UCRL-13054

Report TR 62-1065-2

FEASIBILITY STUDY
OF
ROCKET AND LAUNCHING SYSTEMS
FOR
PARTICULATE SAMPLING OF CLOUDS

Prepared by

ZIMNEY CORPORATION
MONROVIA, CALIFORNIA

For

Lawrence Radiation Laboratory
University of California
Livermore, California

Subcontract 201

Dated 30 September 1962

Facsimile Price $ 5.60

Microfilm Price $ 2.00

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

By: A. G. McLaughlin
Fred S. Soltis
Bruce R. Walker

Approved: [signature]

DISCLAIMER

CONTENTS

1.0 SUMMARY

Methods for improving and expanding a particulate sampling system to increase its utility are discussed. Included are refinements in design of the system, alternate vehicles used as carriers, trajectories, launching methods, tracking systems, and cost-time schedules.

2.0 INTRODUCTION

At the request of the Lawrence Radiation Laboratory (LRL), University of California, the Zimney Corporation has conducted a six-week study and evaluation of an improved and expanded airborne particulate sampling system. Attention is directed to the fact that a detailed study is impossible in the time allotted, and this report represents a comprehensive survey of the potential of alternate systems that would perhaps warrant further study. Certain vehicles were selected and trajectories calculated to obtain representative examples. There exists a wide range of vehicles capable of transporting a particulate sampler payload. The vehicles discussed in this report are capable, with some variation, of accomplishing the desired results.

The necessity of obtaining particles as early as possible from a cloud formed by detonations of nuclear devices, in order to properly evaluate its performance, has required the development of a rocket-borne sampling system. It is now desired to improve the state of the art. Because of the various concepts of the task force required to carry on a nuclear testing program, it may become desirable that the support equipment used for launching the sampling vehicle be extremely mobile.

Methods are discussed relative to improving the efficiency of the sampling section, the performance and reliability of the programmer, and the recovery system of the vehicle.

Various surface and air-launched vehicles are discussed. Trajectories have been included to provide a basis for selection of a system or systems worthy of additional study.

Since support methods are required, surface and air-launching procedures are examined and discussed.

To properly evaluate the final results obtained from the sampled cloud, tracking the vehicle during its flight for confirming the trajectory is desirable. A system is described for providing spatial coordinates as a function of time.

The selection of a given system is a function of its relative availability as well as performance. Consequently, cost and time schedules are presented for the development of various systems for field applications.

3.0 PAYLOAD IMPROVEMENT

3.1 Diffuser and Filter Study

The function of the diffuser is to decelerate the air to a low velocity prior to passing through the filter. The shape of the diffuser must be such as to insure swallowing of the normal shock wave and to avoid flow separation from the walls.

A detailed design of the diffuser would necessarily be a subject of a developmental program, but its principle of operation would be that of a conventional supersonic diffuser utilizing a second throat. Based upon experiments conducted by R. Heckman of LRL, it appears desirable to limit the Mach Number of the flow entering the filter to approximately 0.15. There are indications that this condition corresponds to flow between the filter fibers becoming "choked" ($M = 1.0$), which means that any attempt at increasing the Mach Number of the flow entering the filter would only result in increasing the pressure ahead of the filter and the pressure drop through the filter. The advantages gained from the standpoint of external drag by such an attempt would be offset by the attendant increase in internal drag.

An approach to the over-all design of the sampling head which appears to be deserving of attention is that of changing the filter to cylindrical in shape rather than the previously used circular disc. The diffuser would exhaust into one end of this cylinder and the air would flow through the walls of the cylinder to be collected in an annular chamber and exhausted in a direction parallel to the free stream. Such a scheme could result in substantially increasing the filtering capacity of the head without an intolerable increase in total drag.

The temperature limitation of the filter is a function of the filtering material, and it is a determining factor in the analysis of the vehicle performance parameters. A filtering material which would tolerate higher temperatures would allow filtering at higher free-stream Mach Numbers than possible with the present filter, thus simplifying the problem of matching filter limitations and vehicle performance. The filtering media actually determine the system limitations; therefore, the characteristics should be thoroughly understood before undertaking any extensive design effort. The available experimental data concerning filter characteristics is inadequate. A more intensive investigation is required.

3.2 Programmer

The mechanical timer as designed and used in the Cleansweep II program performed satisfactorily; however, modifications are desirable to provide greater flexibility for timing functions within the rocket. There are two basic types of programmers that may be used: (1) Electronic and (2) Mechanical.

Electronic timers offer high reliability, but they are very complex and expensive. A minimum of one timer must be used for each function desired, and each timer should have its own separate power supply. Separate power supplies are desirable since a transient in the battery voltage arises as a result of squib actuation, which causes a variation in the timing of subsequent functions. The accuracies of successive times would be degraded to become unacceptable in a series of consecutive functions. This could be overcome by the use of a voltage regulator; however, this further increases the complexity of the system.

The mechanical timer used on the previous program permitted adjustment of timed functions prior to vehicle assembly only. Thus, time functions were fixed several hours prior to launch.

To obtain greater flexibility, two six-function mechanical timers coupled with two rotary switches are recommended. The time functions could then be set externally, either manually or remotely, without requiring disassembly of the vehicle. This feature would provide the capability of selecting a variety of discrete times at any instant prior to rocket firing, depending upon whether a manual or remote system were employed.

Three methods which do not affect the reliability of the programmer are available to enable the checkout of the vehicle at any time prior to launch. These three methods are shown in Figure 1. The primary differences between the three systems are the methods of protecting the battery power supply in the event of squib leads shorting upon actuation (and the method of maintaining a short on the squib leads prior to their being fired).

The first method is a refined version of methods two and three combined. It has the advantages of both two and three, as well as serving as a source of power for a beacon if one is employed.

In the Cleansweep II vehicle, provision was made in the programmer to remove a "continuity plug" and insert a test plug and cable for checkout of the electronic components and functions of the vehicle. Although this concept increases the confidence level of the system, there still exists the problem of monitoring the system in the time interval prior to launch. With the programmer changes noted above and shown in Figure 1, a checkout console could be provided that will permit a continuous monitor of the internal condition of the vehicle at any time up to launch. Other advantages gained from a system checkout of this type are (1) remote checkout of the vehicle affording additional protection to personnel in case of accidental actuation of any function, and (2) in the event it is desirable to maintain the vehicle in an inert atmosphere as was done on Dominic, the vehicle may be monitored continuously for long periods in the case of unscheduled delay without requiring physical access to the vehicle.

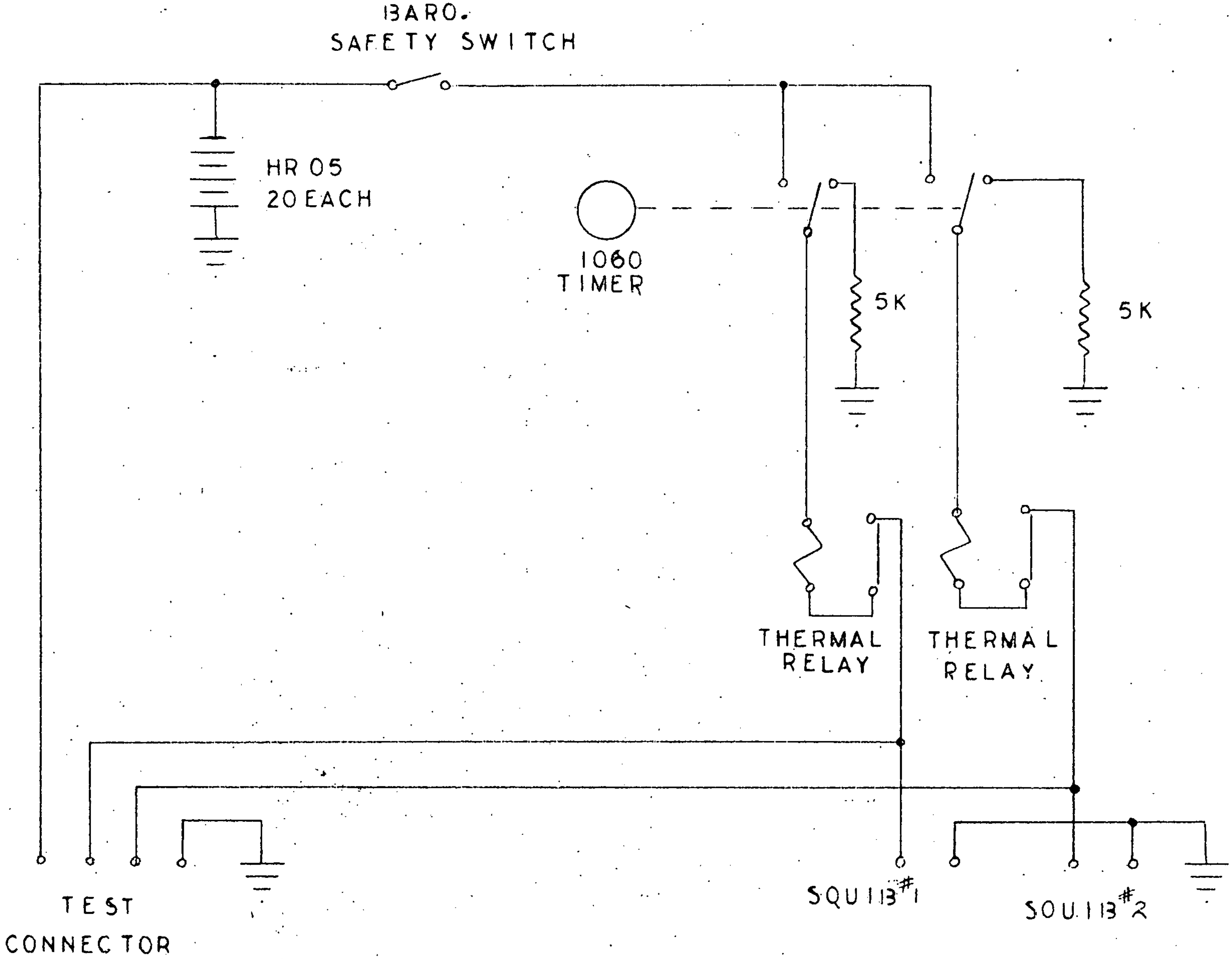

BARO.
SAFETY SWITCH
HR 05
20 EACH
1060
TIMER
5K
5K
THERMAL
RELAY
THERMAL
RELAY
TEST
CONNECTOR
SQUIB #1
SQUIB #2

FIG. 1(a)

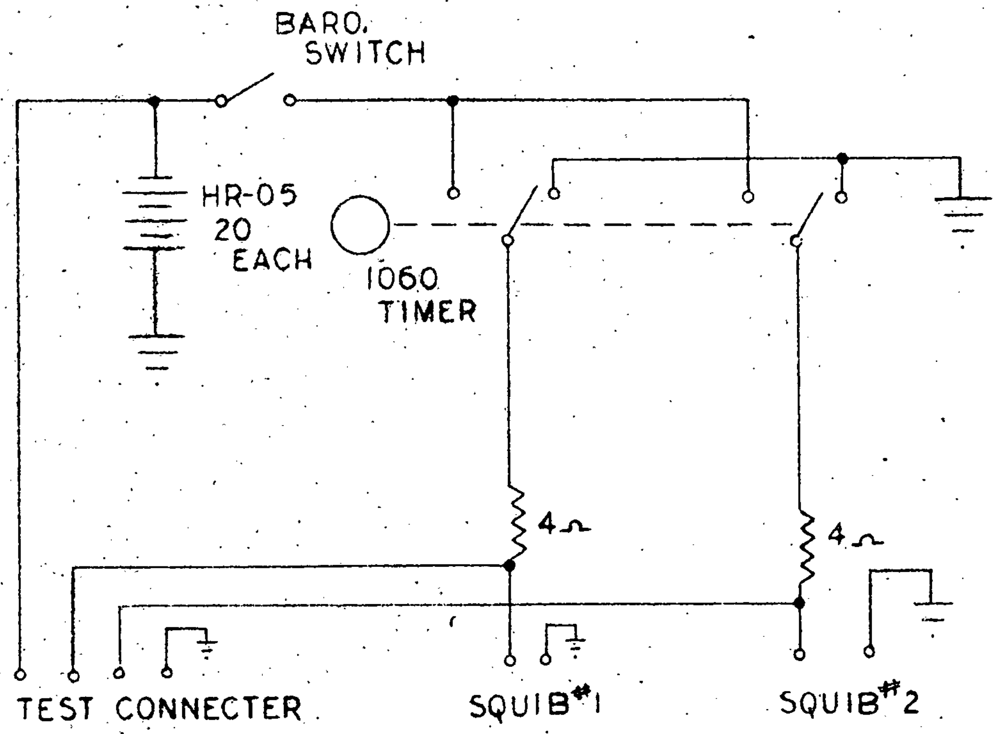

BARO.
SWITCH
HR-05
20
EACH
1060
TIMER
4Ω
4Ω
TEST CONNECTER
SQUIB#1
SQUIB#2

FIG. 1 (b)

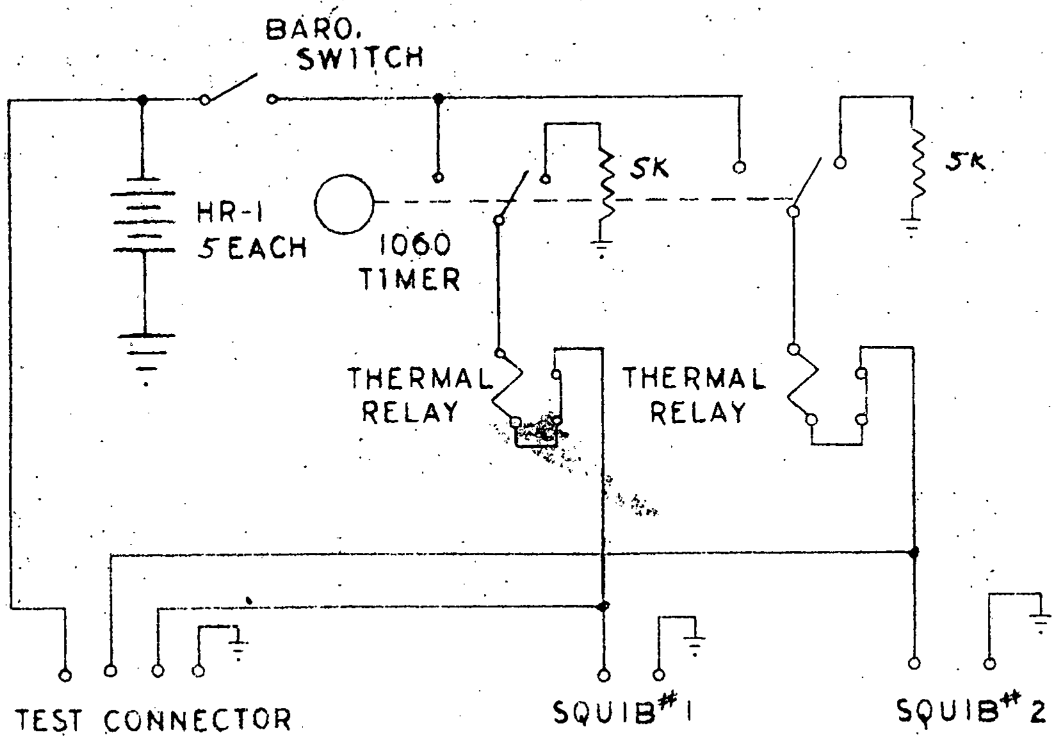

BARO.
SWITCH
HR-1
5 EACH
1060
TIMER
5K
5K
THERMAL
RELAY
THERMAL
RELAY
TEST CONNECTOR
SQUIB#1
SQUIB#2

FIG. 1 (c)

3.3 Payload Separation and Parachute Deployment

A total of 25 rounds were launched at Christmas Island during Operation Dominic. Three rounds failed to deploy the main parachute. Reasons for these failures are unknown. Whether or not the failures were due to system malfunction or some unknown physical phenomena can only be left to conjecture; however, there exists the possibility that the rockets flying through the cloud encountered extremely turbulent conditions. This could conceivably result in entanglement of the drogue chute and payload.

