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MEMORANDUM REPORT NO. 1532
JANUARY 1964

FIVE-INCH HARP TESTS AT WALLOPS ISLAND, SEPTEMBER 1963

Eugene D. Boyer

RDT & E Project Nos. 1M010501A005 and 1A011001B021
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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

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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

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EDBoyer/rhg
Aberdeen Proving Ground, Md.
January 1964

FIVE-INCH HARP TESTS AT WALLOPS ISLAND, SEPTEMBER 1963

ABSTRACT

The results of vertical firing tests of the five-inch HARP system are presented. These tests were conducted at the NASA facility, Wallops Island, Virginia with successful radar tracks of both projectile and payloads.

TABLE OF CONTENTS

1. INTRODUCTION

Studies conducted at the Ballistic Research Laboratories during 1959 indicated the feasibility of using guns for high altitude research.[1] These studies indicated that a 20-lb. fin-stabilized projectile fired from a 5-inch smoothbore gun should be capable of achieving 250,000 feet altitude. The first series[2] of these firings indicated a mechanically weak projectile and a very erosive propellant charge; however, chaff was ejected and tracked by the Nike-Ajax and Hercules radar. The projectile was redesigned, the charge composition was changed from M2 to M17 and, as an added feature, a muzzle extension of 10 feet was incorporated in preparation for a second test series. The redesign of the projectile necessitated a repackaging of the delay ejection system from a short fat configuration to a longer thinner shape. This second test series[3] produced very good altitudes but no events. The gun erosion was reduced, but was still objectionable.

In preparation for a third test series, every effort was bent toward improved package function. Contracts with Picatinny Arsenal (PA) and the Naval Ordnance Laboratory (NOL) were made to produce a delay ejection system. High acceleration level tests (60,000 g's) were employed for all systems and packages. The projectile manufacture was contracted commercially for the first time; however, BRL did procure, test and then supply the critical materials to the vendor. A new chemical erosion inhibitor was planned to further reduce the gun wear. Since package function and exact altitude performance were the prime concern, the program was planned to utilize photoflash packages for direct observation. The radars used on the previous tests had tracked chaff but had never acquired the projectile directly. At about the time when the materials and final plans for this third series of tests, on the Edgewood peninsula, were nearly complete, Wallops Station, of the NASA, suggested that the test be performed at Wallops Island on the basis of mutual interest. Since this offered tracking services well beyond those available near Aberdeen Proving Ground, the opportunity was eagerly accepted. Although the test rounds had been procured for a basically optical test, some additions and juggling yielded a reasonable test program which included chaff, parachutes and photoflash packages. The purposes of the test are to examine:

a. Function of delay ejection system

b. Performance of all packages

c. Feasibility of radar track of projectile and event

d. Obtain exact trajectory data from radar track with optical backup

e. Performance of system at QE's between 45-85° (firings at APG are limited to QE's greater than 85°).

f. Prolonged test of erosion inhibitor.

2. PLANNED PROGRAM AND INSTRUMENTATION

The original planned schedule is given below.

Round	QE	Payload	Maximum Altitude (kilometers)	Delay Time (sec)	Muzzle Velocity (ft/sec)
1	75	Chaff	48.5	120	5000
2	75	Chaff	48.5	105	5000
3	45	Flash	21.3	50 or 55	5000
4	55	Flash	30.8	50 or 55	5000
5	65	Flash	40.7	50 or 55	5000
6	70	Flash	45.0	50 or 55	5000
7	75	Flash	48.5	50 or 55	5000
8	80	Flash	51.2	50 or 55	5000
9	80	Flash	59.0	105 or 120	5250
10	80	Parachute	59.0	105 or 120	5250

The trajectories are given in Figures 1 and 2 with the plotted points at 10-second intervals.

The ejection delay column to be employed in rounds 3 through 10 would depend on which delay column proved most satisfactory in rounds 1 and 2. The delay columns supplied by NOL were for 50 and 120-second delay. The PA delay columns were for 55 and 105-second delays.

The following instrumentation was to be employed:

a. Radar - for tracking projectile and package

	Type	Beam Width (degrees)	Frequency (megacycles)
(1)	SCR-584 acquisition	3.0	2800-2900
(2)	584-Mod 2 acquisition	2.5	2700-2950
(3)	FPS-16 - Tracking (+ AGC records)	1.2	5400-5700
(4)	Spandar - Tracking (+ AGC records)	.39	2700-2900

b. Camera Coverage

(1) BRL Fastax Smears - to determine condition of model on emergence from tube

(2) NASA Fastax framers

(3) New Mexico, K24 and K37 cameras for flash coverage

c. Muzzle Velocity Determination

(1) Doppler Radar 4-degree beam width

(2) In-bore probes

d. Radiosonde - meteorological data

3. TEST PROGRAM AND DATA

During the period 23 September through 3 October 1963, BRL launched 5* completely successful 5-inch vertical probe projectiles out of 13 fired at NASA's Wallops Island, Virginia. All types of packages and ejection systems were functioned satisfactorily. The probes (Figure 3) were fired from an extended smoothbored T123 tank gun, (Figure 4). The gun was trucked to Wallops Island on a 10-ton GMC commercial tractor, 12-ton M127 trailer, and was emplaced for firing on a 20-degree slope with a 25-ton crane. The data obtained from the firing program is given in the table. The 5 completely successful rounds are listed first, with the available data on the other rounds following. An emergency air and sea search mission off the coast restricted the first firings to night hours and there was a resultant diversion from the planned program.

3.1 Chronology of firings

The first two shots, chaff and flash, were successfully tracked by radar and achieved higher than predicted altitudes. The flash was observed visually and by radar at 212,000 ft. Chaff was tracked by radar. For the third shot, a flash unit, an effort was made to obtain maximum performance. This shot failed, with radar indicating a low altitude of 30,000 ft.

On the second day, a flash and chaff package were successfully launched and functioned. Radar tracked the projectile to better than predicted altitudes. At this point, both types of ejection systems had functioned at near prescribed

* Other rounds functioned at less than planned altitudes or may have been lost.

times. The third and final round of the day was a flash unit which radar indicated went to low altitudes. This also had been an attempt to obtain maximum altitude. Since during horizontal proof tests for "g"'s into lead, a flash package auto initiated at only slightly higher "g"'s than those observed on this shot, the failure was initially ascribed to a premature function of the flash unit. In retrospect, this may, or may not, be true.

The third day was started with a lower angle of elevation (70°) and a flash unit. Radar again indicated that this round achieved very low altitudes. A chaff package was fired at the same elevation and once again radar reported low altitudes! Since this was Friday, it was decided to suspend firings until the following Tuesday and utilize the ensuing interval to analyze the available data. In particular, the Fastax smear films of the launch were studied to determine what was wrong.

The review suggested several possibilities:

The films of shots 6, 7 and 8* showed a projectile that appeared to be intact in the forward part but the fins had so much luminosity about them that their state could not be determined. Some of the effect could have been optical, but the film did suggest burning fins. It is known that uncoated aluminum will burn under these conditions. The protective coating used on the fins and boom surfaces exposed to the gun gases had successfully protected the model (and many other R&D projectiles) in all earlier tests. While the previous performances of coated fins made it difficult to accept the burning phenomenon, a check of the manufacturing records indicated that 3 of the 4 failures carried fins which had been coated twice. There seemed to be no background information to suggest that re-coating would substantially weaken the fins, nevertheless, it was decided that they were not to be used in further testing.

At this point, the most probable causes of failure seemed to be a mixture of flash package weakness and recoated fins. It was decided to continue the firings at reduced velocities without using either flash package or recoated fins. More camera coverage was employed to cover up to 120 feet from the muzzle.

Five more rounds were fired before the program was closed. One round was tracked to very low altitudes, three rounds made altitudes of about 100,000 feet

* Shot 3 was a night shot and no coverage was available.

(approximately half programmed) and ejected chaff or parachutes successfully. The fifth round reached full altitude and ejected a parachute which was tracked for wind measurements between 95,000 and 170,000 feet. The improved camera installations gave data on four of the rounds and showed that three of the projectiles had lost most of one fin blade. This was always the lower left fin, looking along the line of flight. Figure 5 shows round 12 being launched successfully and round 9 with the missing fin. These smears were taken with the cameras shown in Figure 6.

3.2 Radar plots

Photographs of the Doppler radar and Spandar are given in Figures 7 and 8. The Spandar plot board information is given in Figures 9 and 10 for round number 12. Figure 9 gives the altitude as a function of range. Spandar was on track 9 seconds after launch and tracked up to 185,000 feet. At this point, the round was lost momentarily; however, it was picked up again at 195,000 feet immediately before ejection of the parachute. After ejection, Spandar stayed with the chute and tracked it for better than fifteen minutes. Figure 10 gives the azimuth plot as it would look if plotted on the earth's surface. The line of fire was 129 degrees 9 minutes. As can be determined from the plot, there is no deviation of the projectile from this line of fire. The parachute, as packaged in the probe is shown in Figure 11. The parachute was the Mk 33. This is a 6-foot-square metalized silk chute. A 12-ounce weight was used which was housed in the nose of the projectile.

The Spandar plot of a flash round (round 2) is given in Figure 12. Acquisition time was at 22 seconds. The round was tracked the entire way up over 200,000 feet with the flash event occurring at 115 seconds, just as the projectile started on the downward leg. The change in track is seen. Spandar is tracking the empty bird from the event point to splash. The flash cartridge (Figure 13) was built by Picatinny Arsenal. It consisted of 180 grams of photoflash composition type A class III and yielded 650,000 candle-seconds light at 200,000 feet. The photograph of the event as viewed by the K37 camera, located at the Spandar site, is given in Figure 14.

A chaff round is tracked by the FPS-16 in Figure 15. The round was acquired at 9 seconds and carried up to 96 seconds. At this point, it was lost. Some time later, the chaff was acquired about 200,000 feet and tracked for ten minutes. In this time interval, the chaff had dropped approximately 10,000 feet. The chaff was X-band chaff 1/2 wavelength 0.0035 inch diameter. It was packaged in the same container as that used for the parachute.

Figure 16 is the FPS-16 trace of a damaged round which attained 95,000 feet. The round was acquired at 9 seconds and ejection occurred at the prescribed 120-second interval. The parachute, although designed to function at 200,000 feet and near 0 velocity, did survive the ejection at 55,000 feet at about 1000 ft/sec and was tracked to 40,000 feet, at which time radar coverage was terminated.

3.3 Fuse delay systems

A photograph of both the Picatinny Arsenal and Navy Ordnance Laboratory delay system is given in Figure 17. Figure 18 is a cross sectional view of the PA delay. The delay is initiated by the pressure from the powder gases going through the 1/4 x 16 1/2 inch hole through the boom and shearing a small copper disc. This allows a firing pin to hit the ignition system and light the delay mix. The delay mix terminates into an ejection charge of 2.7 grams of black powder mixed with 0.9 grams of composition containing Barium Chromate and Boron. The delay mix consists of Barium Chromate, Potassium Perchlorate and Zirconium nickel alloy.

