorado 80302

DISTRIBUTION LIST

No. of Copies	Organization
2	Director Environmental Science Services Administration ATTN: Code R31, Dr. Weickmann Code R44, Dr. Van Zandt U.S. Department of Commerce Boulder, Colorado 80302
1	Director Institute for Atmospheric Sciences U.S. Department of Commerce c/o Robert A. Taft Sanitary Engineering Center 4676 Columbia Parkway Cincinnati, Ohio 45226
2	Headquarters U.S. Atomic Energy Commission ATTN: BM, Mr. Holland Tech Rpt Lib Washington, D.C. 20545
1	Director U.S. Atomic Energy Commission ATTN: Tech Info Div P.O. Box 62 Oak Ridge, Tennessee 37831
1	Director Argonne National Laboratory ATTN: Lib Sv Dept, Rpt Sec 9700 South Cass Avenue Argonne, Illinois 60440
1	Director Brookhaven National Laboratory ATTN: Docu Gp, Clas Docu Sec 25 Brookhaven Avenue Upton, New York 11973
2	Director Lawrence Radiation Laboratory University of California ATTN: Dr. Ken Watson Berkeley, California 94704
2	Director Lawrence Radiation Laboratory University of California ATTN: Mr. R. Brier Mr. C. Cowan P.O. Box 808 Livermore, California 94551
2	Director Los Alamos Scientific Laboratory ATTN: Dr. H. Hoerlin Tech Lib P.O. Box 1663 Los Alamos, New Mexico 87544
1	Director Oak Ridge National Laboratory ATTN: Tech Lib P.O. Box X Oak Ridge, Tennessee 37831
1	Director Federal Aviation Agency ATTN: Sys R&D Svc 800 Independence Avenue, S.W. Washington, D.C. 20553
1	Director Federal Aviation Agency ATTN: NAFEC Lib Atlantic City Airport Atlantic City, New Jersey 08405
1	Director NASA Scientific and Technical Information Facility ATTN: SAK/DL P.O. Box 33 College Park, Maryland 20740
3	Headquarters National Aeronautics and Space Administration ATTN: Code SG, Dr. Dubin Code SL, Mr. Horowitz Code RRP, Mr. Gessow Washington, D.C. 20546

DISTRIBUTION LIST

No. of Copies	Organization
2	Headquarters National Aeronautics and Space Administration ATTN: Code SL, Dr. Fellows Code SAM Washington, D.C. 20546
4	Director National Aeronautics and Space Administration Ames Research Center ATTN: Dr. O. Koontz Dr. J. T. Howe Dr. N. Farlow Tech Lib Moffett Field, California 94035
3	Director National Aeronautics and Space Administration Goddard Space Flight Center ATTN: Mr. L. Brace Mr. K. Medrow Code 610 Greenbelt, Maryland 20771
3	Director National Aeronautics and Space Administration Goddard Space Flight Center ATTN: Dr. A. Aiken Dr. A. Temkin Dr. W. Hess Greenbelt, Maryland 20771
1	Director National Aneroautics and Space Administration Langley Research Center Langley Station Hampton, Virginia 23365
3	Director National Aeronautics and Space Administration Wallops Station ATTN: Mr. R. Krieger Mr. R. Welsh Mr. J. Green Wallops Island, Virginia 23337
2	Director National Science Foundation ATTN: Ch, Atm Sci Prog Mr. J. Heron Washington, D.C. 20550
1	Aerochem Research Laboratories, Inc. ATTN: Dr. H. Calcote P.O. Box 12 Princeton, New Jersey 08540
1	American Institute of Aeronautics & Astronautics ATTN: Tech Info Svc Lib 1290 Sixth Avenue New York, New York 10019
1	G. C. Dewey Corporation ATTN: Dr. M. Hirsch 202 East 44th Street New York, New York 10000
2	Douglas Aircraft Company, Inc. ATTN: Flt Mech Dept Aerophys Br Mr. Aldrich 3000 Ocean Park Boulevard Santa Monica, California 90405
1	Edgerton, Germeshausen & Grier, Inc. ATTN: Dr. M. Shuler 160 Brookline Avenue Boston, Massachusetts 02129