A study has been made of delaying the opening of the drogue chute until approximately 20,000 ft. MSL on the down-leg of the trajectory instead of at the peak of the trajectory. Based on this study, deployment velocities of the order of 1600 ft./sec. could be anticipated. No problem should be encountered at initial deployment at velocities up to 1600 ft./sec. Should much greater velocities exist, additional drag devices may be required before deployment of the drogue chute to reduce the opening loads. The accompanying Figure 2 indicates conditions that exist upon deploying a parachute at 20,000 ft. MSL at 1600 ft./sec. with a 70-pound payload, and a design 30 ft./sec. water entry velocity.

3.4 Recovery Aids

On the Cleansweep II program, after the payload entered the water, it was necessary to initiate recovery aids to determine the location of the payload. Three methods were used to achieve this: (1) a recovery transmitter, (2) stroboscopic light, and (3) dye marker. Although each of these aids worked well, some improvement is desired, along with extended useful lifetimes. The recovery transmitter used was chosen primarily because of availability. It had three drawbacks: (1) vacuum tube construction, rendering a unit susceptible to shock and vibration, (2) large size and weight (5-3/4" x 3-3/8" x

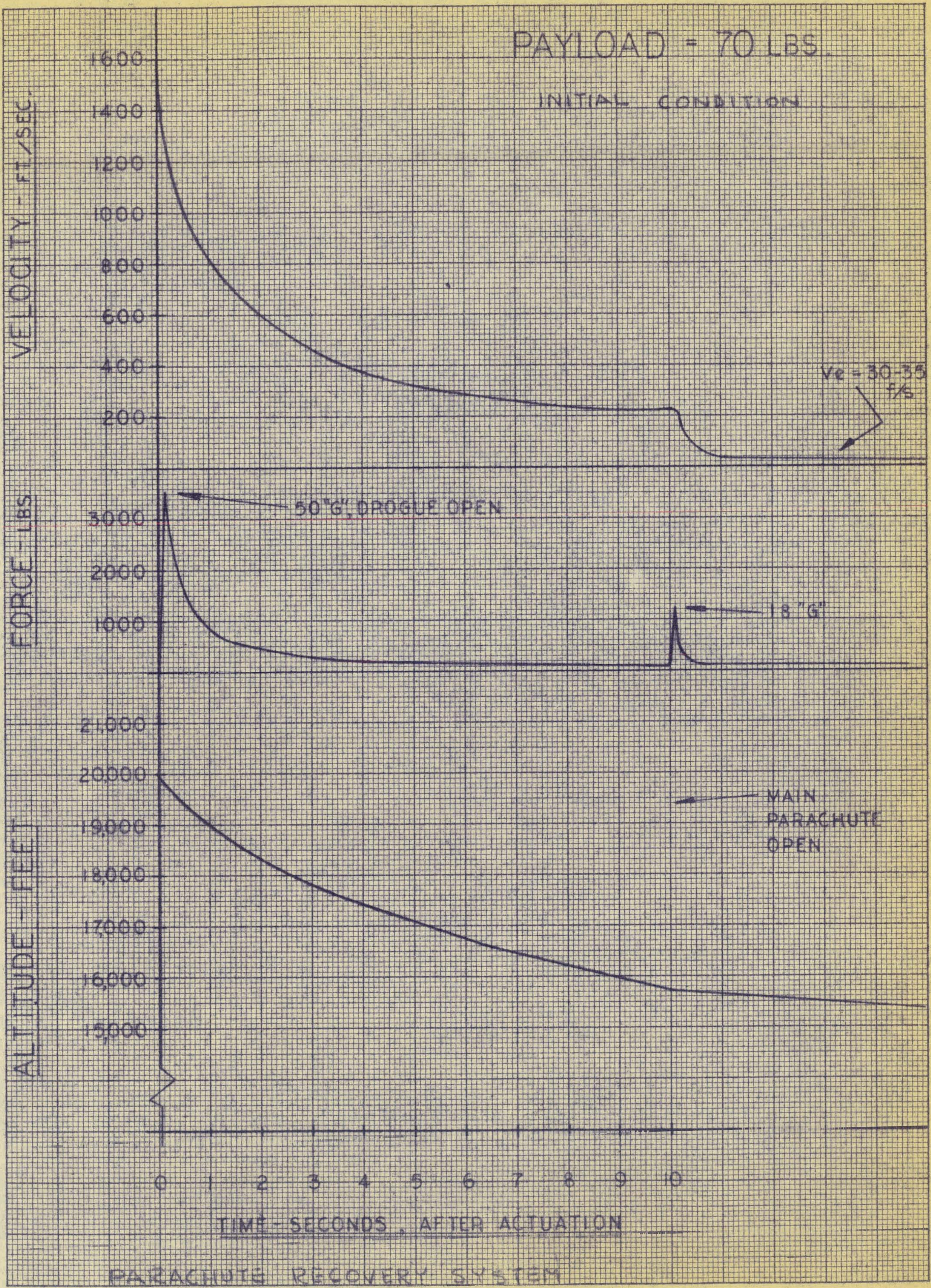

PAYLOAD = 70 LBS.
INITIAL CONDITION
VELOCITY - FT./SEC.
1600
1400
1200
1000
800
600
400
200
Ve = 30-35 f/s
FORCE - LBS.
3000
2000
1000
50 "G", DROGUE OPEN
18 "G"
ALTITUDE - FEET
21,000
20,000
19,000
18,000
17,000
16,000
15,000
MAIN PARACHUTE OPEN
0 1 2 3 4 5 6 7 8 9 10
TIME - SECONDS, AFTER ACTUATION
PARACHUTE RECOVERY SYSTEM

FIGURE 2

1-1/4", and 1.5 lbs.), and (3) battery pack required for 24-hour operation was large and heavy (approximately 6 lbs.).

Solid-state transmitters are currently available that overcome these disadvantages assuming reasonable lead times are available for procurement. The strobe light used on the previous program provided a light intensity visible for approximately two miles at night. Like the beacon, the choice was made primarily on the basis of availability. The range of visibility can be increased by a factor of 5 by utilizing a different model at the sacrifice of a weight increase for the light power supply. The battery leads for the light were located on the outside of the flotation bag, while the 1/4 wave recovery antenna was located inside. Although antenna patterns were not made, the presence of the battery leads undoubtedly modified the pattern of the antenna from a normally omnidirectional pattern. Antenna pattern measurements should be made and perhaps the leads rerouted to obtain an optimum radiation pattern.

The flotation bag used in Cleansweep II was approximately 16 inches in diameter. It was attached to the payload by a 10-foot-long nylon rope. The strobe light was fastened to the top and the recovery transmitter and power supplies were attached to the bottom. Although this proved to work satisfactorily, the shape of the bag did not provide for convenient or efficient packaging. It is recommended that in any future program, studies should be conducted to obtain a more efficient configuration that would require minimum space while stored, yet offer floating characteristics compatible with beacon antenna requirements.

4.0 STUDY OF VEHICLES AND TRAJECTORIES

4.1 Trajectory studies were conducted for both ground-launched and air-launched rocket-propelled vehicles.

Four ground-launched vehicle systems were studied; three two-stage configurations and one boosted single-stage configuration. The latter derives its name from the fact that the booster impulse is small compared to the sustainer impulse, and that both motors are ignited at time of launch. Three air-launched single-stage systems were studied. Several sampling head sizes and several initial launch angles were investigated.

The following table summarizes the configurations for which trajectories were calculated, and pertinent initial conditions.

Launch Mode	Motor Configuration	Sampling Intake Size			Initial Elevation Angle					Initial Mach. No.	Initial Altitude
		2"	3"	4"	40°	50°	60°	70°	80°		
Air	Sword		x		x		x		x	.75	30,000'
	Sparrow	x	x		x		x		x	.75	30,000'
	Archer			x	x		x		x	.75	30,000'
Ground	Javelin-Viper (1)	x	x	x		x	x	x		0	0
	Javelin-Sword (1)		x	x			x	x	x	0	0
	Viper-Sword (1)	x	x(2)	x(2)			x	x	x	0	0
	Zuni-Archer (3)	x		x			x	x	x	0	0

(1) Two-stage vehicles

(2) Second-stage ignition at 20,000 ft. altitude

(3) Boosted single-stage vehicle

In the case of the air-launched vehicles, it was assumed that the sampling head was opened at launch. For the two-stage vehicles, it was assumed that the sampling head was opened at second stage ignition, which occurred at an altitude of 30,000 ft.

The long burn time (38 sec.) of the Archer motor resulted in assuming that the sampling head was opened at motor burn-out, since this did not occur until the vehicle exceeded 30,000 ft. altitude. This restriction was necessary because of the limitations inherent in the computing program that was used. The choice of the various motors mentioned above was based upon a desire to encompass a reasonable range of total impulse; and a past familiarity with the family of motor involved. A final choice of motors would be dependent on more detailed decisions involving performance, availability, and price. The calculated trajectories are presented in graphical form in Appendix 9.1, Figs. 9.1.1 through 9.1.15.

Examination of the plotted trajectories brings to the reader's attention the large effect of sampling head intake diameter on the altitude and range attained by the rocket vehicle. If one assumes that a maximum altitude of 150,000 ft. at a range of 300,000 ft. is desirable, it is evident that the Javelin-Viper combination is required in the case of the larger sampling heads launched from the ground. While the altitude and range attained by the air-launched vehicles is considerably less than that mentioned above, the requirements in this regard for an air-launched system may be considerably less severe than for a ground-launched system.

The drag data used in the above mentioned trajectories was based on flight test data obtained from the Cleansweep II flight test program conducted at Point Mugu, California. These data were reduced to coefficient form. It was assumed that coefficients were valid for all intake and vehicle diameters. That is, no scaling corrections were applied and the variation in drag for a given intake diameter was varied only with the square of diameter of the vehicle.

4.2 Drones

One of the methods studied as possible carriers for samplers on the subject program was rocket-powered drones. These were of interest particularly on specialized cases such as the problems evolved as a result of attempting to sample a small area from a long distance, where other means might require complex guidance or large quantities of vehicles. It was known that two manufacturers were presently working on programs to produce supersonic drones for the armed forces, and these drones might be available as "off-the-shelf hardware."

Northrup-Ventura, Van Nuys, California, formerly known as Radioplane, has a rocket-powered drone, the RP78, developed for the Army and Navy for use as a target. The vehicle is in production, with over 1,000 having been flown. It will attain a speed of M 1.3 at 70,000 ft., but must be air-launched at 40,000 ft. to do this. The vehicle cannot exceed Mach 1 below 40,000 MSL, and their engineers doubt that the addition of 35 lbs. payload (the minimum estimated weight for a sampler system) could be tolerated. Certainly the drone is so marginal in performance that the drag offered by the sampler could be prohibitive as far as the RP78 is concerned. As a result, it seems almost certain that this drone would not be acceptable as a sampler carrier.

Beech Aircraft Corporation, Wichita, Kansas, has developed, under contract from the Air Force and Navy, a target drone designated as the XKD28-I/Q-12. This vehicle's characteristics are such as to make it worth further investigation. The XKD28 is an expendable rocket-powered vehicle of high performance. It is air-launched and weighs a little less than 600 lbs. It is equipped with a "self-contained profile programmed" stabilization and control system. The vehicle will fly a heading from which it was launched with accuracies of 1 part in 50. It is also capable of holding a preselected altitude with less than 100 ft. deviation. The present vehicle has selections from 1,000 ft. MSL to 70,000 ft. MSL. The propulsion system consists of a booster and sustainer using liquid bi-propellant. The Navy F3H aircraft is approved as a launching vehicle at this time.