The NOL delay column (Figure 19) is initiated on setback. The Mk 80 delay detonator is housed in an aluminum container. This unit is then housed in another aluminum container. The inner cylinder is held in place by 2 roll shear pins. There is a stationery firing pin 1/4 inch below the primer. On setback, the pins are sheared and the complete M80 detonator assembly sets back onto the pin and the system is ignited. The delay column consists of a Tungsten delay composition and this terminates into 3 grams black powder, the ejection charge.

3.4 In-bore velocity measurements

The in-bore velocity probes were used on the first 9 rounds. There was some concern as whether they were contributing to our launching problems and they therefore were left out in the latter portion of the program.

The in-bore velocity measurements were obtained by the use of four contact probes inserted in the wall of the gun tube. The distances of the probes from the muzzle were respectively, 24, 18, 12, and 6 inches. This provided 3 velocity measurements each with a 6-inch base line and at an average distance of 15 inches from the muzzle.

The contact probe was a fixture containing an electrically insulated 0.027" diameter steel rod which protruded thru a 0.040" diameter hole into the bore of the gun approximately 0.030". A negative potential of 37 volts was provided at the probe which was capacitor coupled to a double terminated coaxial cable leading to a HP5275A 100-megacycle Time Interval Counter. The passage of the leading edge of the sabot package over the contact probe provided the switch action which shorted the steel rod to the edge of the 0.040" hole in the fixture. The discharge of the capacitor through the shorted probe provided a positive pulse having a rise time of 200 nanosec. with the threshold triggering voltage of the counter being reached in 20 nanosec.

For velocities in the order of 5000 feet per second, the ± 10 nanosecond accuracy of the counter is 0.01% of the time interval. Distance between probe holes was measured to an accuracy of 0.001". However, since there was some nonuniformity of the probe position in the replaceable fixture and since the mechanism of how the probe bends and contacts the gun wall is not completely described, the accuracy of the base line is derated to 0.02" or approximately 0.3%.

Data was obtained on 8 rounds out of the nine on which the probes were used.

On 5 rounds, more than one measurement of velocity was obtained. In these cases, the maximum deviation from the average was better than 1/2%. This agrees with the estimated accuracy of the system.

4. DISCUSSION

The films from the BRL Fastax cameras were available soon after each firing. The films from the NASA cameras were in color and therefore several weeks were required for processing. In this interval of waiting, several experiments were carried out in an effort to shed some light into the abnormal mechanical behavior of the projectile. This effort consisted of:

a. Examination of radar plot data from both the acquisition and tracking radars.

b. Examination of automatic gain control records of the tracking radar.

c. Comparison of damage to coated and recoated fins after exposure to an oxi-acetelene torch for various time intervals.

d. Destruction tests in bending of fins from various manufactures.

e. Close physical examination of remaining fins.

f. Physical examination of gun tube; bore scoping before and after cleaning; gauging for straightness; star-gauging, and finally disassembly for inspection of joint.

In all these efforts, no conclusive single prime cause came to the front to absorb all the blame. The conclusions arrived at from these tests were:

a. Both BRL and NASA Fastax cameras showed high luminosity in the fin region for the low altitude shots which carried recoated fins. This suggests that the fins were ignited for at least some time and may have sustained some degree of damage. The torch tests showed no differences for coated or recoated fins.

b. Physical examination of the remaining fins indicated some blades had a sharper edge at the root than others. However, the destruction tests did not show a degradation of strength for this type condition. There was a slight difference in the strength from blade to blade on an individual fin. It is very unlikely that, if a weak fin did exist, it was always in the same position during launching.

c. Examination of radar data showed one case of two different objects being tracked on the upward leg (round El-1433). The Spandar and FPS-16 radars tracked an object that reached about 20,000 feet altitude and impacted at 7000 ft. range. The Mod II radar tracked a second object to an altitude of 72,000 feet. This object ejected a canister at about 50 seconds (programmed fuze time) and radar received a typical chaff return. The projectile is known to be damaged (BRL Fastax) and would attain a lower than predicted altitude; therefore, this second object must be the projectile. The suggestion is made that the first object may have been a sabot fragment.* The other low altitude tracks, in particular round El-1394, are very similar and may also be those of sabot particles with the projectile reaching partial or full altitudes.

d. Inspection of the tube revealed one unsuspected item and two items that one might logically presume, i.e., (1) a definite sag and a slight curvature to the left (even short gun tubes are not perfectly straight); (2) a pronounced build up of the erosion inhibitor coat and aluminum. The joint was found to have a gap of nearly one-eighth inch, and this was not anticipated. The tube was new and apparently had been assembled incorrectly at the arsenal.

* Data obtained on firings subsequent to tests reported here suggest that the object could also be a preejected nose.

The joint could be (and has been) closed by changing the position of the locking set screws on the extension retaining nut. The loose joint would make the tube less rigid and the gap would constitute an added hazard.

5. CONCLUSIONS

The tube condition is the most logical prime source of the problem. However, it is clear that burning of reanodized fins, possibly lost rounds, and possibly preinitiation of the flash unit have contributed to the total picture.

It is planned to avoid these problems in future tests by the following innovations:

a. Maintain alignment of tube by a "suspension bridge" system and rigorous inspection of all new tubes.

b. Use of steel fins or aluminum fins coated with an ablative material for added strength and burning resistance.

c. Utilizing a honing operation along with conventional tube cleaning procedures to prevent bore build up.

ACKNOWLEDGEMENTS

The contributions of other agencies outside of the Ballistic Research Laboratories should be acknowledged. In particular, NASA Wallops Island, Virginia, and Development and Proof Services, Aberdeen Proving Ground, Maryland. The services of Mr. R. Welsh (NASA) and his associates, and Mr. J. Whiteford (D&PS) were instrumental in the successful completion of the program.

Eugene D. Boyer

EUGENE D. BOYER

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2. Marks, S. T., MacAllister, L. C., Gehring, J. W., Vitagliano, H. D., Bentley, B. T. Feasibility Test of an Upper Atmosphere Gun Probe System. BRL Memo Report 1368, October 1961.

3. Marks, S. T., Boyer, E. D. A Second Test of an Upper Atmosphere Gun Probe System. BRL Memo Report 1464, April 1963.

TABLE 1

Shot No.	NASA Round Number	Package	Launch Angle (deg.)	Altitude kilo/feet	*Flight Weight (lbs.)	Sabot Diameter (in.)
			GOOD ROUNDS			
1	E1-1386	Chaff	75	181	19.72	5.102
2	E1-1387	Flash	80	201	19.27	5.102
4	E1-1389	Flash	80	218	19.27	5.102
5	E1-1390	Chaff	75	212	19.23	5.102
12	E1-1434	Parachute	80	200	20.04	5.105
			DAMAGED ROUNDS			
3	E1-1388	Flash	80	30	19.27	5.102
6	E1-1391	Flash	80	66	19.08	5.103
7	E1-1392	Flash	70	23	19.08	5.103
8	E1-1393	Chaff	70	16	19.53	5.103
9	E1-1394	Chaff	70	13	19.72	5.104
10	E1-1395	Parachute	80	95	20.04	5.104
11	E1-1433	Chaff	80	70	19.72	5.104
13	E1-1443	Parachute	80	98	20.04	5.105

* Add 5.20 lbs. sabot weight for launch.

TABLE 2

Shot No.	Propellant Charge (lbs.)	Chamber Pressure (True)	Delay Column Type	Delay Column Time (sec)	Delay Column Function (sec)	Velocity In bore (ft/sec)	Velocity Doppler (ft/sec)
			GOOD ROUNDS				
1	33.50	50,500	NOL	120	113	4848	
2	34.50	55,800	NOL	120	118	5002	
4	35.25	61,900	NOL	120	109	5163	
5	34.50	64,800	PA	105	127	5224	
12	33.50	52,800	NOL	120	108	xx	4870
			DAMAGED ROUNDS				
3	35.25	63,300	NOL	120		5169	
6	35.50	62,600	PA	105			
7	34.50	59,200	PA	105		5094	
8	34.50	59,200	PA	105		5095	
9	34.00	58,800	NOL	50		5020	
10	33.50	52,100	NOL	120	117	xx	4300
11	33.50	49,500	NOL	50	50	xx	
13	35.00	58,800	NOL	120	107	xx	5040