DISTRIBUTION LIST

No. of Copies	Organization
1	Electro-Optical Systems, Inc. ATTN: Dr. Richter 124 N. Vinedo Avenue Pasadena, California 91107
2	GCA Corporation ATTN: Mr. A. Block Dr. F. Marmo Burlington Road Bedford, Massachusetts 01730
1	General Applied Science Laboratories, Inc. Merrick & Stewart Avenues Westbury, New York 11590
1	General Dynamics/Convair ATTN: Dr. P. Mahadevan P.O. Box 1950 San Diego, California 92112
1	General Electric Company Center for Advanced Studies 816 State Street P.O. Drawer QQ Santa Barbara, California 93101
1	General Electric Company Re-Entry Systems Department ATTN: Dr. M. Bortner 3198 Chestnut Street Philadelphia, Pennsyvlania 19104
1	General Electric Company Space Sciences Laboratory ATTN: Dr. T. Baurer P.O. Box 8555 Philadelphia, Pennsylvania 19101
1	General Motors Corporation Defense Research Laboratories ATTN: Dr. Utterback Santa Barbara, California 93108
1	Kaman Nuclear A Division of Kaman Aircraft, Inc. ATTN: Dr. Shelton Garden of the Gods Road Colorado Spring, Colorado 80907
2	Lockheed Missile & Space Company ATTN: Dr. R. Meyerott Mr. J. Nakanishi Dept 85-71 1111 Lockheed Way Sunnyvale, California 94086
1	The Martin Company Orlando Division Orlando, Florida 32805
1	Meteorological Development Laboratory ATTN: Mr. Sissenwine 1065 Main Street Waltham, Massachusetts 02100
1	Metro Physics, Inc. 331 North Milpas Street Santa Barbara, California 93103
1	The Mitre Corporation P.O. Box 208 Middlesex Turnpike Bedford, Massachusetts 01730
2	National Center for Atmospheric Research ATTN: Lib Dr. W. Roberts P.O. Box 1558 Boulder, Colorado 80301
1	Nuclear Research Associates, Inc. ATTN: Mr. S. Goldblatt 3501 Queens Boulevard Long Island City, New York 11101

DISTRIBUTION LIST

No. of Copies	Organization
3	The Rand Corporation ATTN: Dr. R. Holbrook Dr. D. E. Gilmore Tech Lib 1700 Main Street Santa Monica, California 90406
3	The Rand Corporation ATTN: Dr. R. LeLevier Dr. C. Crain Dr. R. Latter 1700 Main Street Santa Monica, California 90406
1	RCA David Sarnoff Research ATTN: Dr. Sturzer Princeton, New Jersey 08540
1	Sandia Corporation ATTN: Info Dist Div P.O. Box 5800 Albuquerque, New Mexico 87115
1	Thiokol Chemical Corporation ATTN: Astro-Met Div Mr. Gil Moore P.O. Box 1497 Ogden, Utah 84401
1	TRW Systems Group One Space Park Redondo Beach, California 90278
1	United Aircraft Corporation ATTN: Mr. R. Bullis 400 Main Street East Hartford, Connecticut 06118
2	Western Microwave Laboratories, Inc. ATTN: Mr. E. Loeswich Mr. L. Miller 1045 DiGiulio Avenue Santa Clara, California 95050
1	Westinghouse Research & Development Center Beulah Road, Churchill Borough Pittsburgh, Pennsylvania 15235
1	Cornell Aeronautical Laboratory, Inc. P.O. Box 235 Buffalo, New York 14221
1	Denver Research Institute ATTN: Fed Cen Fld Op University of Denver Denver, Colorado 80210
1	Harvard College Observatory ATTN: Mr. R. McCrosky 60 Garden Street Cambridge, Massachusetts 02138
2	IIT Research Institute ATTN: Mr. R. Sears Docu Lib 10 West 35th Street Chicago, Illinois 60616
1	Massachusetts Institute of Technology Lincoln Laboratory ATTN: Mr. J. Pannell P.O. Box 73 Lexington, Massachusetts 02173
1	Professor M. Biondi Cathedral of Learning University of Pittsburgh Pittsburgh, Pennsylvania 15213