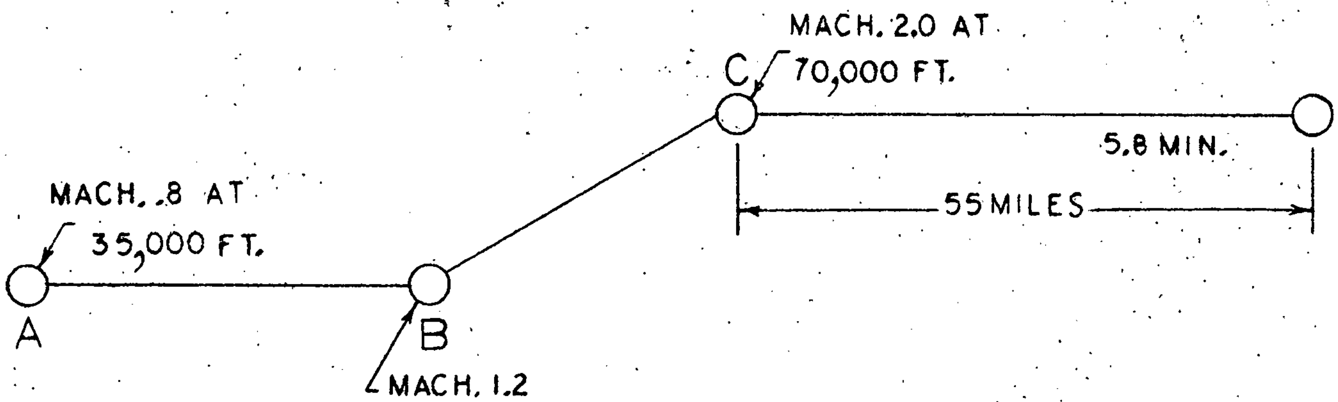
The most serious problems associated with this vehicle at the present are: (1) no production status, as the vehicle is just finishing its acceptance tests, and (2) because of the canard-type control surfaces, a considerable amount of redesign appears to be necessary to house the sampler payload.

The cost of 10 basic vehicles with beacon for tracking, but less engineering for modification for sampling, is $34,300.00 each for a total of (10) $343,000.00. The support equipment required for these vehicles will cost an additional $45,550.00, making a grand total of $388,550.00. Delivery would be two in 9 months ARO, and the complete order of ten within 12 months ARO. For production quantities, the price is approximately $25,000.00 each, based on 100 units in any fiscal year.

Fig. 3 is a typical trajectory of the Beech XKD2B-1 vehicle.

4.3 Methods for Reducing Dispersion

During the firing of both developmental and operational Cleansweep II vehicles, some random dispersion was observed. The random nature of the dispersion leads one to the suspect that mechanical or aerodynamic malalignments were experienced. It is well known that the sensitivity of a rocket vehicle to aero-elastic effects increases as the length-to-diameter ratio increases, and since the launch configuration of the Cleansweep II vehicle was a length-to-diameter ratio of 36.6:1, it is quite possible that aeroelastic effects contributed to this observed dispersion. Another factor to consider in the case of the Cleansweep II vehicle is the alignment and rigidity of the joints connecting first and second



- A-B Launch at Mach 8 at 35,000 ft. altitude and accelerate to Mach 1.2

  B-C Positive 3 "g" pull up and negative 0 "g" push over to Mach 2.0 at 70,000 ft.

  C-D Cruise 5.8 minutes at Mach 2.0 at 70,000 ft. (55 miles)

TYPICAL TRAJECTORY BEECH X KD 23-1 VEHICLE

FIGURE 3

motors and second-stage motor to the payload. Any attempt at reducing the dispersion due to aeroelastic effects by reducing the length-to-diameter ratio is generally undesirable, since this would be detrimental to the ballistic performance of the vehicle. Improvement could possibly be attained by re-examining the design methods of fabrication and assembly of the coupling between the first-stage and second-stage rocket motors and also the connection between the payload and the second-stage motor, and taking those steps necessary to perhaps obtain a more rigid connection at these points.

Introducing spin about the longitudinal axis of the vehicle is a means of reducing dispersion due to such effects as fin malalignment and thrust malalignment. Utilization of the spinning technique demands that proper precautions be taken to avoid the undesirable effect of roll resonance. This condition occurs when the frequency of the roll rate is the same as the frequency of the yaw oscillation.

The ammunition dispersion of a rocket vehicle of this type with two stages could be held to a one sigma deviation of 20 mils. The over-all dispersion will be considerably greater. In order to properly assess the contribution of rocket dispersion, wind effect, aiming accuracy, parachute deployment, and parachute drift to over-all dispersion, it will be necessary to carry out a rigorous analysis which, in turn, should be supported with a modest test program to substantiate the findings.

5.0 LAUNCHING PLATFORMS

Three different types of launching platforms have been investigated on this program and are discussed below.

5.1 Land-Based Launchers

The most desirable method for launching rockets is from land-based launchers. This method provides (1) a stable platform for firing, (2) easy method of orienting with respect to given reference point, and (3) relatively simple logistics requirements. Two types of ground-launch sites can be used: (1) manned and (2) remote (unmanned). Of the two, the manned site, of course, offers the simplest method of launching rockets. This method can be further broken down to (1) fixed base and (2) mobile base, and the fixed base launcher is the least complicated. This type of launching complex was used at Christmas Island in support of the Cleansweep II rocket program in the summer of 1962, and provided a virtually maintenance and trouble-free system. One might say that if this system worked so well, why consider other methods; however, the big drawback to a fixed-base launcher complex is lack of flexibility. By that, we mean to say the area that is intended to be explored by a given rocket vehicle must, of necessity, be confined to a relatively limited area, dependent, of course, on the performance characteristics of the rockets. It becomes apparent that to increase flexibility, the first expedient is to utilize a mobile launcher. Under certain conditions, of course, a mobile launcher is an absolute necessity.

An alternate method for obtaining added flexibility is the utilization of multiple fixed-launcher sites. This has an advantage if the test location is fixed, and it is desired to sample more than one area. The limit of the number of sites would be influenced by many variables, and it is conceivable since it is relatively simple that it could prove to be most economical. This could only be determined by establishing definite mission objectives.

Certainly one should consider a mobile land-based launcher. This type launcher could be essentially the same type of launcher used on the fixed base, but modified to accept gear adapting it to a somewhat rapid movement from one proposed site to another. Again, the limitations are the size and type of land mass available within the test area, and the logistics problems associated with the movements. In any case, a launcher of this type concludes that the test area would be essentially fixed in location and the mobility would only be used for moving the rockets into a more advantageous position based on the expected size of the target.

Consideration must be given to the degree of mobility desired in designing the launcher. The economics of the over-all objectives influence the picture considerably inasmuch as by introducing various types of ground-support equipment and intelligent planning, one could possibly more economically move launchers from location to location only by requiring firing pads, flat-bed trailers, lifting gear, and a power trailer.

Another refinement of land-launching involves a remote-controlled launching site. The remote-controlled site is used when it is desired, or becomes necessary, because of the performance of the rocket or the particular nature of the sampling, to sample the target from a launching area that is considered unsafe for personnel occupancy. An example of remote launching sites was the Cleansweep I rocket program at Eniwetok atoll in 1958. There several launching sites were activated with a quantity of launchers ranging from 2 to 8, and the launchers were designed to program in azimuth and elevation from preset adjustments before the rockets were launched. It is true that many problems arose with this design. However, from this program much information was obtained to justify serious consideration of remote-controlled launchers inasmuch as the small additional cost increases the utility of the launcher.

Not only can the launcher be located in areas hazardous to personnel, but it could be adjusted in azimuth and elevation just prior to firing in the event the target's movement was not as predicted.

Summarizing, land-based launchers, fixed or mobile, manned or remote, offer greater launching accuracy for reasonable costs at the sacrifice of mobility.

5.2 Sea Launching

Since the Task Forces conducting nuclear tests have not limited themselves to operations in the proximity of land masses, it is desirable to look at other means of launching rockets if rockets are to continue to be used in support of all types of tests. Thus, consideration must be given to the use of a ship as the basic launcher support platform. Actually, rocket firing from shipboard has become commonplace, and a wide variety of methods present themselves in support of this system.

The U.S. Navy, as part of their fleet preparedness, have converted several destroyers and cruisers into guided missile ships. Since accuracy in azimuth and elevation is necessary, the launchers are linked with the ship's fire control and are gyro-stabilized so that a stable platform for launching is presented. For rocket vehicles of not too large size, it is feasible to also convert the 5" -38 naval gun into a rocket-launching platform. For the testing program in the summer of 1962 in which, at the early stages of planning, an aircraft carrier was to be used, a design was evolved that would launch 3 two-stage rocket vehicles, Cleansweep II, from a 5" gun.

With this background, and in preparation for evaluating methods of launching rockets from shipboard, visits were made to Long Beach Naval Shipyard, and Hunter Point, San Francisco, where a guided missile cruiser and a destroyer being equipped to launch Azroc's were visited. From these visits, it was apparent that the Navy has a number of ships capable of launching rockets of the size required for a sampling program. Modifications would be required to use either the Terrier launching system or the Azroc system as presently installed. Of the two, it seems likely that less modification would be required for the Terrier system. The problem here, however, is that only a few ships are equipped for firing the Terrier rocket, and therefore, a problem might arise as to their availability. Costs for modification of either the system for launching Terriers or Azrocs could not be assembled in the time allocated for this report; however, a considerable amount of money could be expended.

For the short-range outlook, to adapt existing equipment for rocket launching in the shortest possible time and with the least amount of dollar expenditures, the 5" -38 cal. naval gun seems to lend itself acceptably. These guns are to be found on destroyers, cruisers and aircraft carriers. The most acceptable launching platform from the standpoint of stability, accessibility and space requirements is the carrier. These three conditions tend to become more acute as the ship's size decreases, to a point that it may prove almost impossible to assemble a two-stage rocket and payload on its launcher aboard a destroyer in heavy seas.

5.3 Air Launch

A third method available for launching of rocket vehicles is by aircraft. This method presents several unique possibilities, each with its attendant advantages as well as its problems. Although time has not been sufficient to explore in detail all the phases and attendant problems associated with air launchings, this method presents an attractive means of launching rockets in view of its mobility.

For ground and shipboard launching, to obtain the performance required to do the sampling job, it is necessary to use a two-stage vehicle. For air launching, it is almost certain that a single-stage vehicle can do the job if the aircraft can get in close proximity to the target.

The Navy, Air Force, and NASA have all air-launched rocket vehicles from aircraft. Some methods have been investigated and will be discussed. The armed forces have what is known as a LABS (Low Altitude Bombing System). This system was originated by the Navy, and both Navy and Air Force planes are equipped with the gear. The LABS gear is actually a launching system consisting of a computer tied into the aircraft's instruments to sense angle of attack, air speed, "g" loading, etc. The accuracy of the system depends on how accurately the air speed, gyros, and associated flight instruments have been calibrated and integrated into the system, and also how well the pilot flies the programmed manuever. It can be expected that for any given LABS gear equipment, the inherent inaccuracies will give a launch error of about 2°; however, if the complete system is carefully calibrated and the pilot thoroughly trained to the particular flight path desired, the accuracy will fall well within 1° of error. Normally, the release angle is preset on the ground before takeoff; however, this can be changed while airborne with some deterioration of accuracy, again based on the pre-calibration check. The angle of release of this system can be any angle from horizontal to vertical. The release is automatic and requires only a minimum of monitoring from the pilot. The pilot must be given heading and a "pip" point to start his equipment and run, and since it seems logical to assume all aircraft will be under positive control by AOC at all times, this does not seem to be a particular problem. It is understood that almost all combat aircraft are equipped with the LABS gear; however, the Navy recommends the use of the F-4H aircraft. This is a two-place, very high performance aircraft that is in fleet service at the present time. It is quite capable of carrying at least six rocket vehicles of the conceivable size for sampling with enough fuel to remain airborne at least 1-1/2 hours. It can launch at Mach .8 and up to 40,000 ft. MSL. Being two-place, an observer can be placed aboard.

In launching a number of vehicles, consideration must be given to the aircraft turn-around time for each pass in the event he does not release in salvos.

Both NASA and the Navy have launched Viper-powered rockets from F104's for experimental work. For this work, the vehicle was either dropped from the aircraft or launched from a rail extended below the aircraft at launch time. NASA launched their vehicle from 50-60,000 ft. altitude at speeds of from Mach 1.4 to 1.7 at angles of +35 to +50 degrees from the horizon.

Although not of the same performance as the F4H, the B-57 - type aircraft certainly could be used as a launching platform. Vehicles weighing 1,600 pounds and consisting of three stages have been successfully launched from a B-57; therefore, it can be assumed that at least four sampling rockets should be able to be launched from a single aircraft. No information is available at this writing regarding the altitude and speeds available for launching, but it seems reasonable to assume 30,000 feet and Mach .75 could be achieved.

Although further investigations must certainly be made, another aircraft capable of air launching is the B-47 Air Force bomber. These aircraft should be capable of not only carrying and launching any quantity of rockets conceivable for use in any one test, but have the capability of long range and/or long periods of time on station. Again, the type of task force organized to handle the complete test would dictate whether this aircraft should be considered.

For analyzing the cost of air launching, it seems that compared to shipboard modification, the costs will be less. For the F-4H, at least, the only modification required would be the design of a pylon capable of holding a multiple quantity of rocket vehicles. A standard bomb rack can be utilized and would be actuated by the LABS gear. It seems conservative to assume modification of this aircraft could be made for $25,000.00 per plane. Costs for modifying B-47's could become substantially higher, depending on the amount of sophistication desired. It seems that for redundancy, assuming six rockets are desired to be launched in a single test, a minimum of four of the F-4H or B-57 would be required and two of the B-47 type.

It should be noted in the case of moving platforms such as a ship and aircraft that errors no longer are limited to ammunition launching and wind effects, but, in addition, one must include position error as well. Although the aircraft is firing over considerably shortened ranges, it is more difficult to control the point in space for release; hence its total dispersion cannot be defined in the conventional manner. It is thought, however, that in view of the relatively short range, the total absolute error for air launching will be less than long-range rocket launch from sea level.

6.0 TRACKING SYSTEMS

In order that the point of penetration and the trajectory through the cloud be known, radar tracking of the payload is desirable. For a single vehicle, tracking is a relatively simple matter. When position information is desired on more than one vehicle at the same time, the problem becomes very complex if high resolution and accuracy are required.

Since single-vehicle tracking can be done with a single modified SCR-584 radar or similar set, this will not be discussed in detail. The only requirement is the incorporation of an "S" band transponder in the vehicle. The transponder is necessary since the vehicle presents a very small reflecting target, and greatly enhances the possibility of obtaining consistent tracking.