xx velocity probes not used

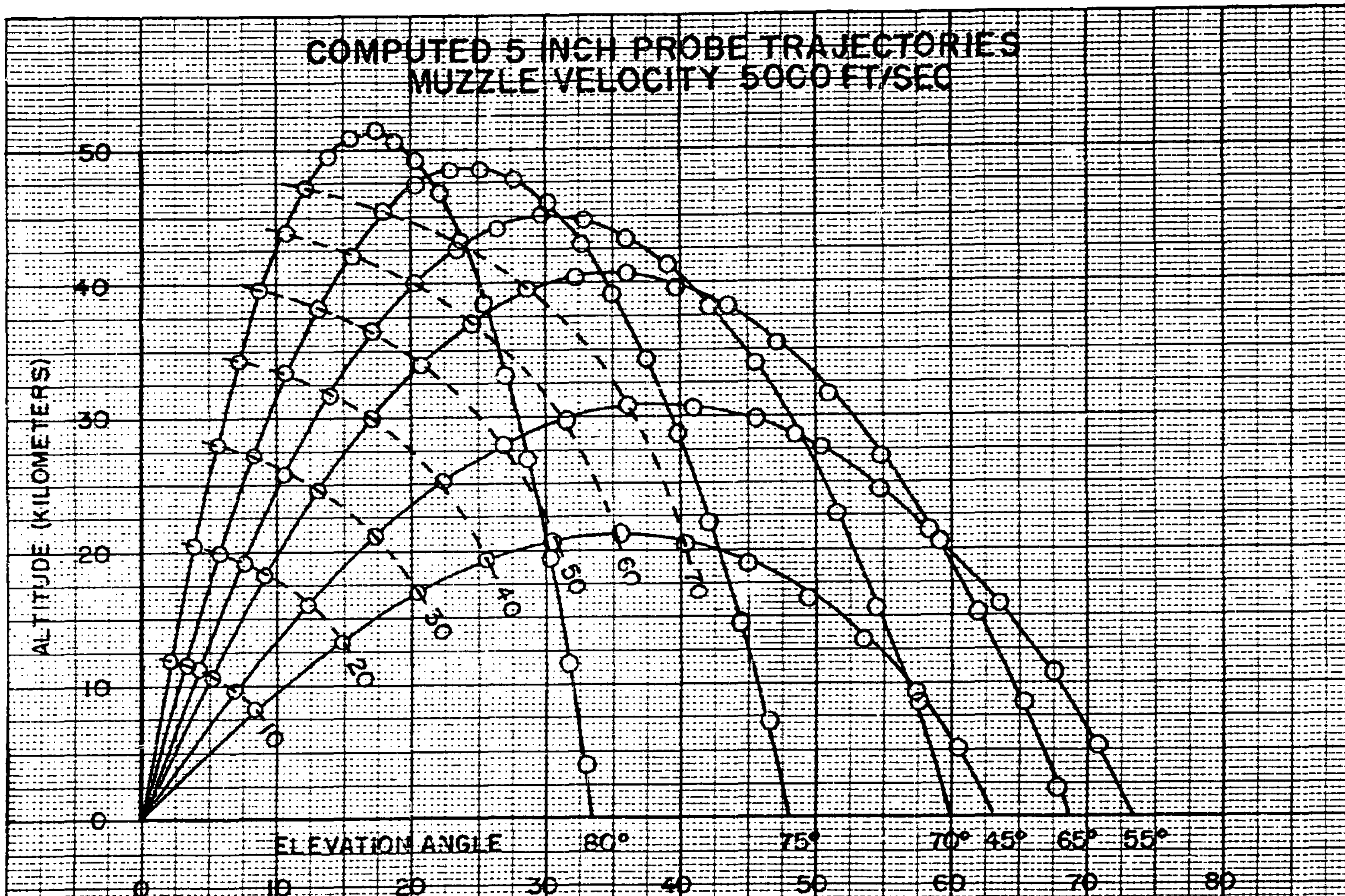

COMPUTED 5 INCH PROBE TRAJECTORIES
MUZZLE VELOCITY 5000 FT/SEC
ALTITUDE (KILOMETERS)
0
10
20
30
40
50
ELEVATION ANGLE
80°
75°
70°
45°
65°
55°
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