DISTRIBUTION LIST

No. of Copies	Organization
1	Professor S. Bowhill Department of Electrical Engineering University of Illinois Urbana, Illinois 61803
1	Professor C. Elvey Geophysical Institute of the University of Alaska College, Alaska 99735
1	Professor W. Fite Cathedral of Learning University of Pittsburgh Pittsburgh, Pennsylvania 15213
1	Professor E. Gerjuoy Cathedral of Learning University of Pittsburgh Pittsburgh, Pennsylvania 15213
1	Professor J. Gibbons, Jr. The Pennsylvania State University 330 Electrical Engineering East University Park, Pennsylvania 16802
1	Professor H. G. Houghton Department of Meteorology Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, Massachusetts 02139
1	Professor F. Kaufman Cathedral of Learning University of Pittsburgh Pittsburgh, Pennsylvania 15213

No. of Copies	Organization
1	Professor A. H. Waynick Ionosphere Research Laboratory The Pennsylvania State University 319 Electrical Engineering East University Park, Pennsylvania 16802
1	Professor J. Weiman Department of Meteorology University of Wisconsin Madison, Wisconsin 53706
1	Dr. B. Bederson Department of Physics New York University University Heights New York, New York 10053
1	Dr. L. Branscomb Joint Institute for Laboratory Astrophysics University of Colorado Boulder, Colorado 80304
1	Dr. C. J. Cook Stanford Research Institute 333 Ravenswood Avenue Menlo Park, California 94025
1	Dr. M. McCormac IIT Research Institute 10 West 35th Street Chicago, Illinois 60616
1	Dr. J. Nicolaides Department of Research University of Notre Dame Notre Dame, Indiana 46556
1	Dr. A. Peterson Stanford Research Institute 333 Ravenswood Avenue Menlo Park, California 94025

DISTRIBUTION LIST

No. of Copies	Organization
1	Dr. I. Poppoff Stanford Research Institute 333 Ravenswood Avenue Menlo Park, California 94025
1	Dr. G. Rumi School of Electrical Engineering Cornell University Ithaca, New York 14850

Aberdeen Proving Ground

Ch, Tech Lib

Air Force Ln Ofc
Marine Corps Ln Ofc
Navy Ln Ofc
CDC Ln Ofc

CG, USATECOM
ATTN: AMSTE-SM, Mr. Phelps
AMSTE-EL
AMSTE-BAF
AMSTE-NB

Dir, D&PS
ATTN: Mr. A. Kaper

THIS DOCUMENT IS UNCLASSIFIED - JCP-I, DPG.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Ballistic Research Laboratories Aberdeen Proving Ground, Maryland	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

REVIEW OF THE HIGH ALTITUDE RESEARCH PROGRAM (HARP)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Murphy, C.H. and Bull, G.V.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1966	49	24

8a. CONTRACT OR GRANT NO. b. PROJECT NO. RDT&E 1A011001B021 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Report No. 1327 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Materiel Command Washington, D.C.

13. ABSTRACT

Project High Altitude Research Program (HARP) is directed toward the use of guns for scientific probing of the upper atmosphere. The attractive features of guns for this purpose are the basic economy of such a system and the high inherent accuracy of guns for placement at altitude as well as accuracy in ground impact. The basic liability for such an approach lies in the very high accelerations experienced by gun-launched payloads.

The guns used in Project HARP vary in size from 5-inch and 7-inch extended guns on mobile mounts to transportable fixed 16-inch guns. Altitude performance varies from 20 pound, 5-inch projectiles reaching 240,000 feet to 185 pound 16-inch projectiles reaching 470,000 feet. Single and multiple stage rockets launched from the 16-inch gun have very promising predicted performance and are under development.

Scientific results to date are primarily wind profiles measured by radar chaff, aluminized balloons and parachutes, and tri-methyl-aluminum trails, although a number of successful 250 MHz and 1750 MHz telemetry flights have been made. Sun sensors, magnetometers, and temperature sensors have been flown and an electron density sensor was fired in early June. Development of other active sensors is continuing.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Project HARP						
Upper Atmosphere Probe						
Gun Launched Projectiles						
High Altitude Research						
Wind Measurements						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
____________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
____________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
____________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Raytheon Co., Missile Systems Div.
ASR-15
15 October 1960

~~CONFIDENTIAL~~ UNCLASSIFIED

REGRADED Unclassified, by authority
(New Classification)
of 8011652 (So194 DTC 18 Dec 72)
(Identify Reclassification Authority)
on 31 Dec 72, by M. Mitchell
(Date of Change) (Identify person who accomplishes change)

[redacted]

RAYTHEON MISSILE SYSTEMS DIVISION

15 Oct 60

UNCLASSIFIED

~~CONFIDENTIAL~~