For multiple tracking, two methods are available: (1) A single antenna in which the transmitted beam is electronically swept across the antenna, both vertically and horizontally, somewhat in the manner of a television screen. Thus, a portion of the sky is completely scanned. This scanning takes place at a high rate, and virtually a constant track is made. This system is actually still in the development phase, although sufficient tests have been made to prove the design concept. Very high accuracy can be realized utilizing this concept, but there are several drawbacks: (a) the system is large in size and heavy in weight; e.g., the antenna structure is in the neighborhood of 30' x 60'; (b) the time for delivery would be 1 - 2 years minimum; (c) 4 - 8 personnel would be required for operation; (d) the cost would be approximately 3.5 - 5 million dollars. (2) A two-antenna method which scans a portion of the sky in approximately 1 - 2 seconds. In this system, one antenna scans horizontally and the other scans vertically. Normally, these motions are not displayed simultaneously; therefore, the elevation and distance are first displayed on the indicator, followed by the azimuth and distance. The Gilfillan Company in

Los Angeles manufactures a ground control approach radar which works on this principle and it appears to be adaptable to tracking multiple targets. For this purpose, it would be desirable to modify the set. These modifications would be: (a) extend the range of the present equipment from 40 miles to 60 miles; (b) add two more indicator scopes, one to display azimuth and range, and the other elevation and range. These two scopes would be photographed with a frame-by-frame camera. The display furnished with the unit would be retained for monitoring; (c) provide sync pulses for the cameras; (d) since the set is designed for an elevation search of 0° to 30° and an azimuth search of plus or minus 15°, provide means to search plus or minus 15° from variable mean elevation angles from 0° to 90°.

This set, however, has several limitations when used for multiple missile tracking. The resolution is such that if several vehicles are launched on the same trajectory and the azimuth-elevation-slant range spread is small, individual targets will not be evident on the radar indicator. This result will be experienced if the vehicles have less than approximately a 1° angular spacing and small slant range differences when observed from the radar site. The radar display will show a large spot which will represent a group of vehicles. However, differences of greater than 1° in angular spacing will be shown as separate targets regardless of range. Separate targets will generally be evident if the targets are 500 feet apart.

In operation where one antenna is scanning horizontally, its beam width is 3.5°. This means that if the target is out of this angle, it will not be seen. However, the vertical antenna will see the target if it is directed in approximately the right direction ± 1.25°. In either case, whichever antenna sees the target, the other antenna is servoed to that position by the operator. This makes it desirable to launch all vehicles at very short intervals (Δt). The radar can then be positioned to the correct "point in space" and the operator will manually servo the antennas as necessary to keep the targets positioned on the indicator.

In general, it is felt that if the vehicle can be tracked through second-stage ignition, the trajectory can be fairly well established. In the past operation, no vehicle tracking was done; however, tracking of the radar reflective main parachute was accomplished. This would give impact data for recovery people to use. The radar set mentioned above has at present a 40-mile range, which can be extended to 60 miles. For long-range trajectories, the parachute may be below the radar horizon when deployed at 10,000 ft. MSL, so tracking of the parachute to impact may not be done regardless of the range capabilities of the radar set due to ground effects.

A survey was made of radar beacons to augment the tracking capability of the radar. Generally speaking, the available beacons are awkward to package in the Cleansweep vehicle. Accordingly, requests were made to two companies which have a very good history of beacon reliability to propose modifications to their beacons for incorporation in the Cleansweep vehicle.

The beacons require 24-32 VDC at .5 ampere max. This power would be derived from the battery pack in the programmer. Also, a simple on-off switching would be provided as well as external power for checkout.

It is felt that trajectory information can be obtained from a fairly simple, low-cost radar set, in conjunction with a radar beacon. It should be realized, however, that the information gathered will not be of the accuracy provided by a high-resolution missile tracking system such as a modified SCR-584 or FPS-16 radar, but would give fairly good results on point of cloud penetration and deviation of a vehicle from its calculated trajectory if this occurs.

7.0 GUIDANCE SYSTEMS

7.1 For long ranges and small targets, the use of unguided ballistic missiles must be carefully analyzed and the introduction of a guided missile may be feasible under such circumstances in spite of the higher costs and longer lead times required. It must be kept in mind that the economics of both systems must be compared as well as their performances.

The above situation happens in the case of a high yield detonation being considerably lower than expected. For this "worst case" the target is of a small enough size and at a large enough distance to prompt the investigation of some means of guiding the sampling payload through the cloud.

In view of the complexities associated with the design, testing and successful use of a new guidance system, it was deemed most feasible to attempt to either utilize an existing operational guidance system or to make minor modifications to such a package to adapt it to this specific problem.

The guidance systems considered were chosen primarily because of space and weight requirements to insure that a vehicle of reasonable size could be used. These initial considerations definitely ruled out such things as inertial guidance systems and auto pilot systems. In addition, the above types were rejected because of exceptionally high costs. The systems considered were Sidewinder, Shrike, and Falcon.

7.2 The Sidewinder guidance package has size and weight requirements compatible with the type of vehicle and payload contemplated for use on this program. The basic seeker head consists of a single cooled infrared detector, scanning a conical surface in front of the vehicle, which is at the apex of this cone. The guidance package itself is thus a null seeking type and is not appropriate to our needs for the following reasons. The cloud is at best a poor infrared source, due to the rapid initial expansion. It is also possible that an overexpansion does occur, resulting in a cloud temperature below the ambient temperature. If another type of detector is used, such as a gamma detector, the electronics is still not applicable because of the size and distribution of the target. A null seeker looking at a large annular target will become confused very easily, and cannot make and execute a simple guidance command. The Sidewinder system also flies on an intercept course, and since the target in our case would be stationary, also adds to "confusion" in the guidance system. If a decision was made, it would very probably be to guide the vehicle to the center of the cloud, which is not the area it is desired to sample. Therefore, the only portions of the Sidewinder system that could be used are the control mechanism and servo system. A completely new electronics package, including target sensor, would need to be designed and developed; the resulting program and its associated cost are not readily justifiable for the present program.

7.3 The Shrike system was basically the same control surfaces and mechanisms as Sidewinder except for some minor changes in structural strength and size. The sensing head of Shrike consists of four interwoven spital antennas. Phase comparisons are made between these antennas of an S-band signal received from a remote location to guide the vehicle to the target transmitter. Due to the problems of accurately locating a high-powered radiating source below the cloud and the fact that this system is still in the development phase, this system was not considered feasible.

7.4 The Falcon system basically differs in that it flies a collision course, which more fits the requirements. As in the case of the Sidewinder, the detector would have to be changed to a gamma detector. In order that a certain area of the cloud were to be penetrated, the detector could be electrically offset from the missile axis immediately prior to launching. This would consist of determining the cloud size optically, and converting this into the desired angle of penetration from the straight line penetration. This "error" signal would then be put into the guidance system by means of an externally available switch. Some problems would probably arise from integrating the system into the Cleansweep payload. These would mostly be mechanical, as the Falcon missile is greater in diameter and adds approximately 30 pounds in weight.

It is also remotely possible that a Falcon system could be utilized in an "as is" condition electrically, by using an infrared laser beam to illuminate the desired point of penetration. However, to do this would require laser development, and any clouds between the launch point and the target would absorb the infrared radiation and render the system useless. Also, since the properties of the cloud are not accurately known, there is a possibility of absorption rather than reflection.

The most logical method of detecting the target is to use some inherent property for detection. This is limited to either visual or radiation detection.

To detect the cloud visibly would require a television system or a large array of photocells with a rather complicated electronic system in either case.

For the radiation detection system, a study will have to be made of the gamma ray radiation intensity as a function of range, altitude, and time. Assuming a field adequate to detect, two methods are possible to provide a signal out of the detection system compatible with the Falcon type of guidance system.

(1) A collimated detector spun at a high rate which is set off the missile axis at several degrees. (If the detector were offset 6°, a field of view of slightly more than 6° would be required.) The missile would correct its course for maximum signal out of the detector. At a predetermined time (before penetration into the cloud) when the vehicle was on course toward the center of the cloud, an error signal would be fed to the guidance to direct the vehicle to a particular point of penetration. As soon as the vehicle moved to this

new position, the fins would "lockup" (at zero position), the guidance would be turned off at this point, and the normal vehicle sequence continued; i.e., nose (detector ejection, etc.). (2) Four detectors mounted slightly off axis would be sampled electronically. This signal would be the same as in the aforementioned method; however, the mechanical problems associated with spinning the detector at high speed (approximately 600 rps) would be eliminated.

By combining components and assemblies of the Falcon and Sidewinder, a reliable system could be developed. However, considerable time and money for development would be required.

Some rocket exploration of nuclear clouds has been made since 1956; however, there is still a lack of basic knowledge of the characteristics of clouds that would aid the systems designer. A program to measure these characteristics would provide much valuable data.

8.0 COST ANALYSIS

The systems that appeared feasible were further analyzed to provide relative costs of one system with respect to the other. The costs presented herein are based on assumed mean direct labor rates of $5.50 per hour for all engineering and $3.25 for all manufacturing. A hypothetical corporation was assumed with an overhead of 125 percent for engineering and manufacturing labor, an overhead of 20 percent for general and administrative expense. Ten percent of the total cost was added as the hypothetical fee. These values are typical for the aerospace industry and could be used for budgeting purposes.

The systems control and the scope of the program for each system were determined by mutual agreement between Zimney and LRL personnel.

8.1 Cleansweep II Head with Sword Motor - Air Launch, 4 and 20 Units

	4 Units		20 Units
Engineering Labor 3600 hrs.$5.50	$19,800.00	5600 hrs.$5.50	$30,800.00
Engineering O/H 125%	$24,750.00	125%	$38,500.00
Manufacturing Labor 1200 hrs. $3.25	$ 3,900.00	6000 hrs. $3.25	$19,500.00
Manufacturing O/H 125%	$ 4,875.00	125%	$24,375.00
Field Labor 480 hrs. $5.50	$ 2,640.00	1700 hrs. $5.50	$ 9,350.00
O/H 125%	$ 3,300.00	125%	$11,687.50
Purchased Parts, Materials, etc.	$22,400.00		$112,000.00
Sub Total	$81,665.00		$246,212.50
G & A 20%	$16,333.00		$ 49,242.50
Total Cost	$97,998.00		$295,455.00
Fee 10%	$ 9,799.80		$ 29,545.50
Total Estimated Cost	$107,797.80		$325,000.50

1. Engineering includes adapting vehicle to aircraft and liaison required to qualify system for air launch.

2. Ref. Fig. 9.2.3, Time Schedule

8.2 New Diffuser & Head Development

Engineering Labor	2000 hrs. $5.50	$11,000.00
Engineering O/H	125%	$13,750.00
Manufacturing Labor	1000 hrs. $3.25	$3,250.00
Manufacturing O/H	125%	$4,062.50
Purchased Parts, Materials, etc.		$1,500.00
Sub Total		$33,562.50
G & A 20%		$ 6,712.50
Total Cost		$40,275.00
Fee or Profit 10%		$ 4,027.50
Total Estimated Cost		$44,302.50

1. Includes:
   (a) Complete engineering and analysis of diffuser study
   (b) Wind tunnel tests
   (c) Correlating data
2. Ref. Fig. 9.2.2, Time Schedule

8.4 T[illegible]each Single-Stage Vehicle (Sword) with New Diffuser Design - Air Launched

Elements of Cost	Payload		Rocket Vehicle		Engineering		Total 8.4
Engineering Labor					9000 hrs. $5.50	$49,500.00	$49,500.00
Engineering O/H					125%	$61,875.00	$61,875.00
Manufacturing Labor	4000 hrs. $3.25	$13,000.00	750 hrs. $3.25	$2,437.50			$15,437.50
Manufacturing O/H	125%	$16,250.00	125%	$3,046.88			$19,296.88
Purchased Parts & Materials		$89,000.00		$30,000.00			$119,000.00
Sub Total		$118,250.00		$35,484.38		$111,375.00	$265,109.38
G & A 20%		$ 23,650.00		$ 7,096.88		$ 22,275.00	$ 53,021.88
Total Cost		$141,900.00		$42,581.26		$133,650.00	$318,131.26
Fee or Profit 10%		$ 14,190.00		$ 4,258.13		$ 13,365.00	$ 31,813.13
Total Estimated Cost		$156,090.00		$46,839.39		$147,015.00	$349,944.39

1. Includes adapting vehicle to aircraft and liaison required to qualify system for air launch.

2. Ref. Fig. 9/2/1, Time Schedule

8.3 [illegible] each Two-Stage Vehicles (Viper-Javelin III) with New Diffuser Design - Surface Launched

Elements of Cost	Payload		Rocket Vehicle		Engineering		Total 8.3
Engineering Labor					9000 hrs. $5.50	$49,500.00	$49,500.00
Engineering O/H					125%	$61,875.00	$61,875.00
Manufacturing Labor	4000 hrs. $3.25	$13,000.00	2000 hrs. $3.25	$6,500.00			$19,500.00
Manufacturing O/H	125%	$16,250.00		$8,125.00			$24,375.00
Purchased Parts & Materials		$89,000.00		$57,000.00			$146,000.00
Sub Total		$118,250.00		$71,625.00		$111,375.00	$301,250.00
G & A 20%		$ 23,650.00		$14,325.00		$ 22,275.00	$ 60,250.00
Total Cost		$141,900.00		$85,950.00		$133,650.00	$361,500.00
Fee or Profit 10%		$ 14,190.00		$ 8,595.00		$ 13,365.00	$ 36,150.00
Total Estimated Cost		$156,090.00		$94,545.00		$147,015.00	$397,650.00

Note: Above does not include Launcher Design and Fabrication.

Ref. Fig. 9.2.4, Time Schedule

8.5 Guidance System

No cost and time scale estimates are given for a guidance system. Because of the complications in a system of this type, considerable time and effort must be made to present a meaningful estimate. It can be stated, however, that a program of this type will extend considerably longer than 12 months and cost greater than one million dollars for development.

9.0 APPENDIX

9.1 Trajectories

9.2 Time Schedules

10.0 REFERENCES

Final Report, Cleansweep II Rocket Sampler, Zimney Corporation, dated September 30, 1962.