RANGE (KILOMETERS)

FIG. 1

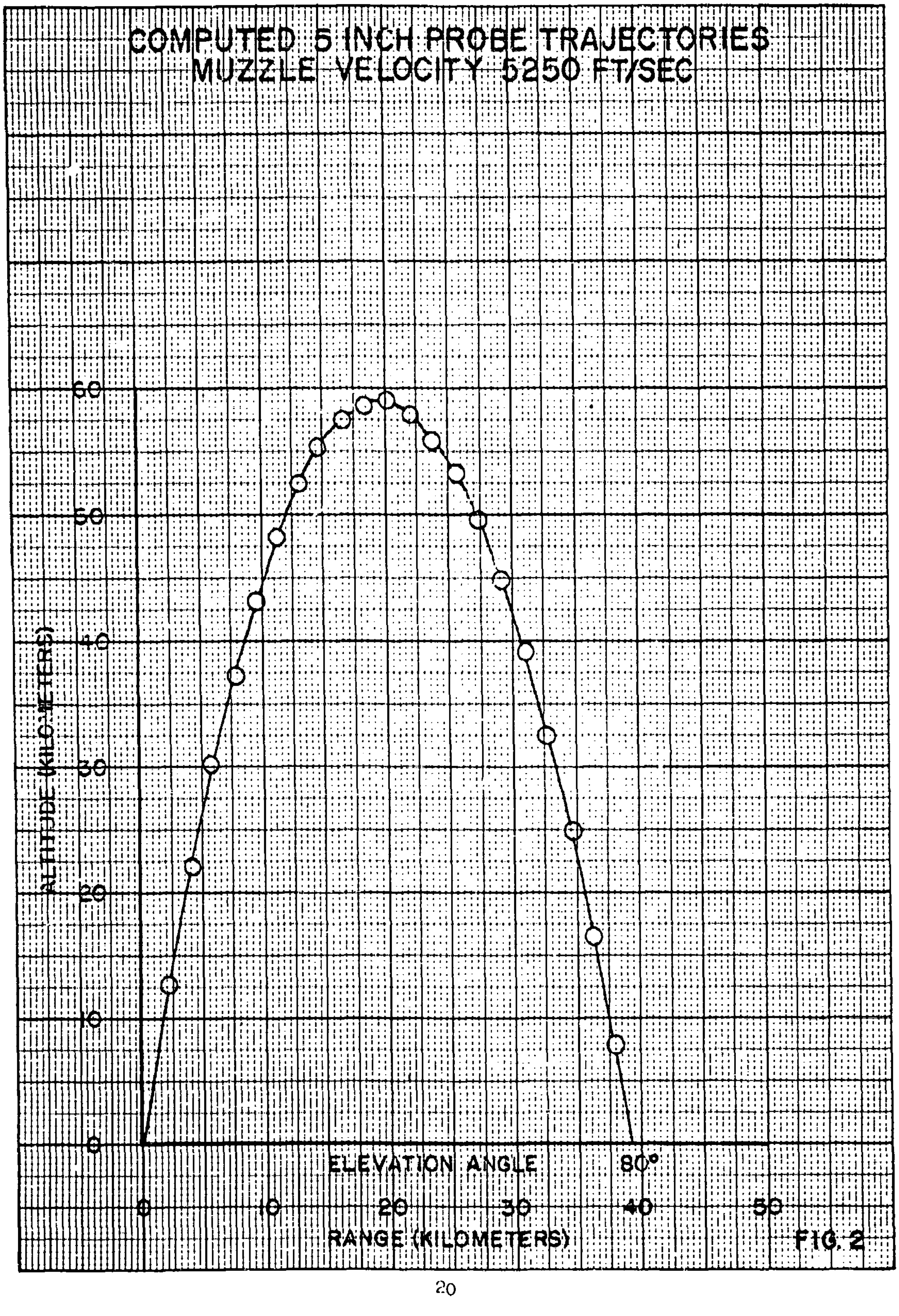
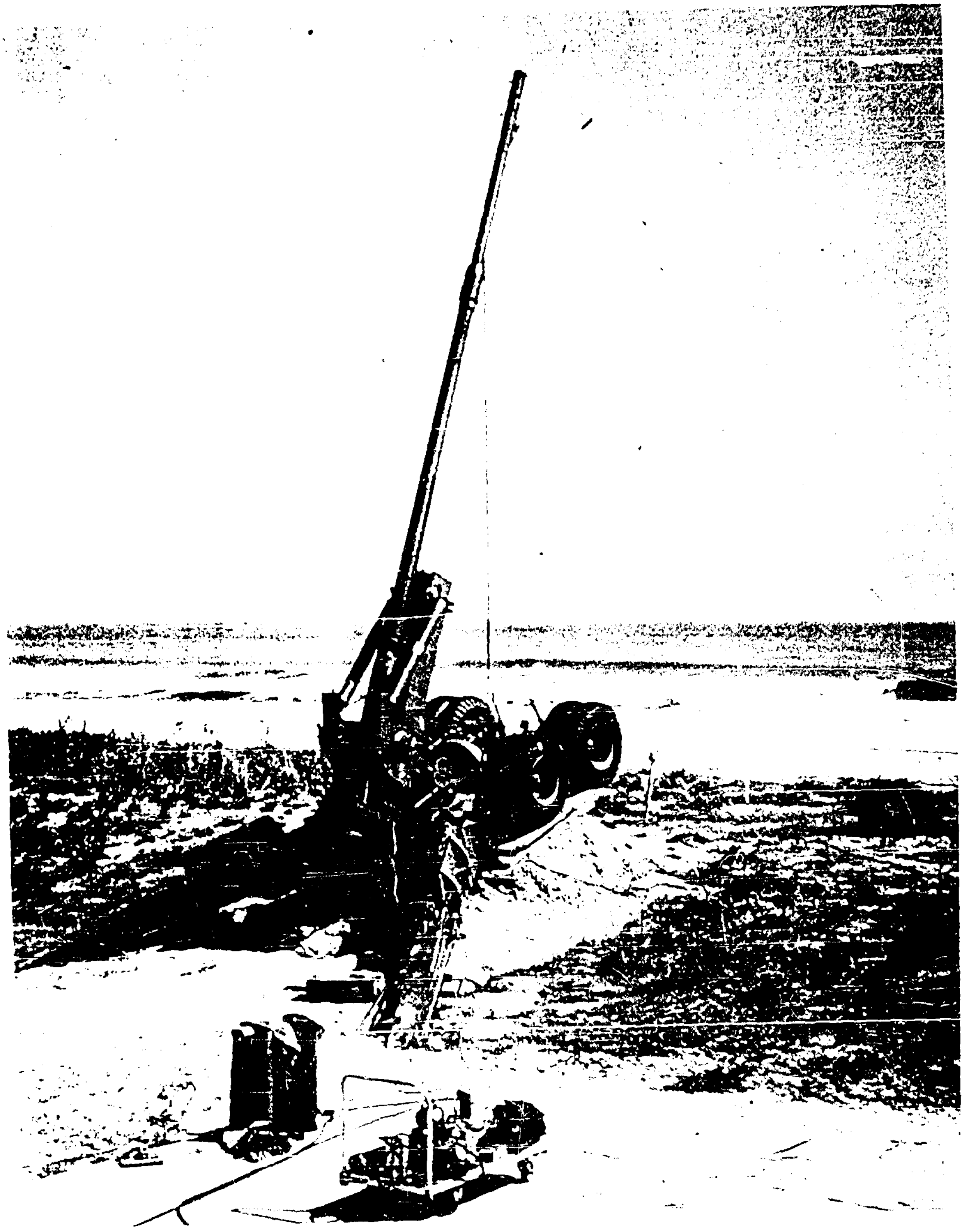
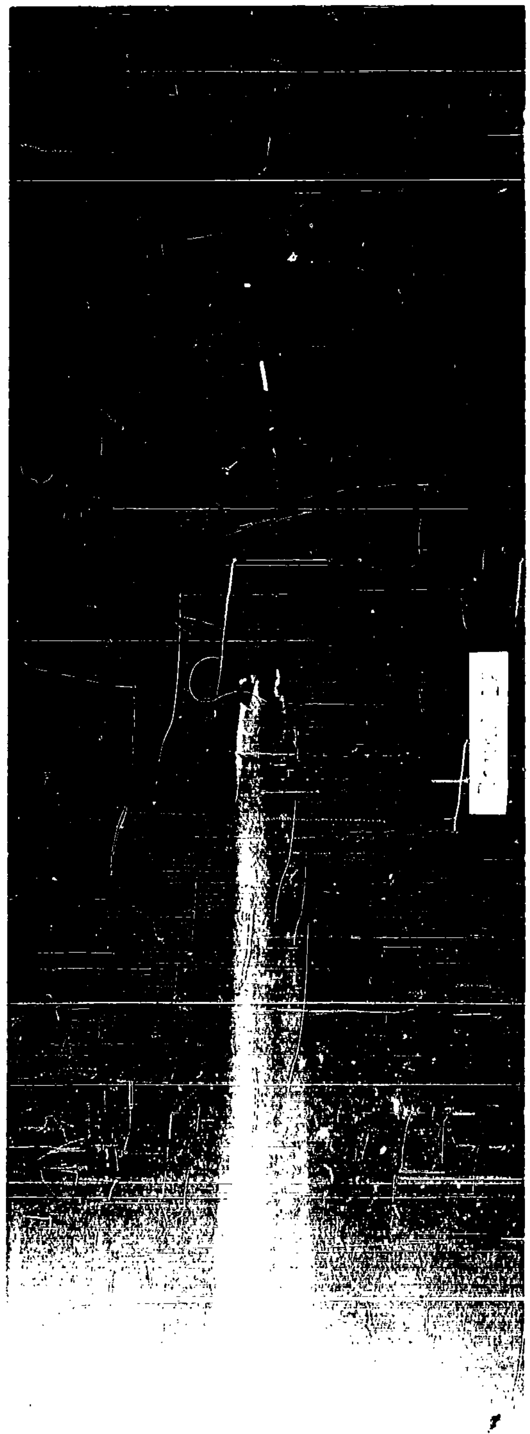
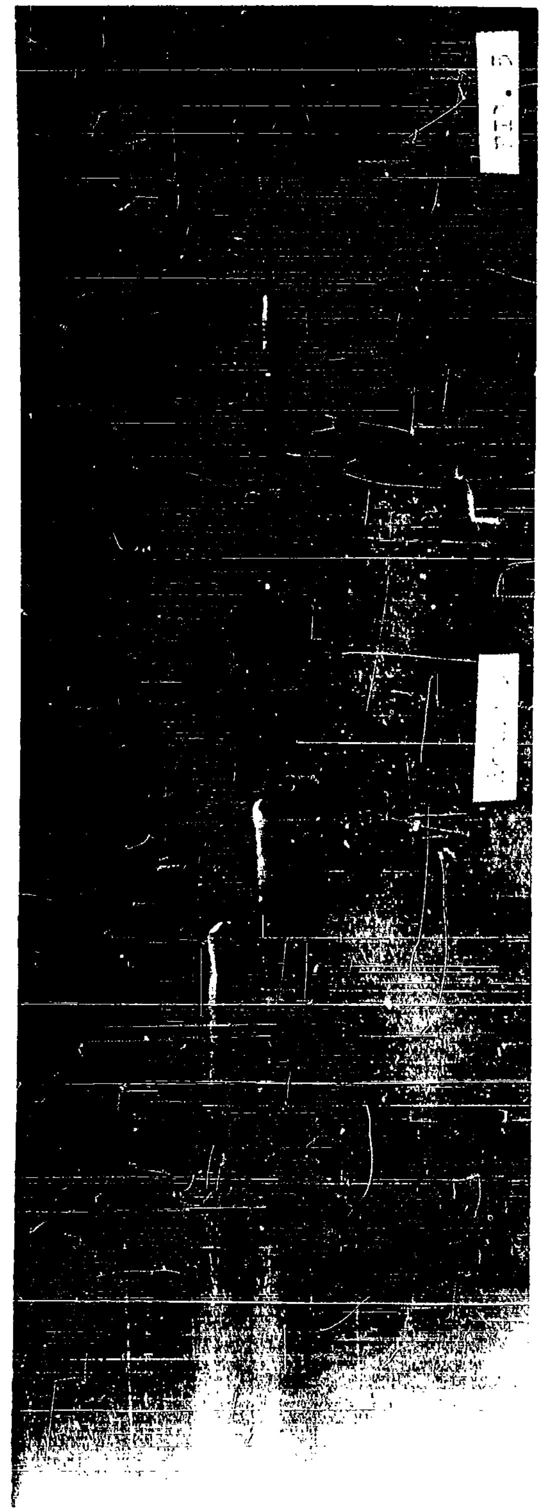
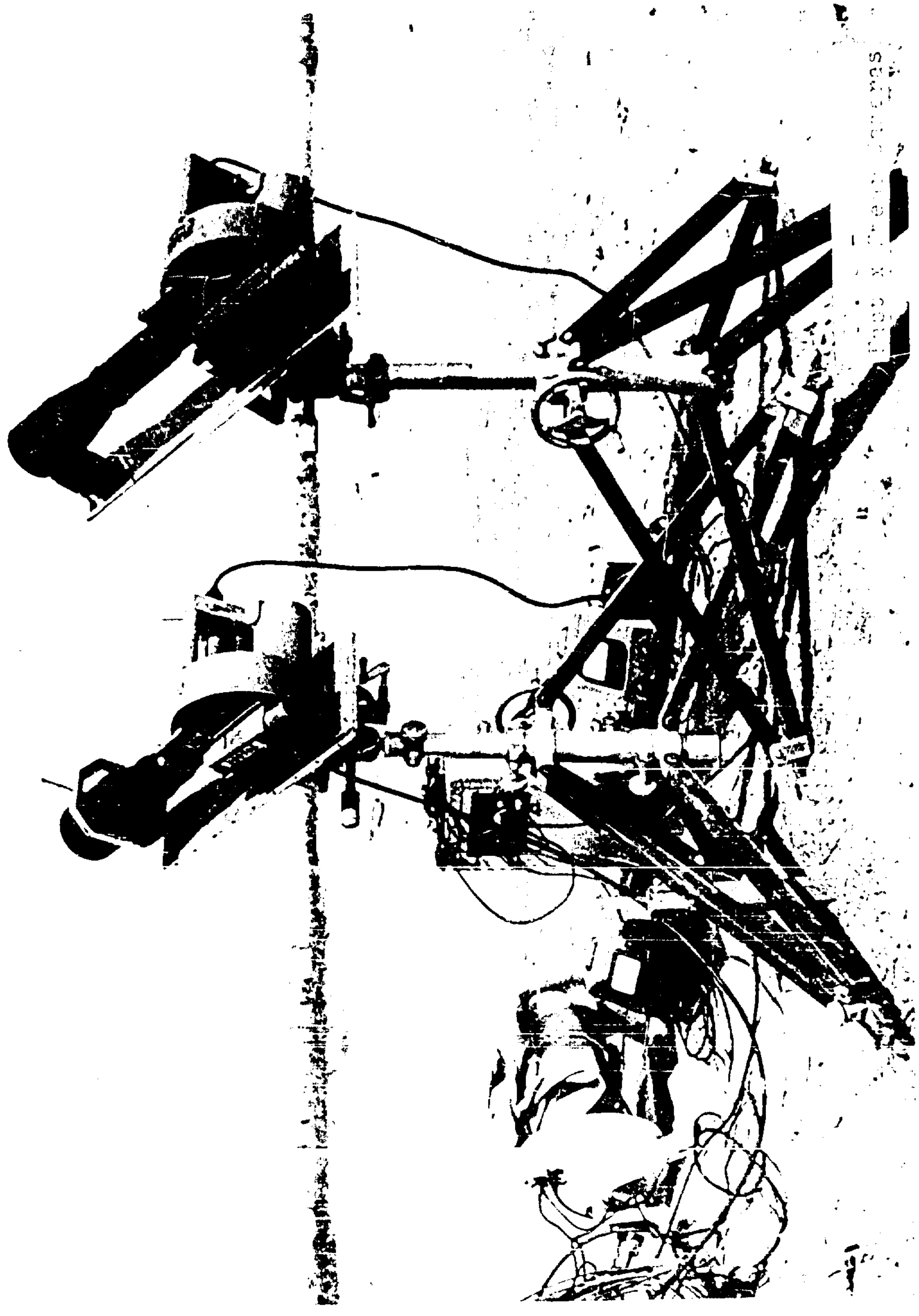

COMPUTED 5 INCH PROBE TRAJECTORIES
MUZZLE VELOCITY 5250 FT/SEC
ALTITUDE (KILOMETERS)
60
50
40
30
20
10
0
ELEVATION ANGLE
80°
0
10
20
30
40
50
RANGE (KILOMETERS)

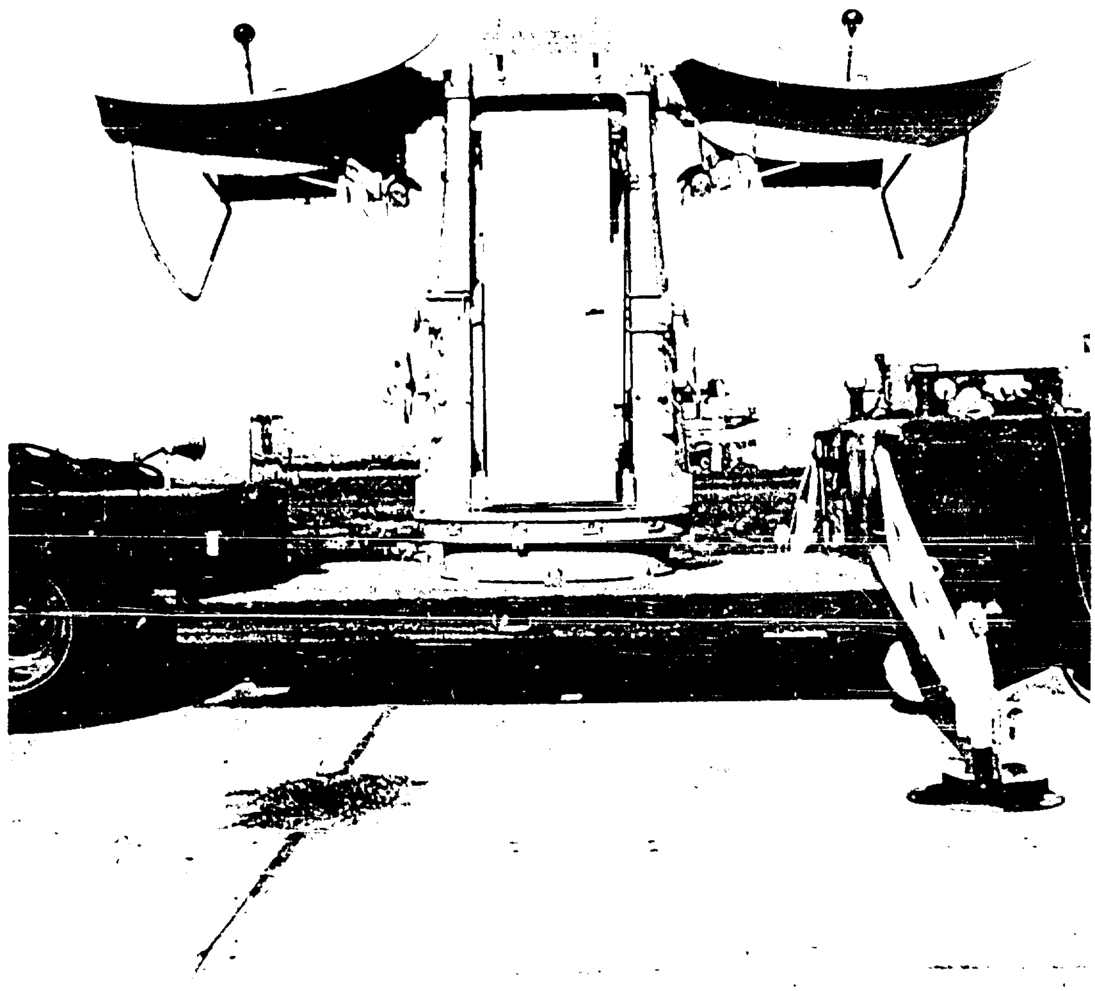
FIG. 2

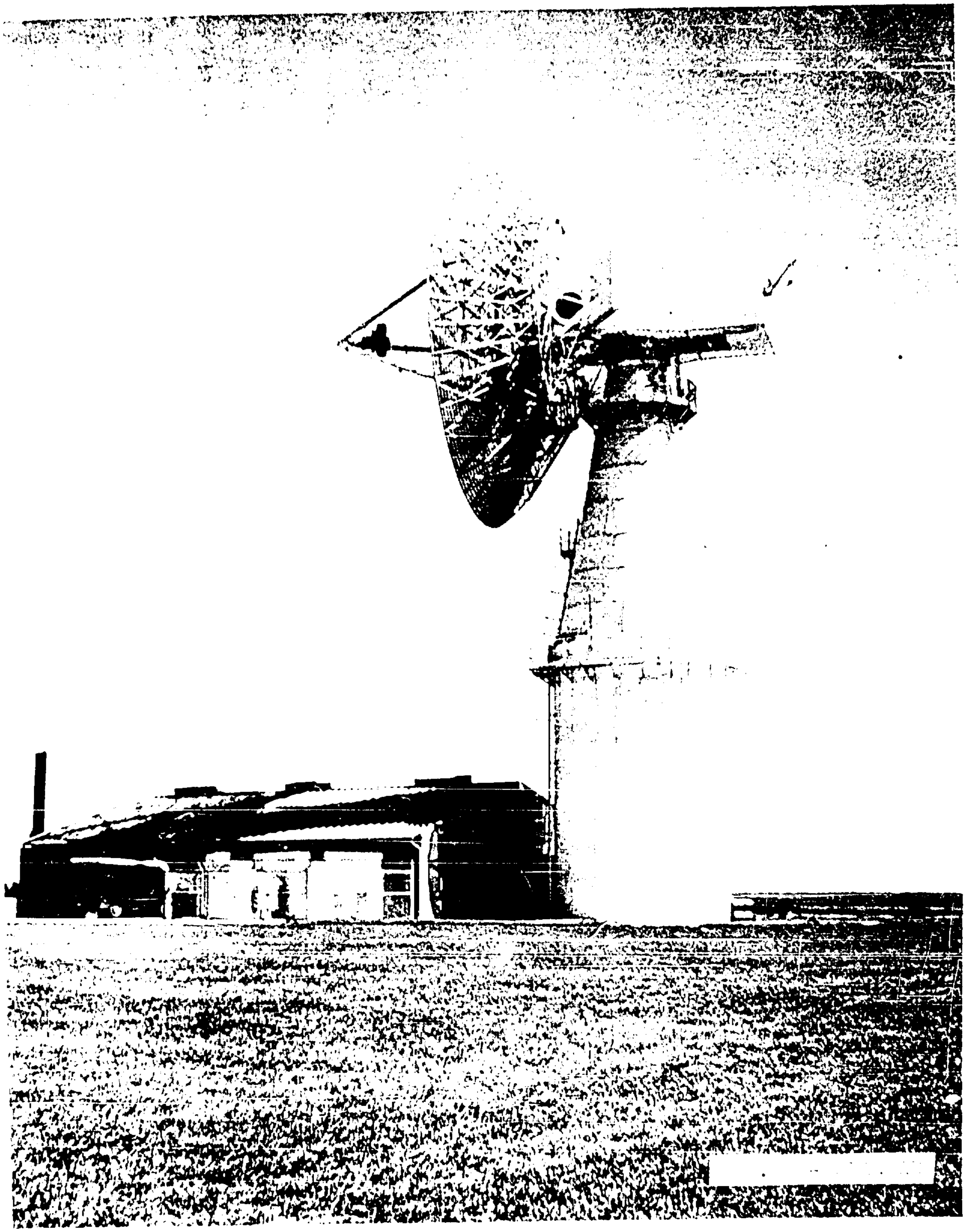


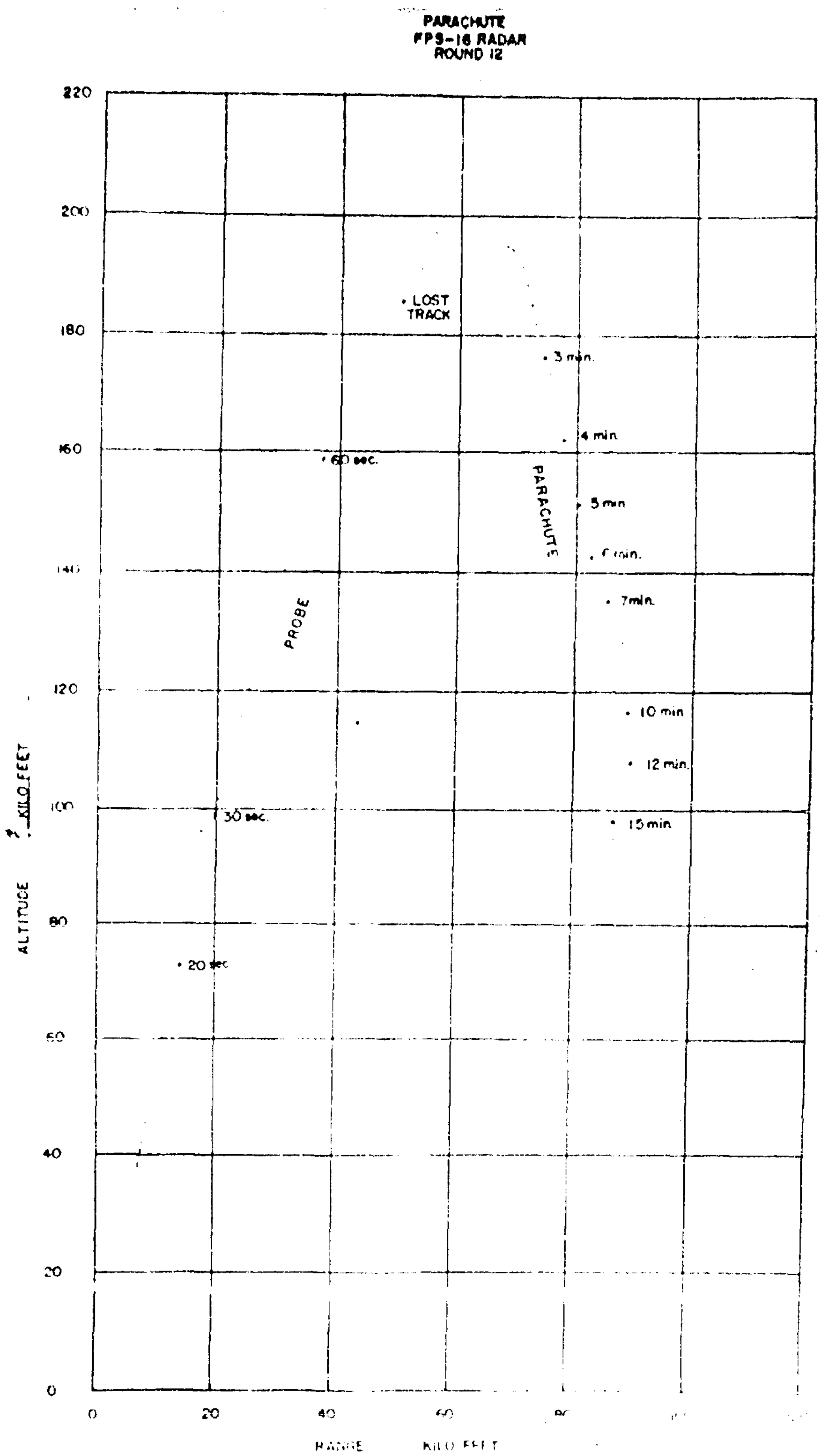