Final Report, Cleansweep I, Cooper Development Corporation, dated January 31, 1959.

Solid Propellant Motors, TDS 102, Lockheed Propulsion Company

Archer Sounding Rocket 35KS1375, Atlantic Research Corporation

Rocket Motor Manual, Volume II, SPIA (Confidential)

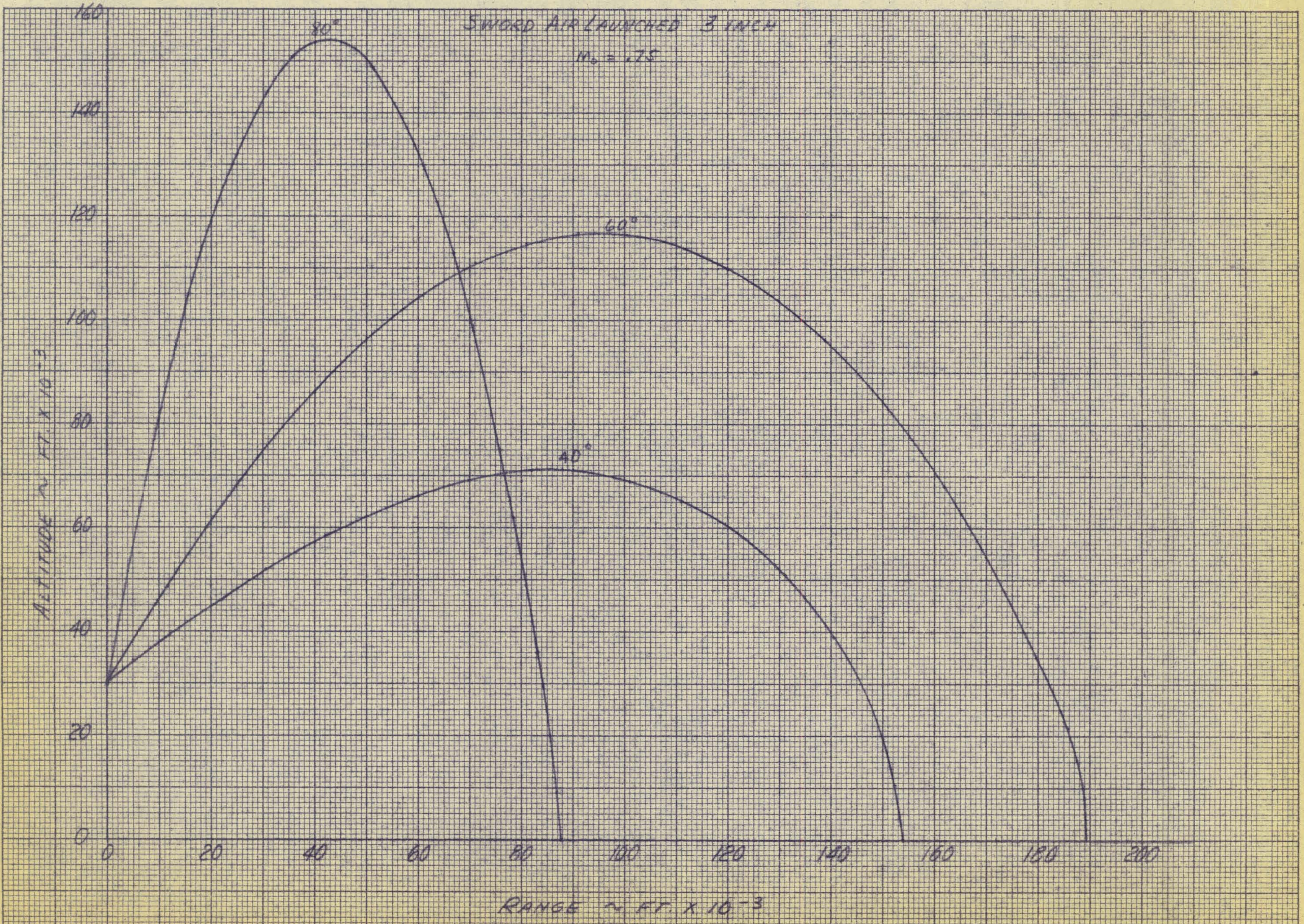

SWORD AIR LAUNCHED 3 INCH
M₀ = .75
80°
60°
40°
ALTITUDE ~ FT. X 10⁻³
RANGE ~ FT. X 10⁻³
0
20
40
60
80
100
120
140
160
180
200

FIG 9.1.1

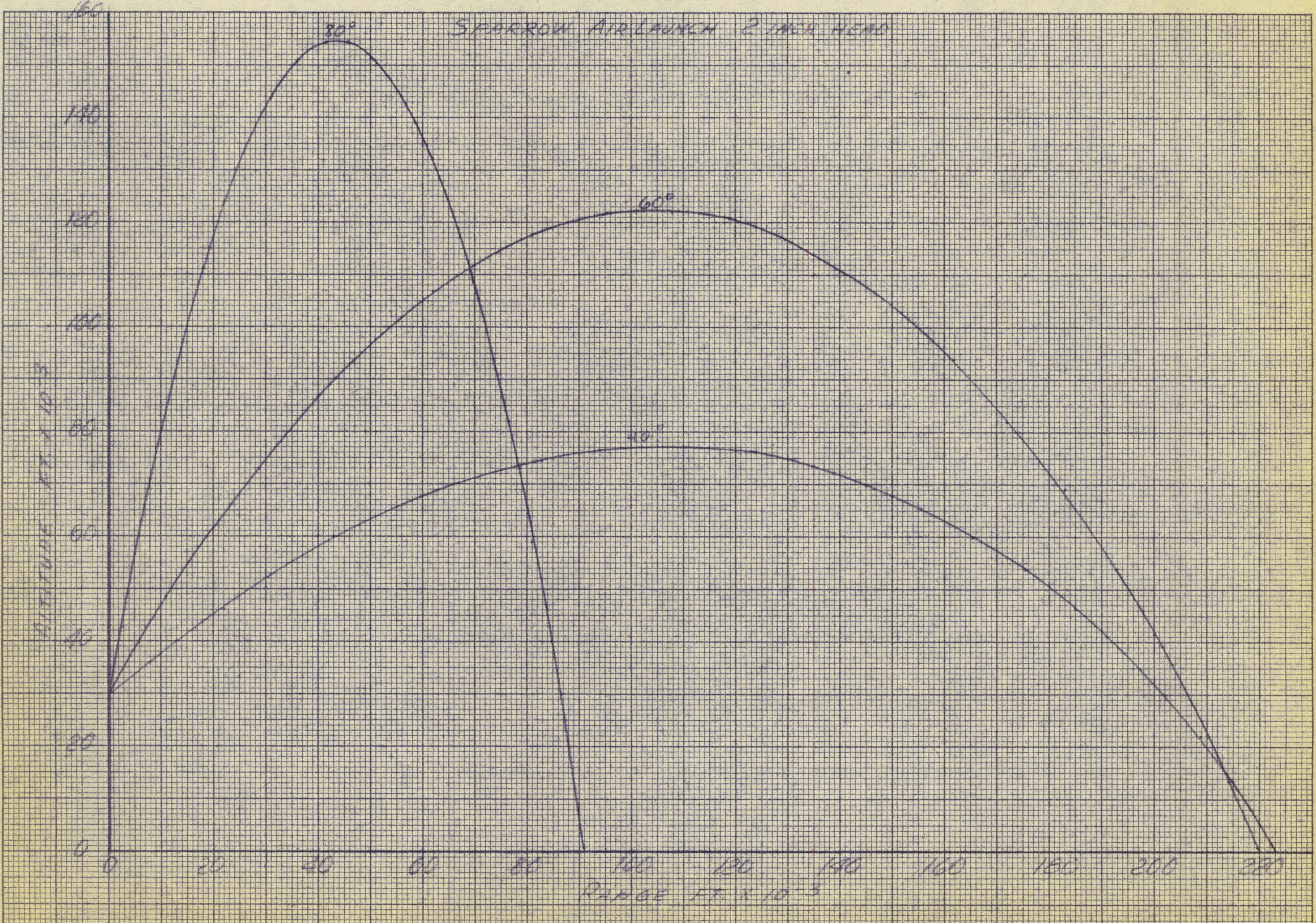
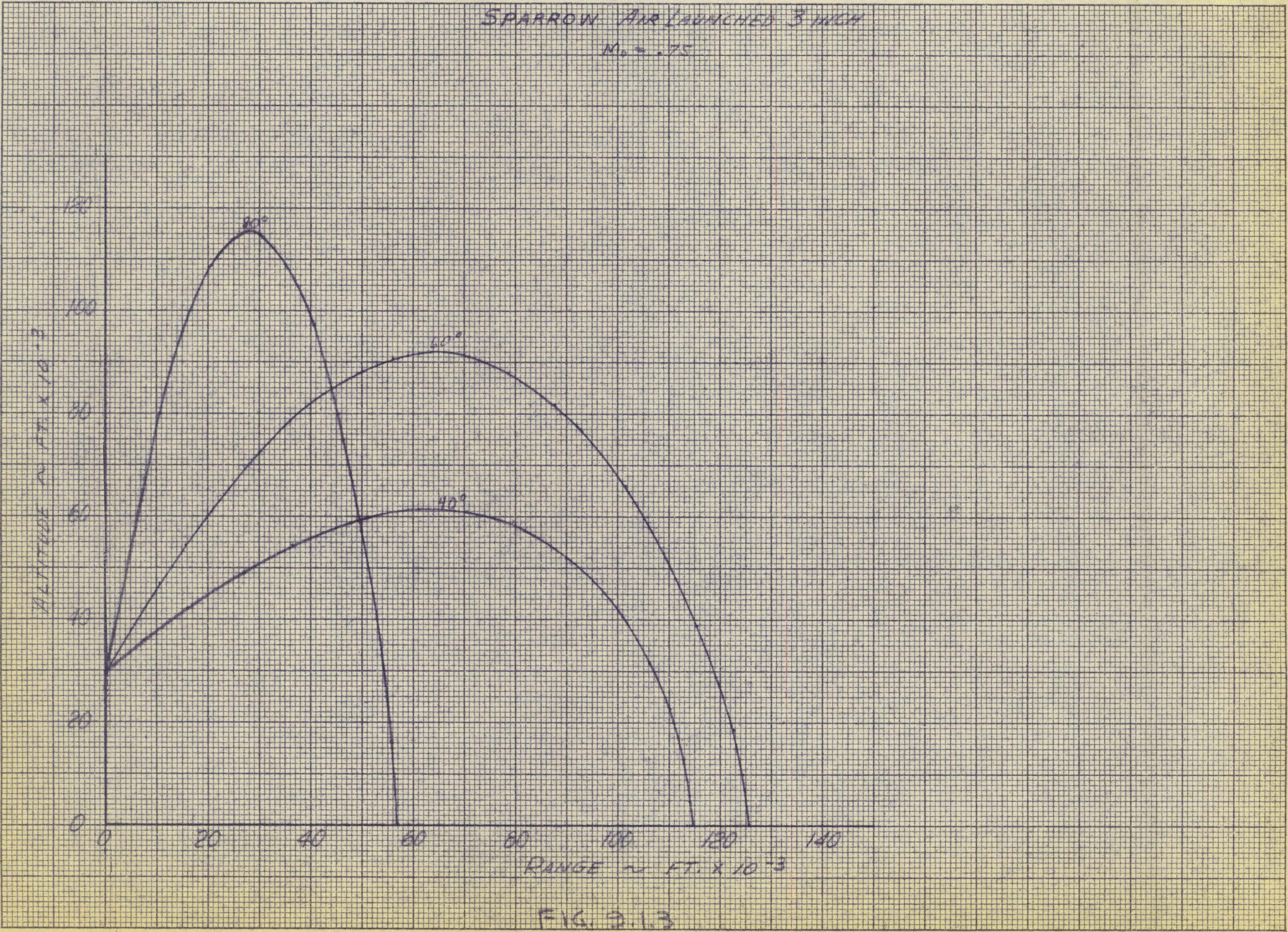

SPARROW AIRLAUNCH 2 INCH HEAD
80°
60°
40°
ALTITUDE FT x 10^-3
RANGE FT. x 10^-3
0
20
40
60
80
100
120
140
160
180
200
220