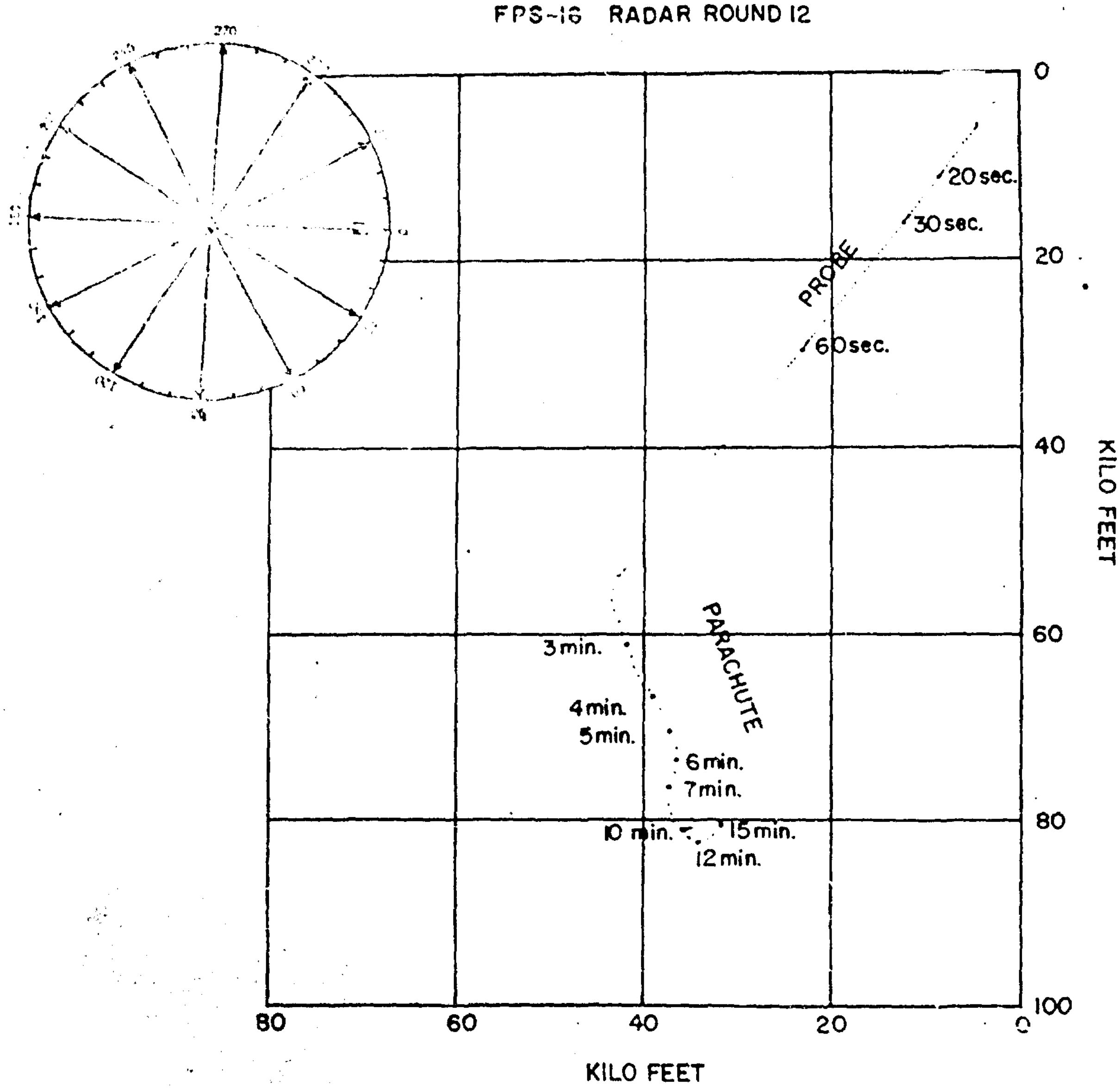


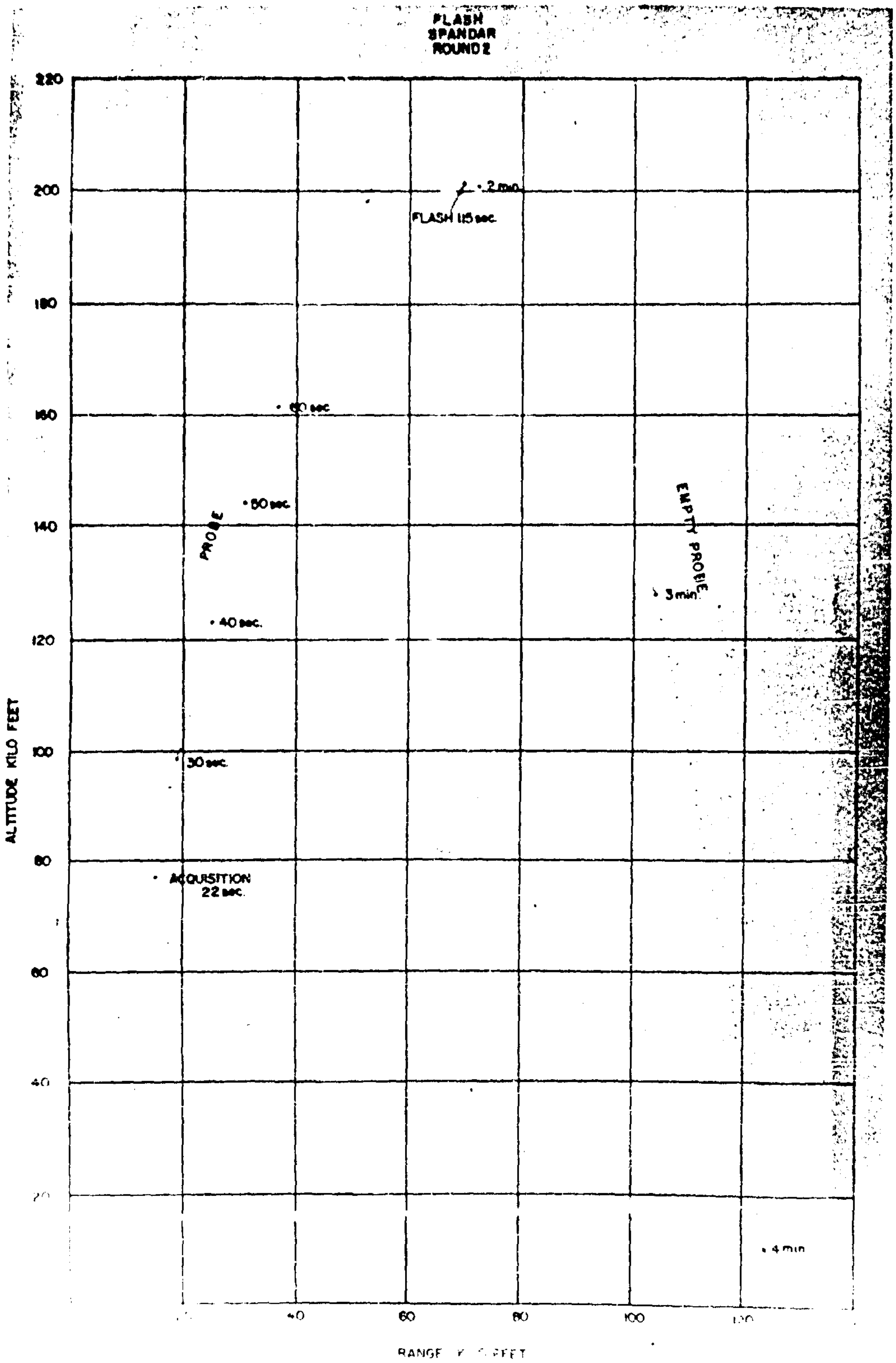


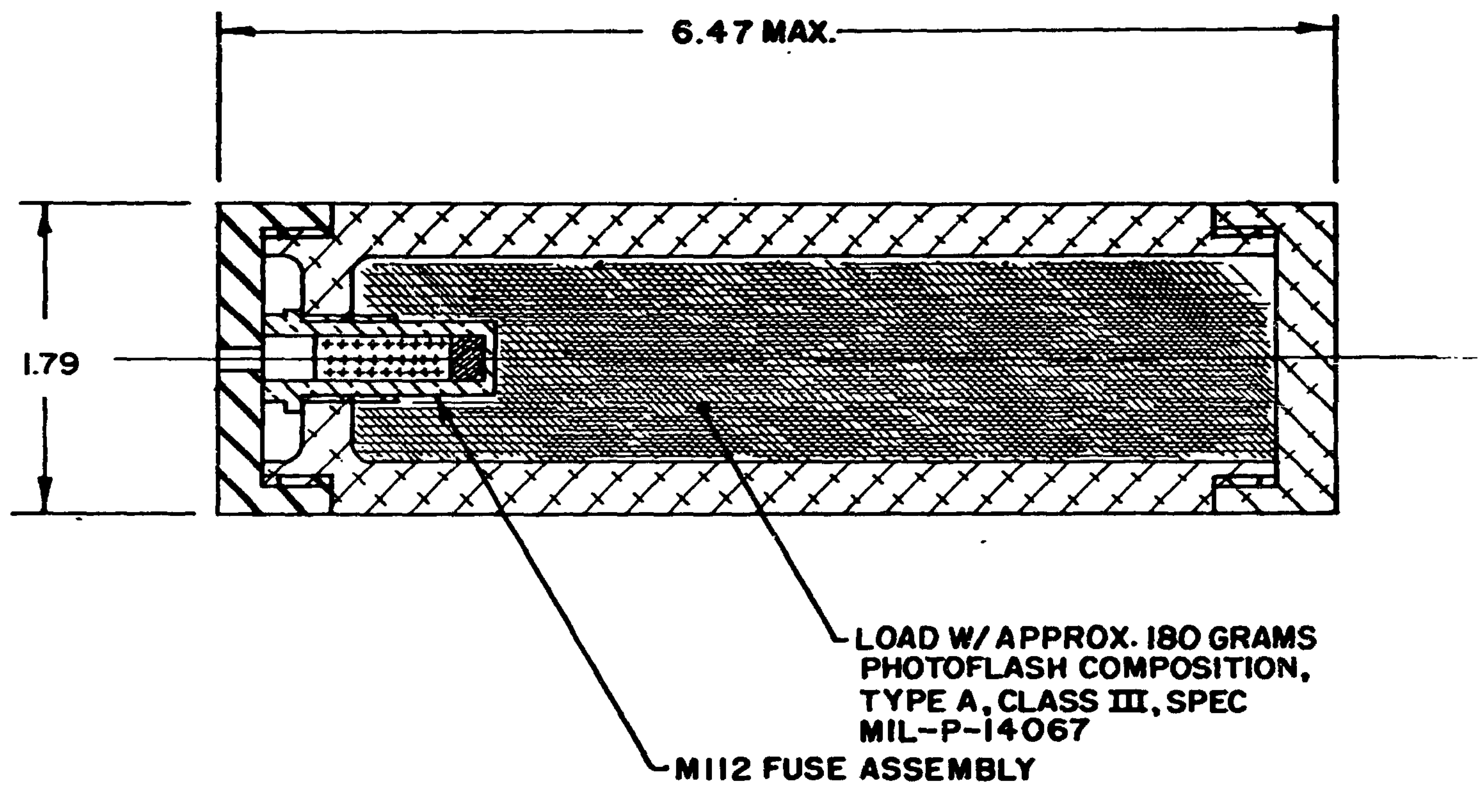


PARACHUTE
FPS-16 RADAR
ROUND 12
LOST TRACK
3 min.
4 min.
60 sec.
PARACHUTE
5 min
7 min.
PROBE
10 min
12 min.
30 sec.
15 min
20 sec
ALTITUDE , KILO FEET
RANGE , KILO FEET