FIG 9.1.2



SPARROW AIR LAUNCHED 3 INCH
M_0 = .75
90°
60°
40°
ALTITUDE ~ FT. x 10⁻³
RANGE ~ FT. x 10⁻³
0
20
40
60
80
100
120
140

FIG. 3.1.3

ARCHER AIR LAUNCH 4 INCH HEAD

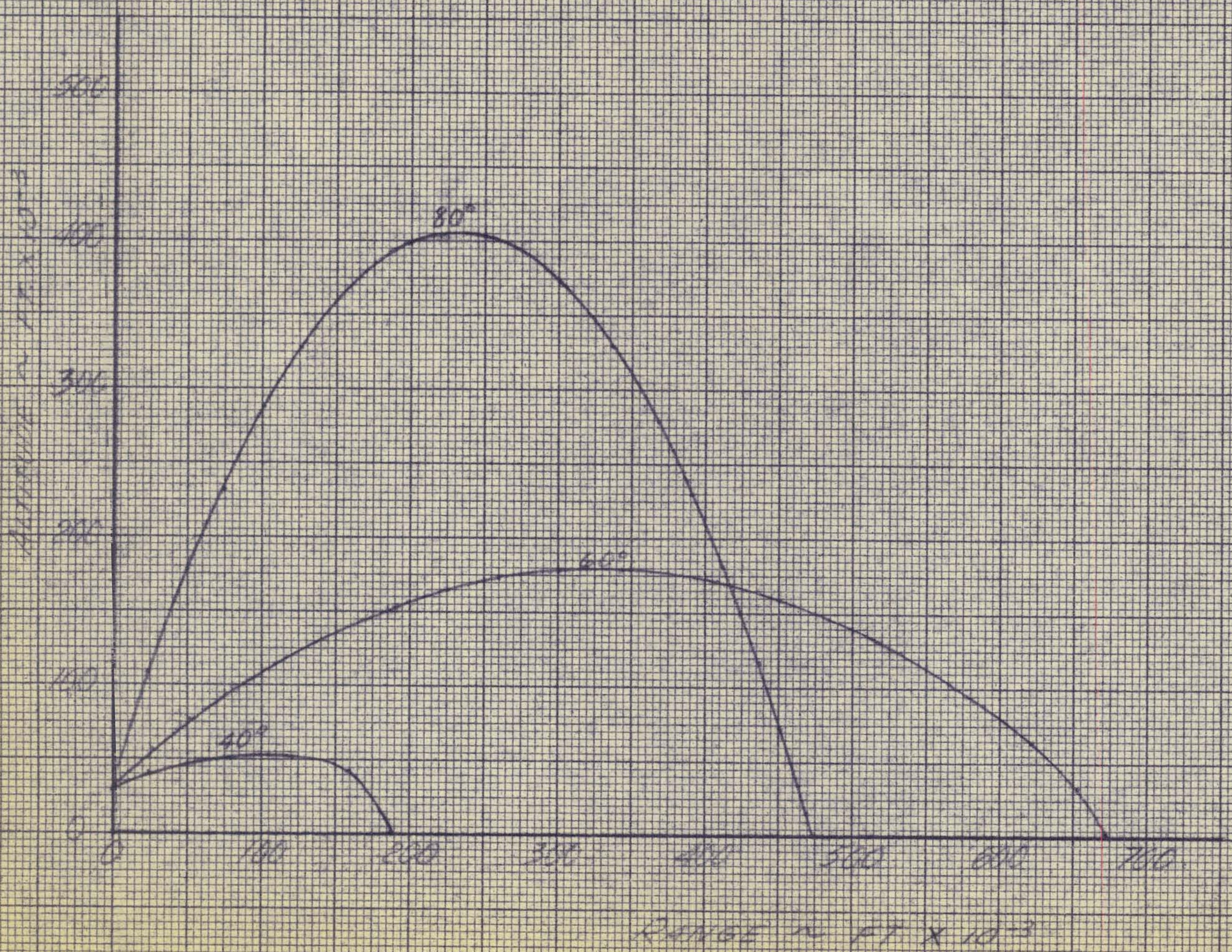


FIG 9.14

JAVELIN - VIPER 2 INCH

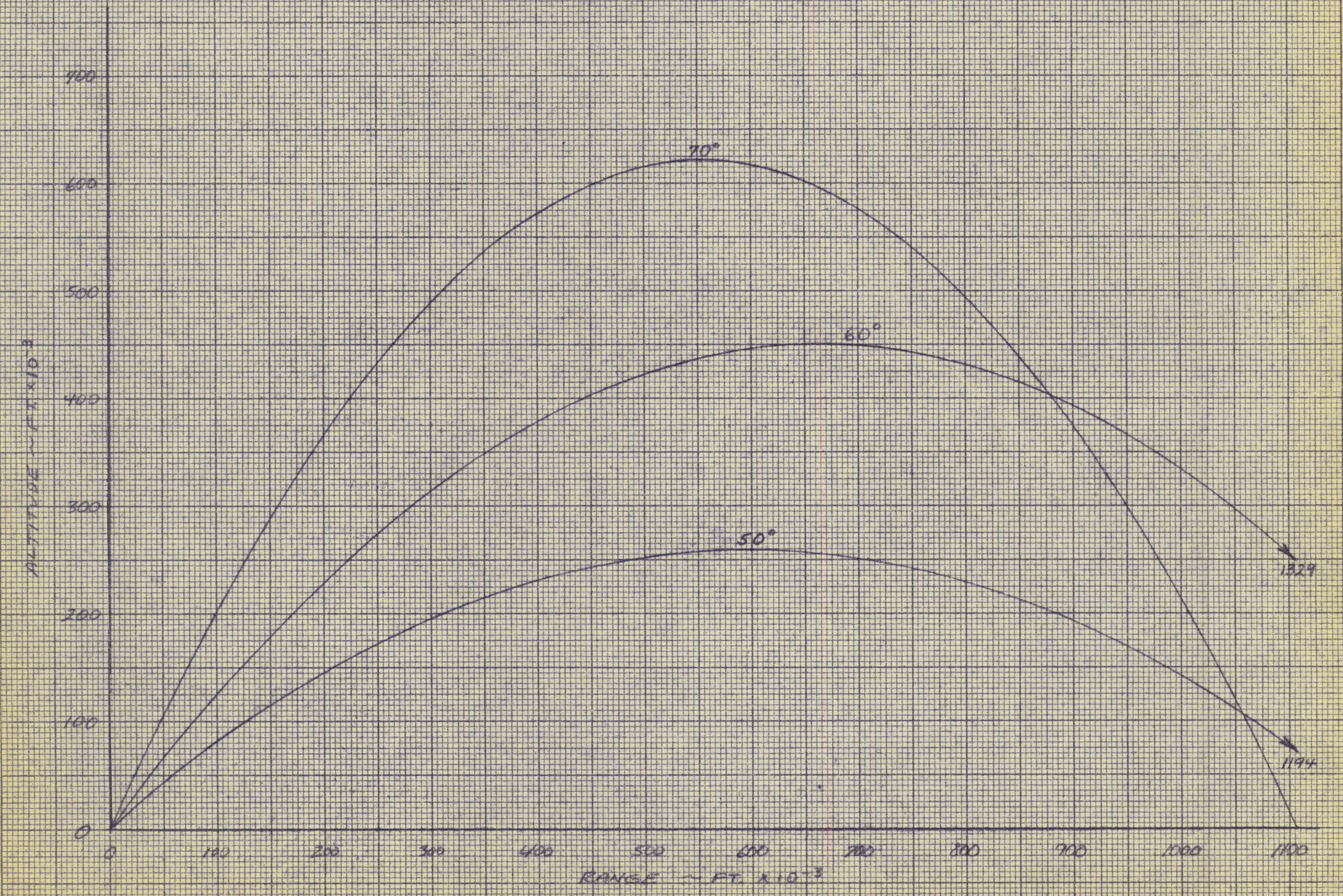


FIG 9.1.5

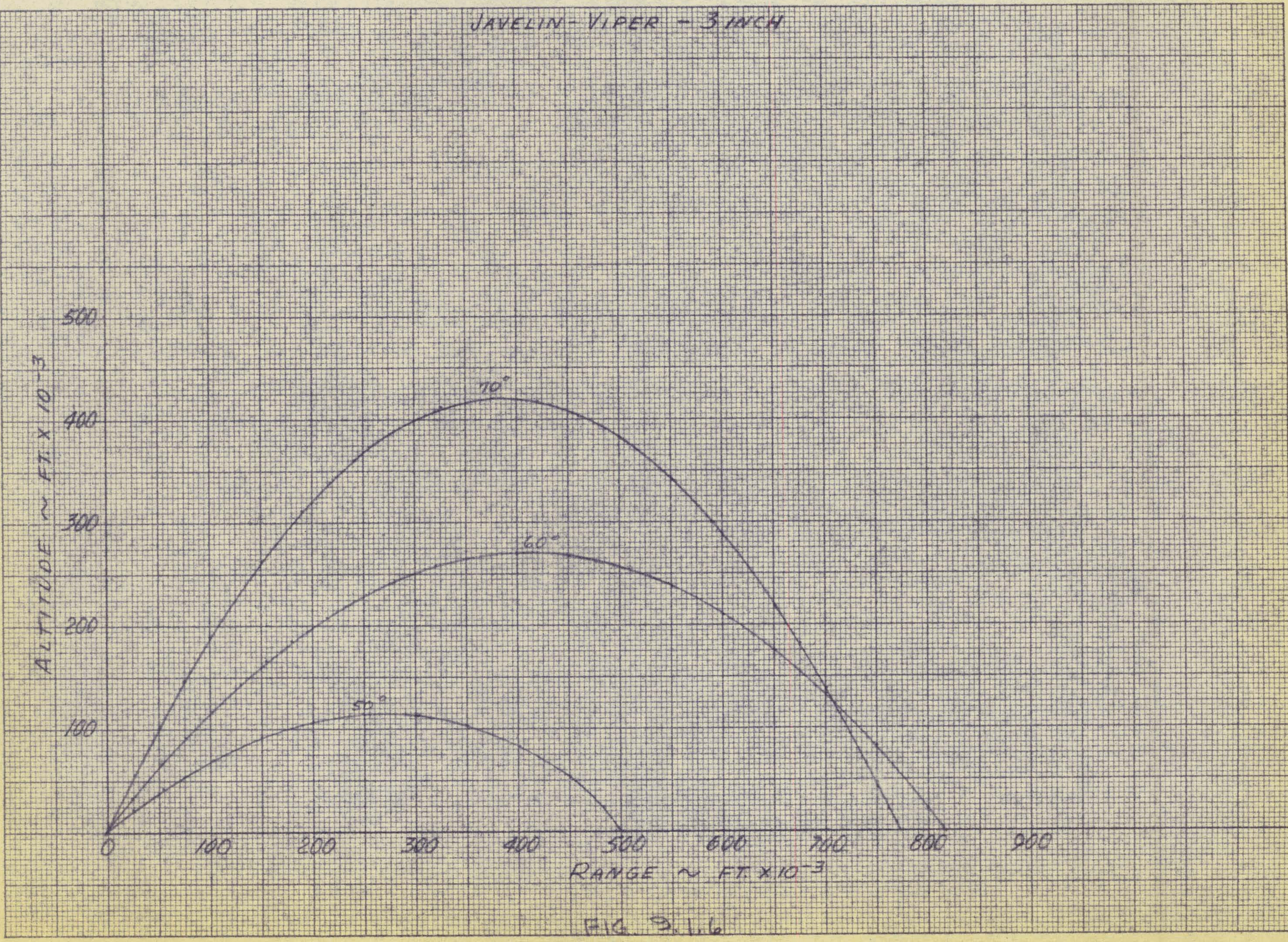

JAVELIN - VIPER - 3 INCH
ALTITUDE ~ FT. X 10⁻³
RANGE ~ FT. X 10⁻³
70°
60°
50°
0
100
200
300
400
500
600
700
800
900

FIG. 9.1.6

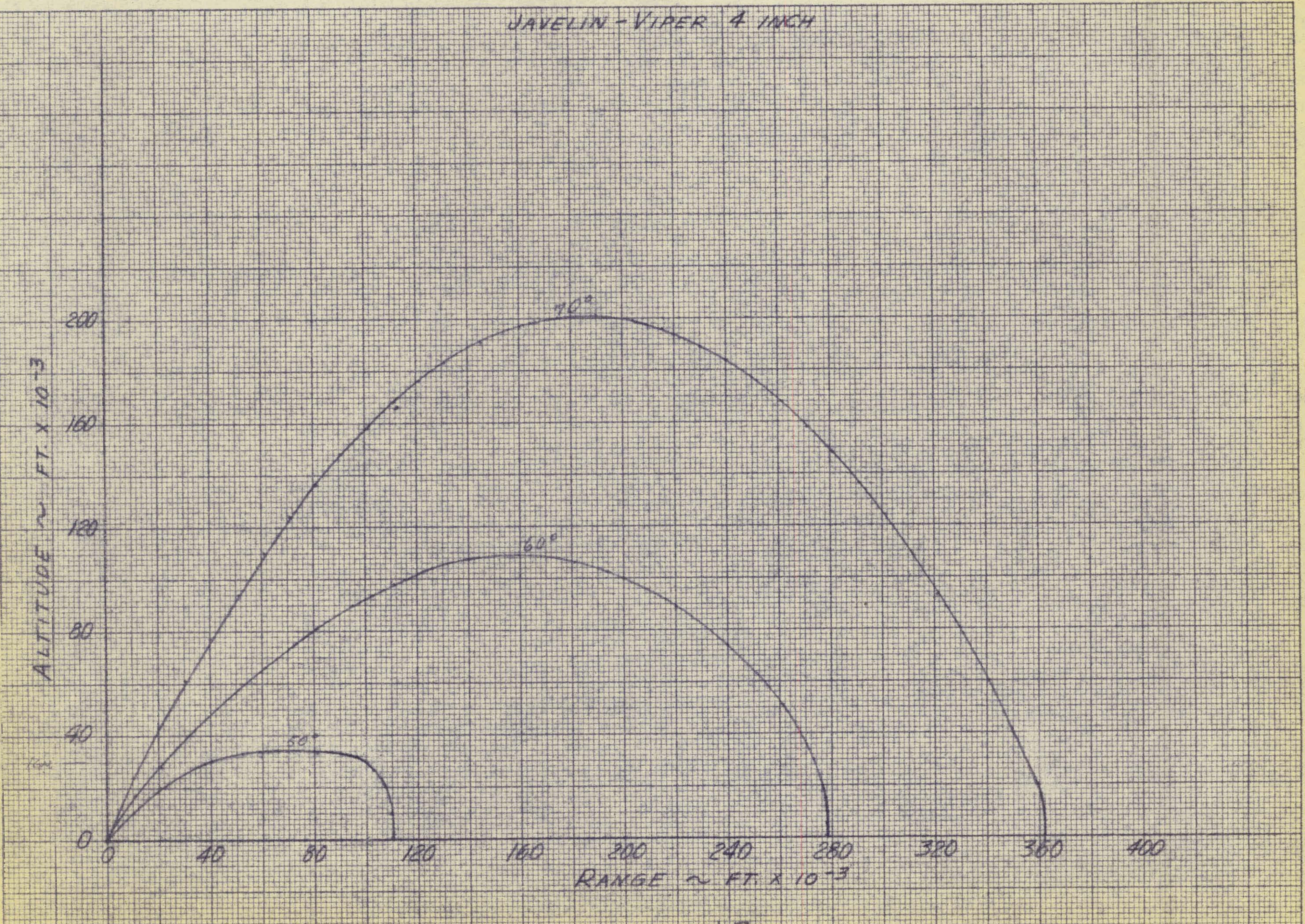

JAVELIN - VIPER 4 INCH
70°
60°
50°
ALTITUDE ~ FT. X 10^-3
0
40
80
120
160
200
0
40
80
120
160
200
240
280
320
360
400
RANGE ~ FT. X 10^-3