FPS-16 RADAR ROUND 12

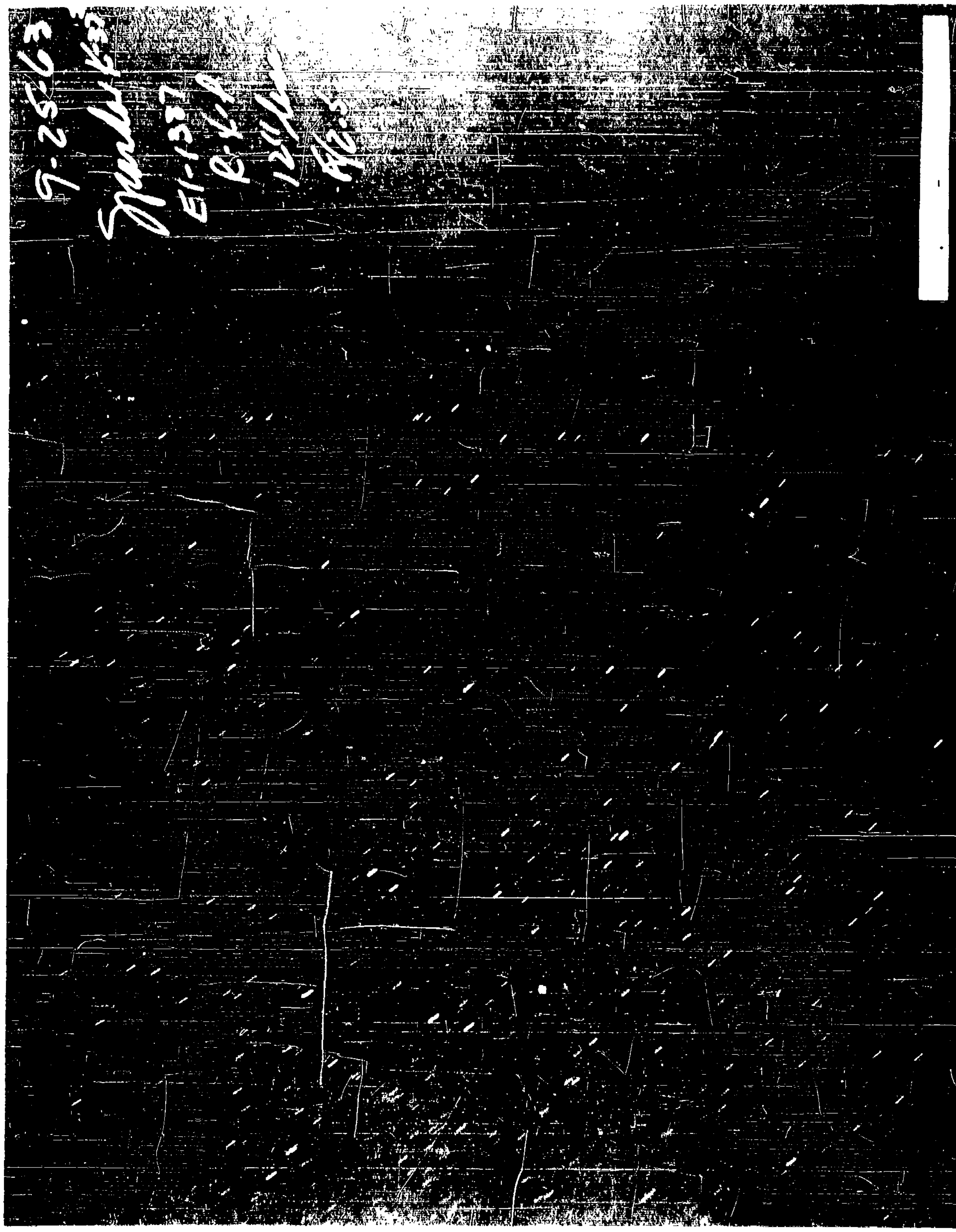



FLASH
SPANDAR
ROUND 2
220
200
180
160
140
120
100
80
60
40
20
ALTITUDE KILO FEET
• 2 min
FLASH 115 sec.
• 60 sec.
• 50 sec.
PROBE
• 40 sec.
30 sec.
ACQUISITION
22 sec.
EMPTY PROBE
• 3 min
• 4 min
40
60
80
100
120
RANGE



FLASH CARTRIDGE ASSEMBLY

FIG. 13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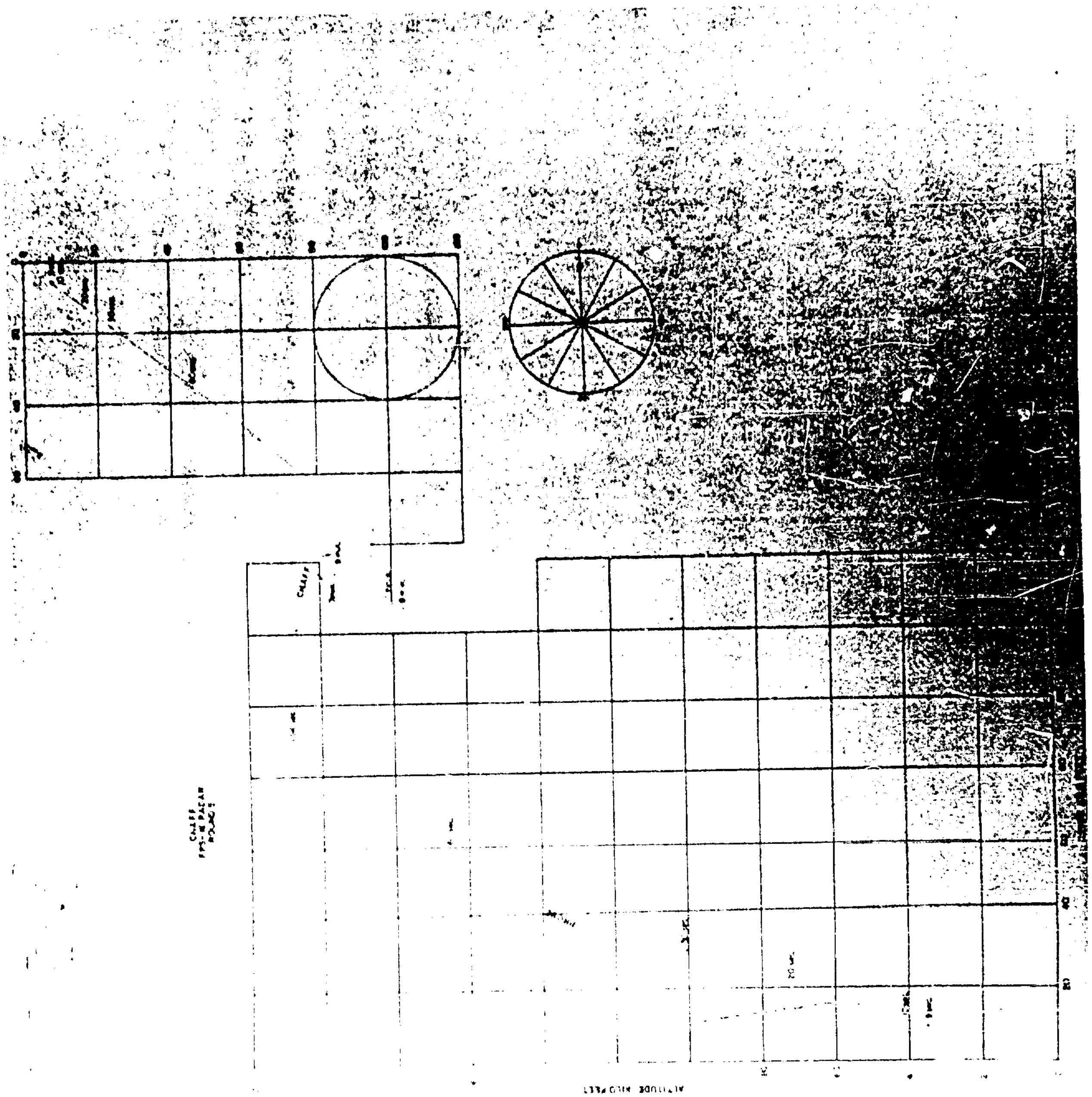
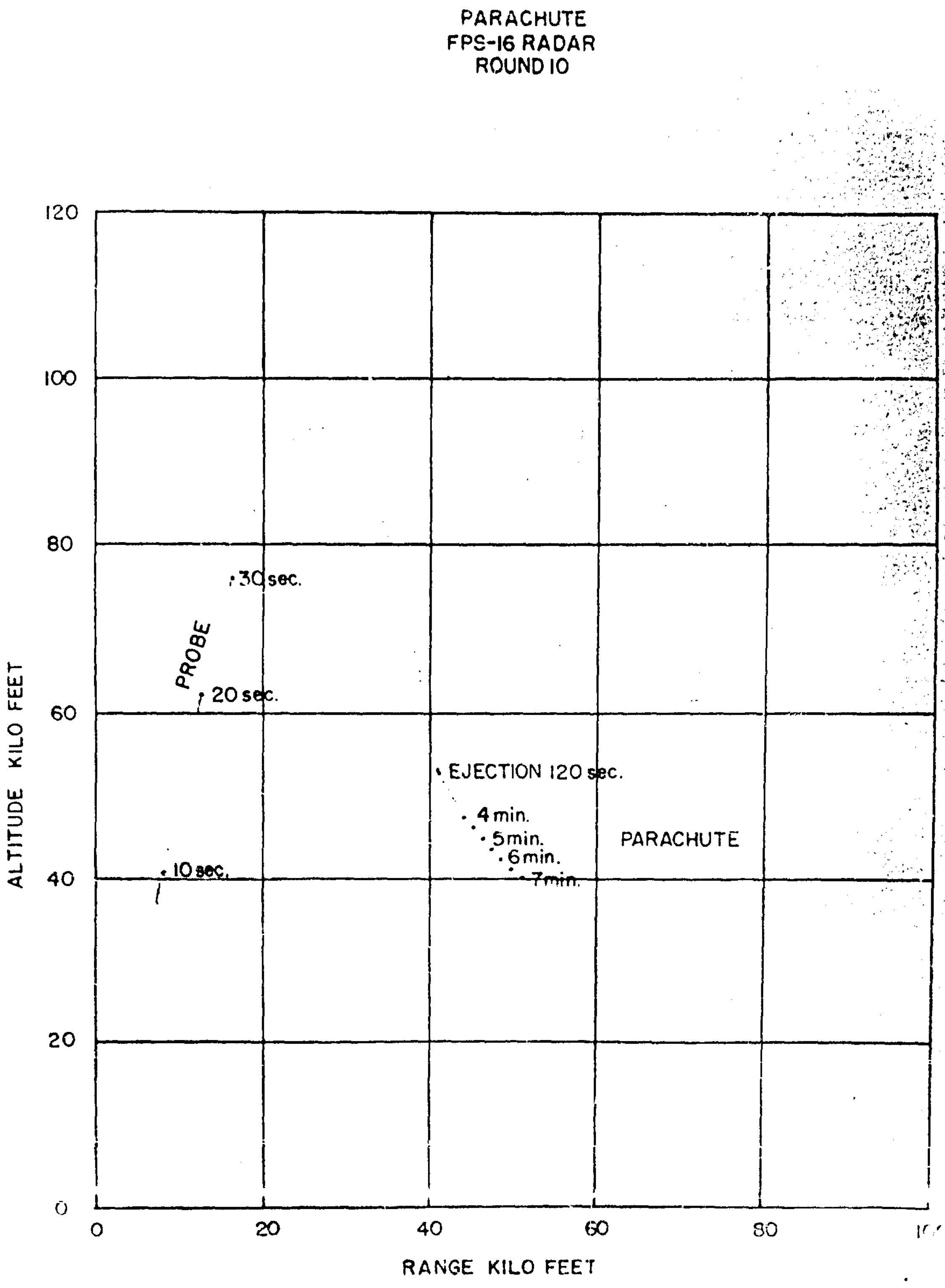
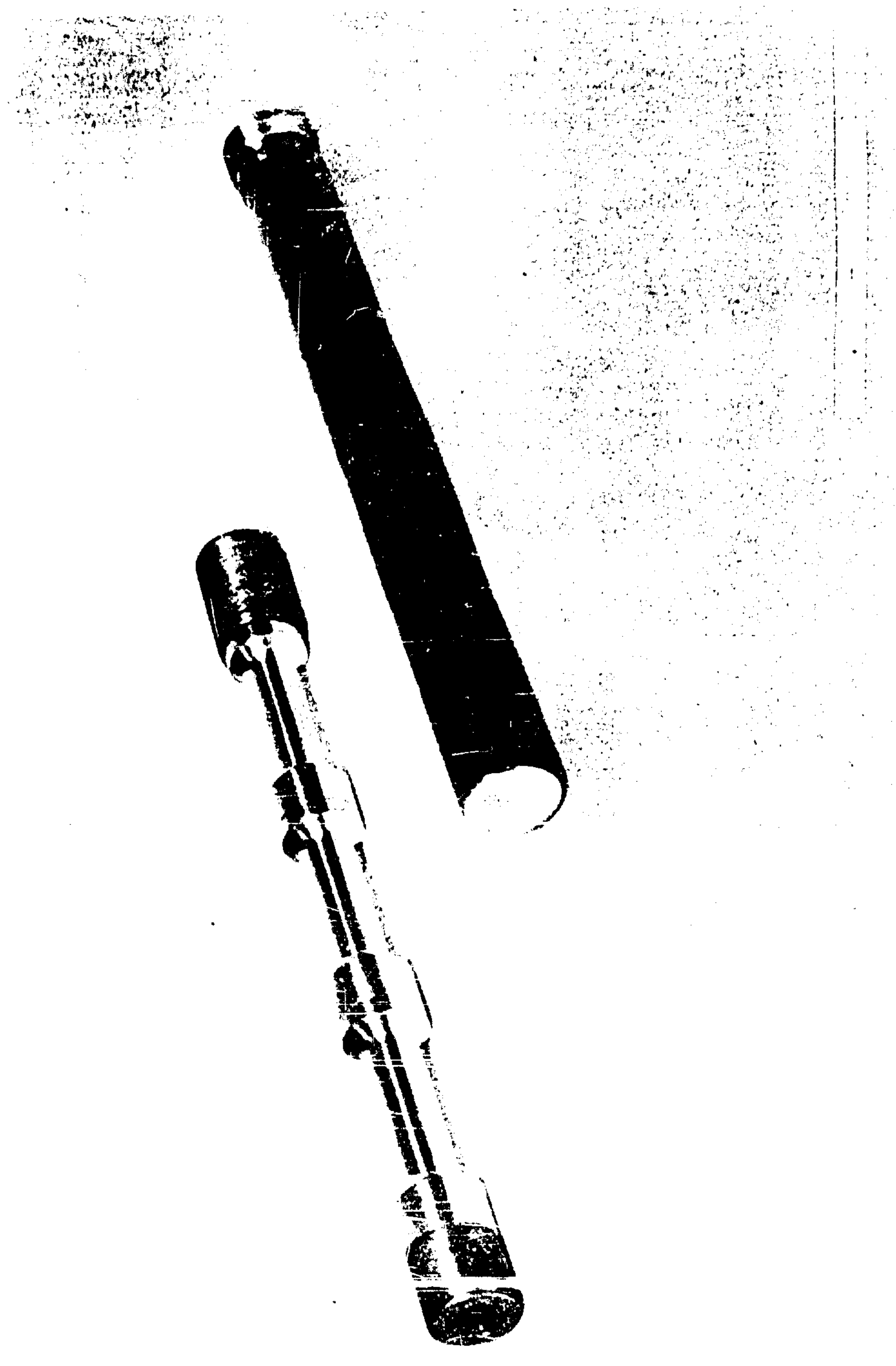
E1-1387




PARACHUTE
FPS-16 RADAR
ROUND 10
120
100
80
60
40
20
0
0
20
40
60
80
ALTITUDE KILO FEET
RANGE KILO FEET
PROBE
30 sec.
20 sec.
10 sec.
EJECTION 120 sec.
4 min.
5 min.
6 min.
7 min.
PARACHUTE



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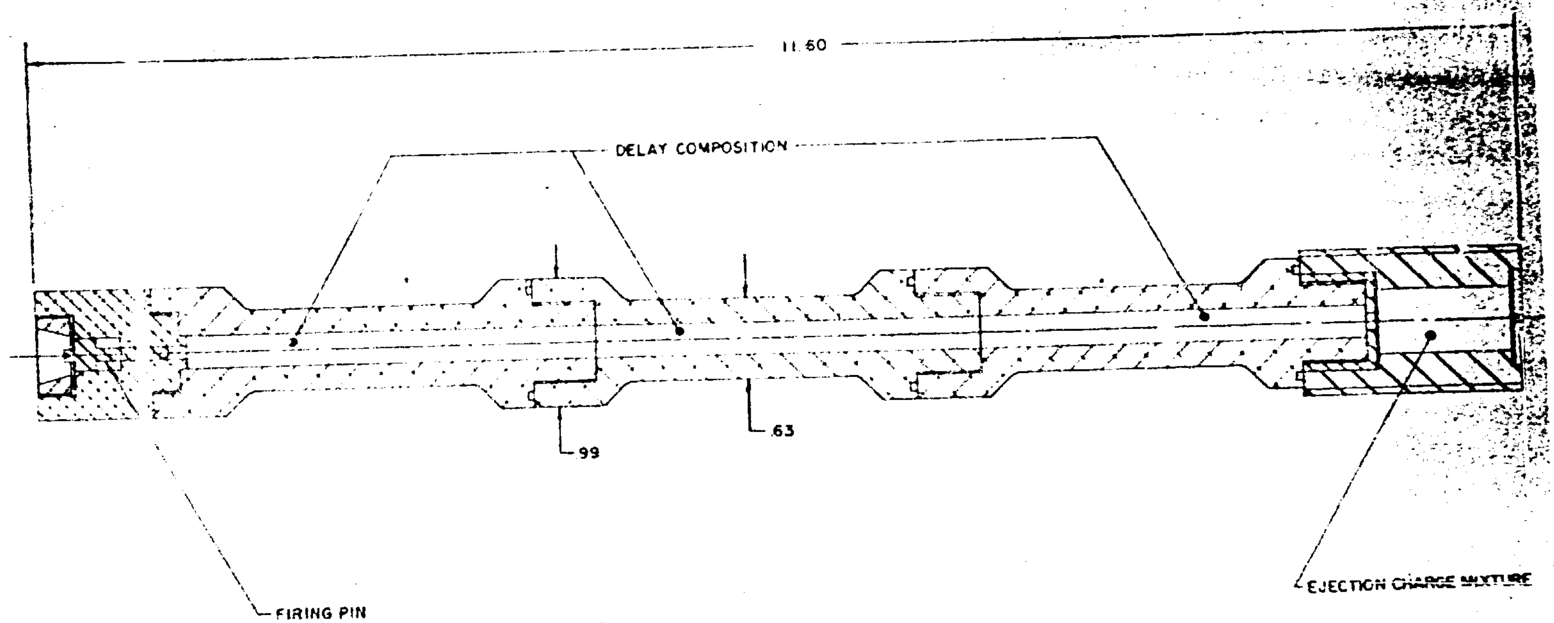

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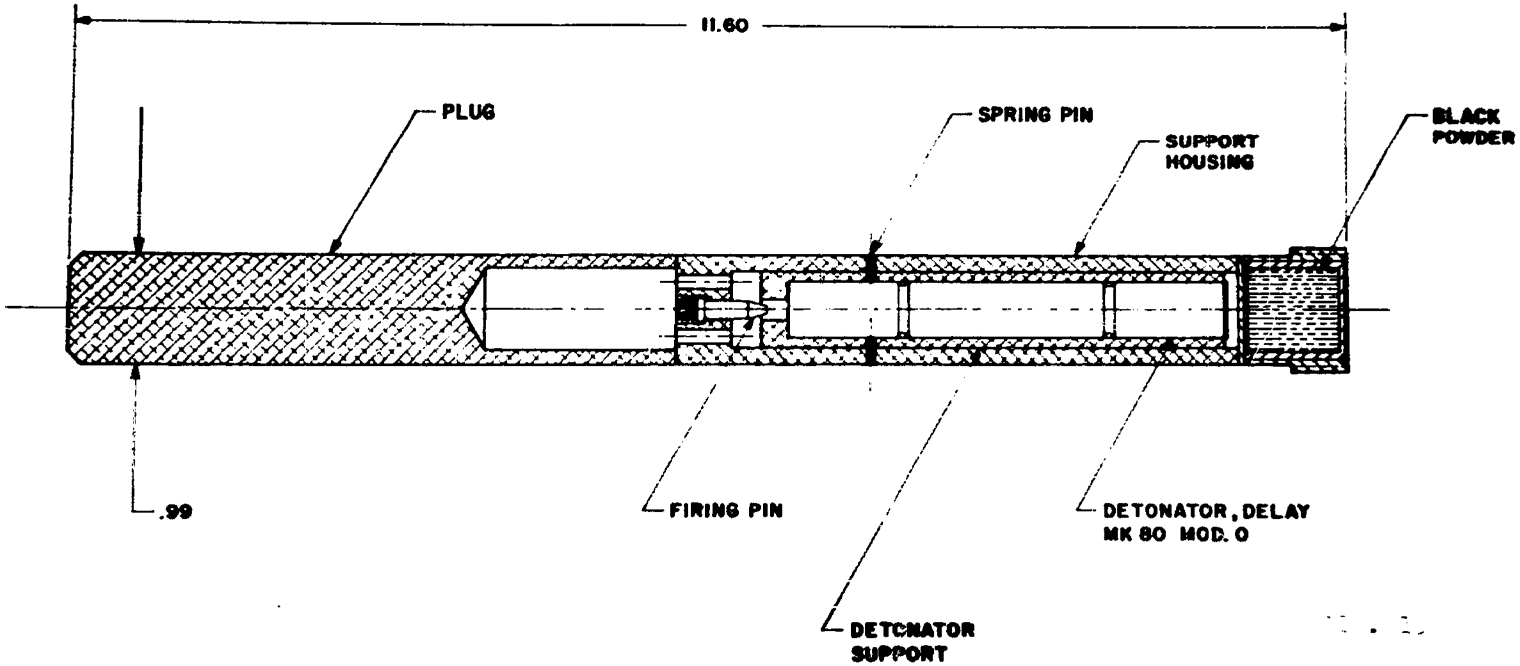

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