FIG. 9.1.7

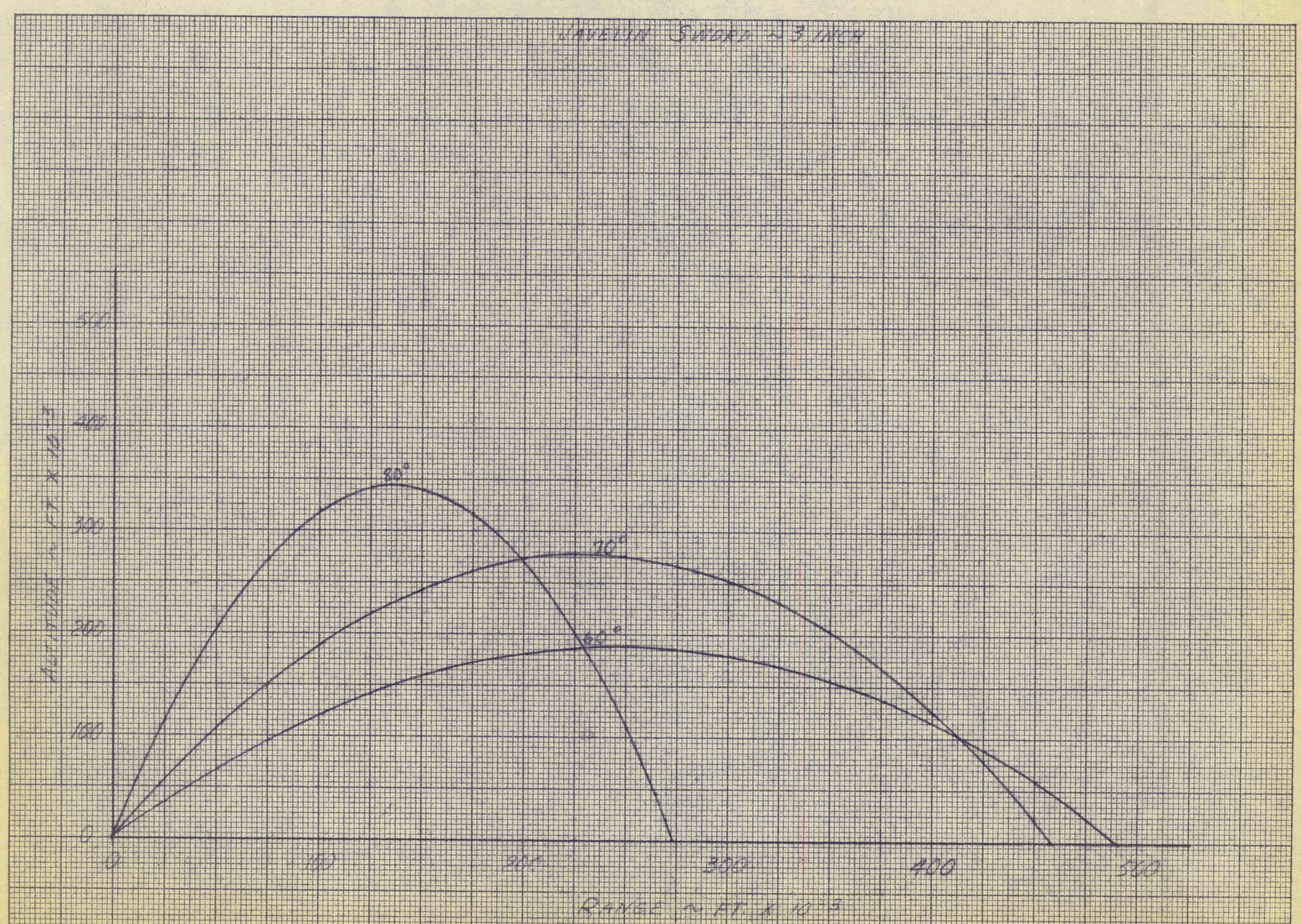

JAVELIN SWORD ~ 3 INCH
ALTITUDE ~ FT. x 10^-3
RANGE ~ FT. x 10^-3
0
100
200
300
400
500
80°
70°
60°

FIG. D.1.8

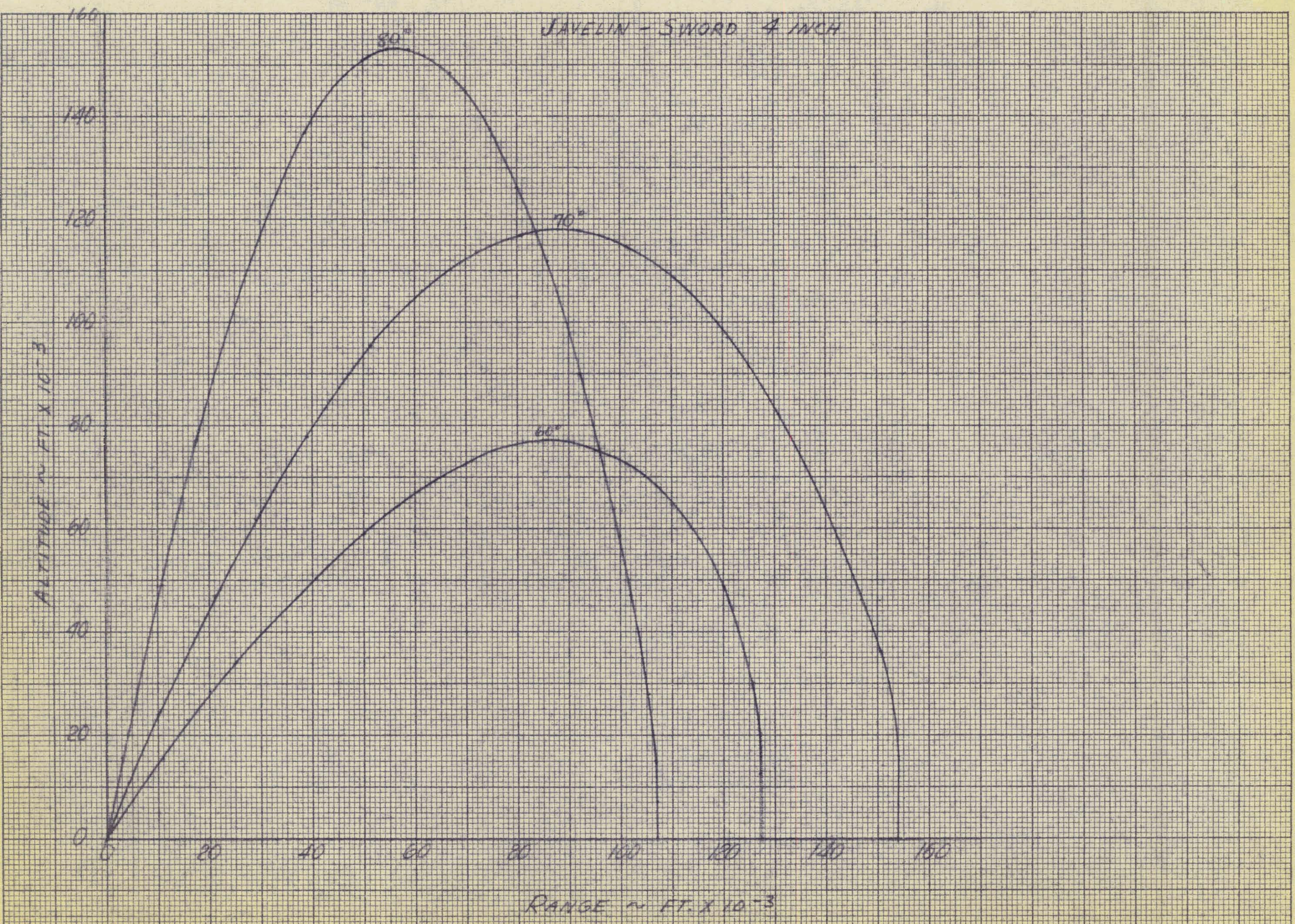

JAVELIN - SWORD 4 INCH
80°
70°
60°
ALTITUDE ~ FT. X 10^-3
RANGE ~ FT. X 10^-3
0
20
40
60
80
100
120
140
160

FIG. 9.1.9.

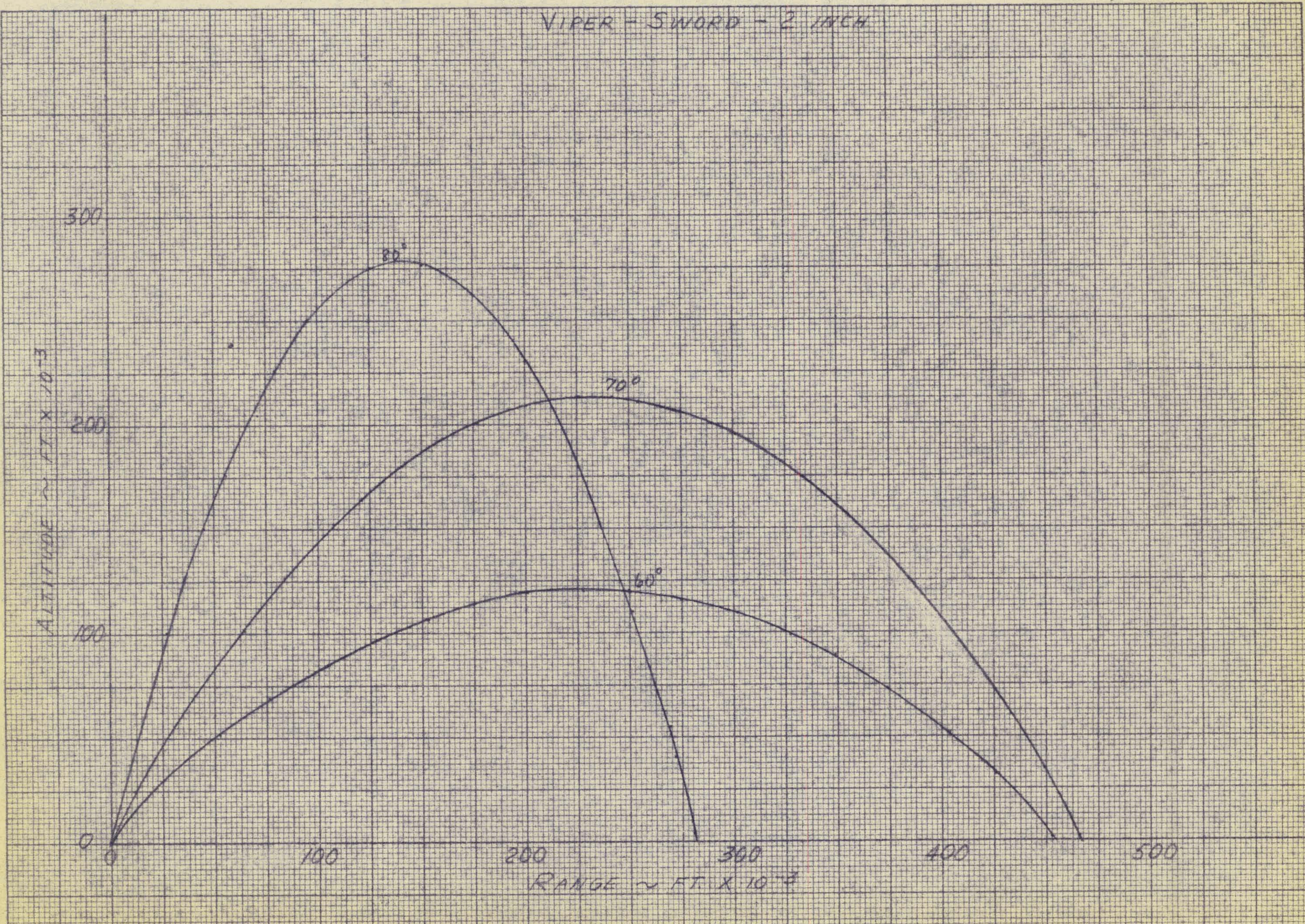

VIPER - SWORD - 2 INCH
80°
70°
60°
ALTITUDE ~ FT. X 10^-3
300
200
100
0
0
100
200
300
400
500
RANGE ~ FT. X 10^-3

FIG. 9.1.10

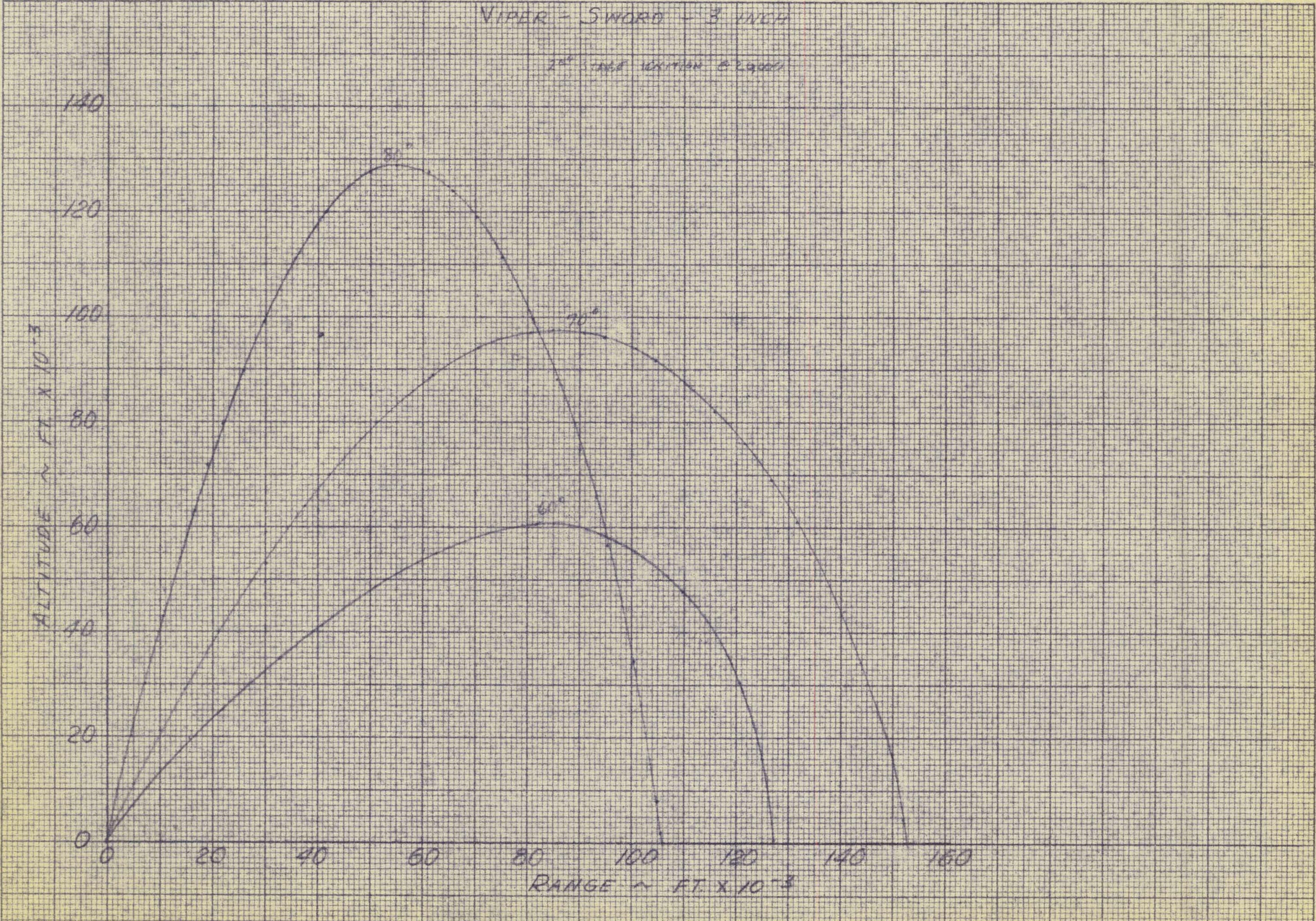

VIPER - SWORD - 3 INCH
2nd STAGE IGNITION
ALTITUDE ~ FT. x 10^-3
RANGE ~ FT. x 10^-3
0
20
40
60
80
100
120
140
160
80°
70°
60°

FIG 9.1.11

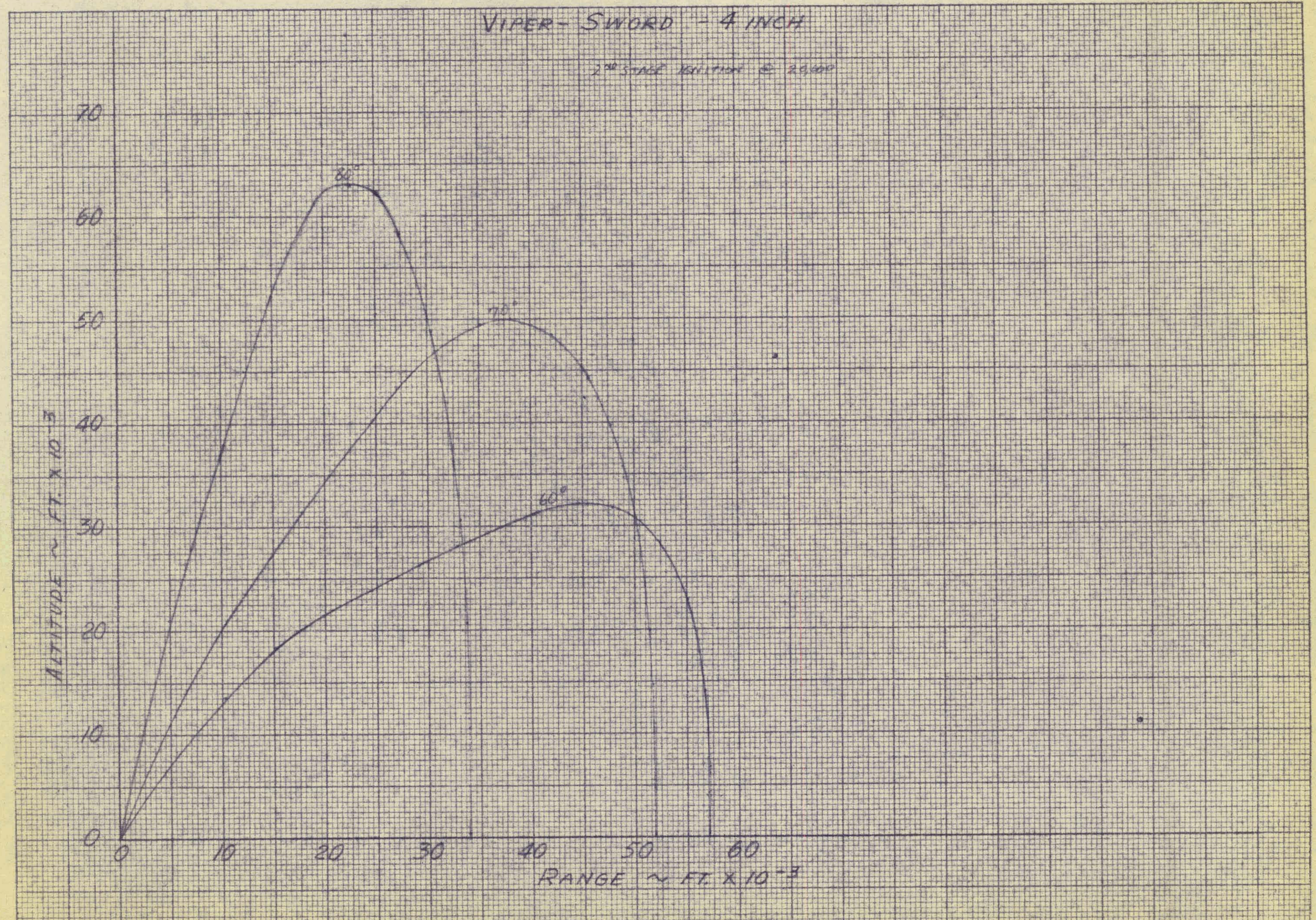

VIPER - SWORD - 4 INCH
2ND STAGE IGNITION @ 20,000
80°
70°
60°
ALTITUDE ~ FT. X 10⁻³
0
10
20
30
40
50
60
70
RANGE ~ FT. X 10⁻³

FIG. 9.1.12

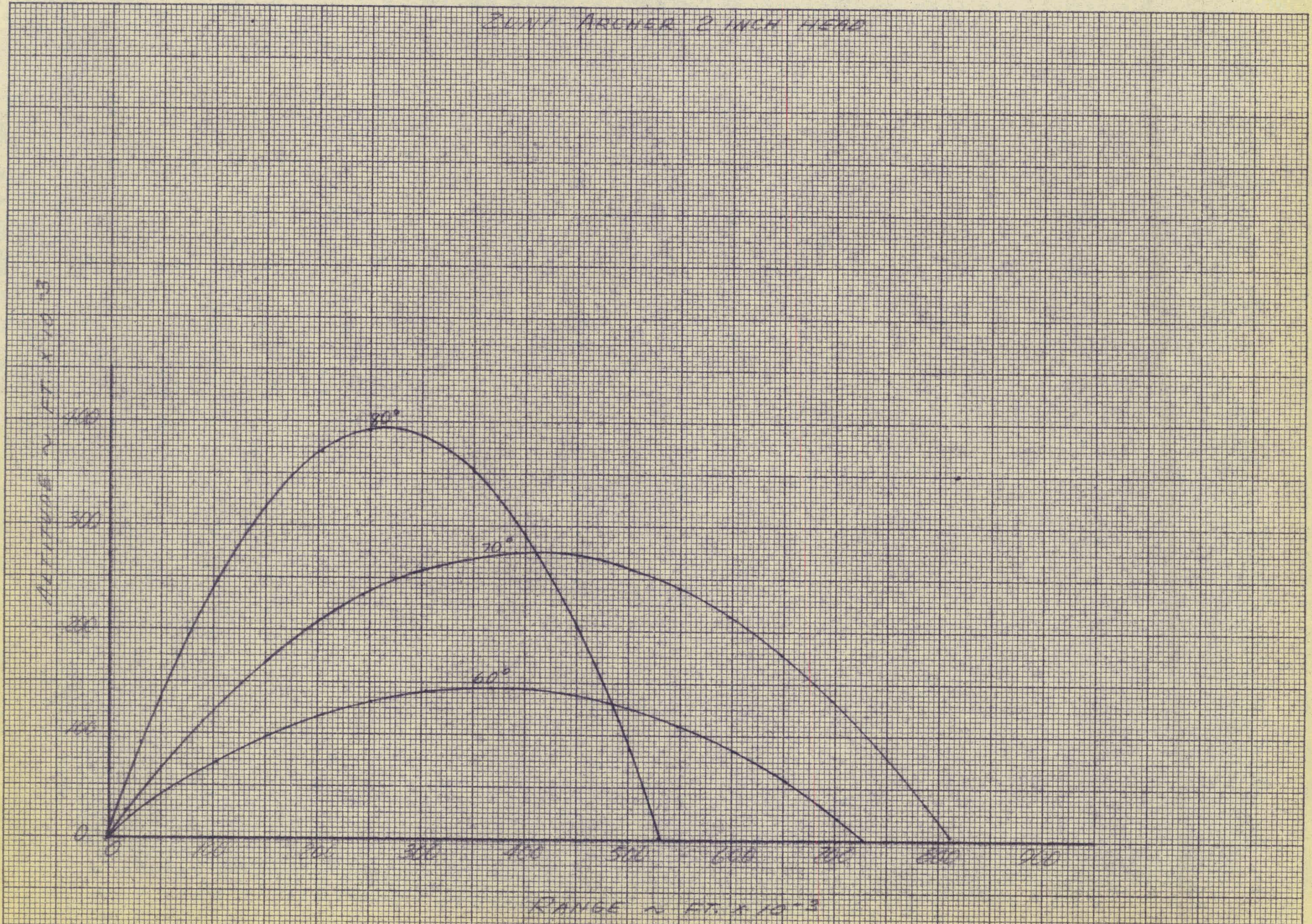

ZUNI ARCHER 2 INCH HEAD
ALTITUDE ~ FT. x 10-3
RANGE ~ FT. x 10-3
80°
70°
60°
0
100
200
300
400
0
100
200
300
400
500
600
700
800
900

FIG. 9.1.13

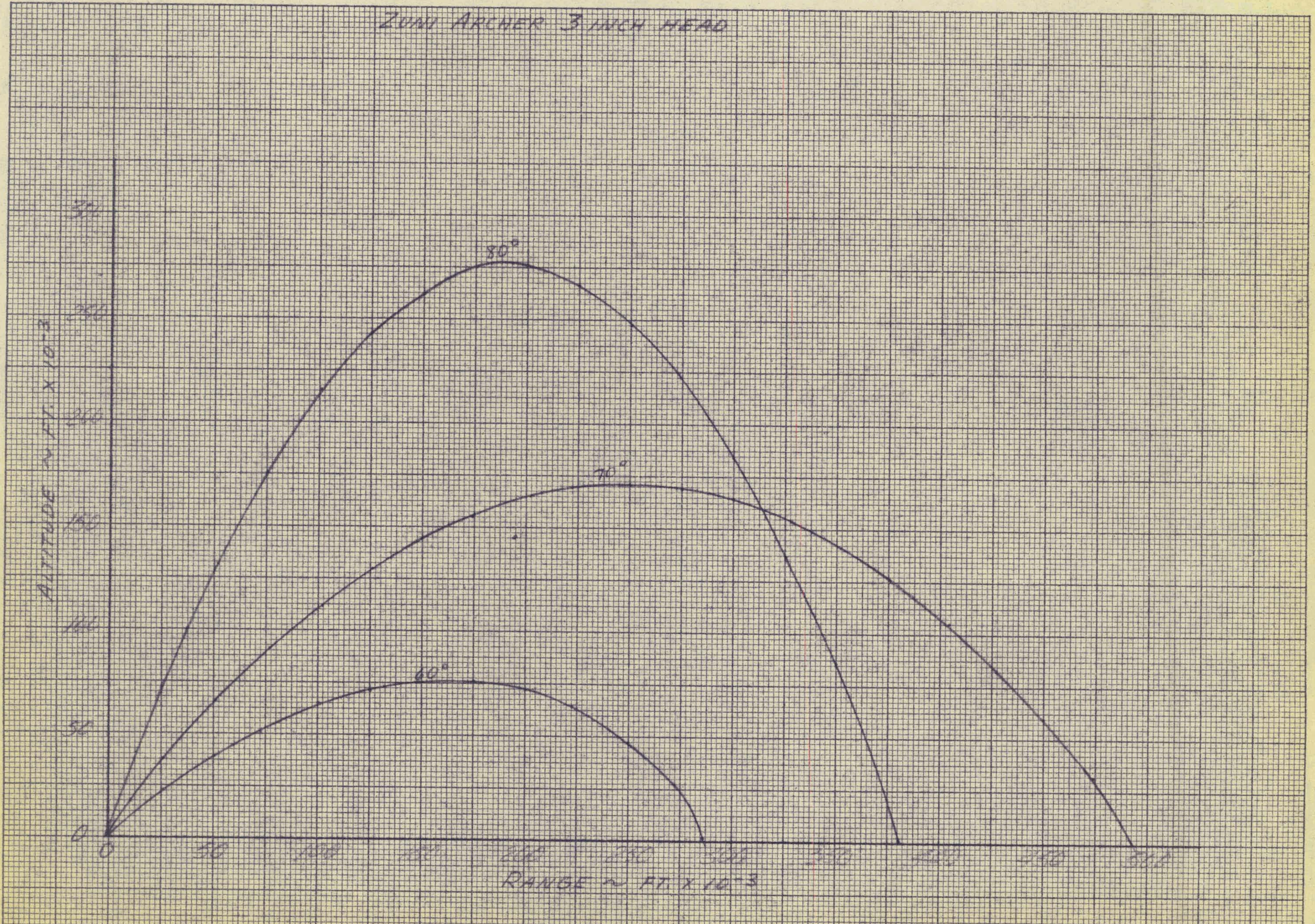

ZUNI ARCHER 3 INCH HEAD
80°
70°
60°
ALTITUDE ~ FT. X 10⁻³
0
50
100
150
200
250
300
RANGE ~ FT. X 10⁻³
0
50
100
150
200
250
300
350
400
450
500

FIG. 9.1.14

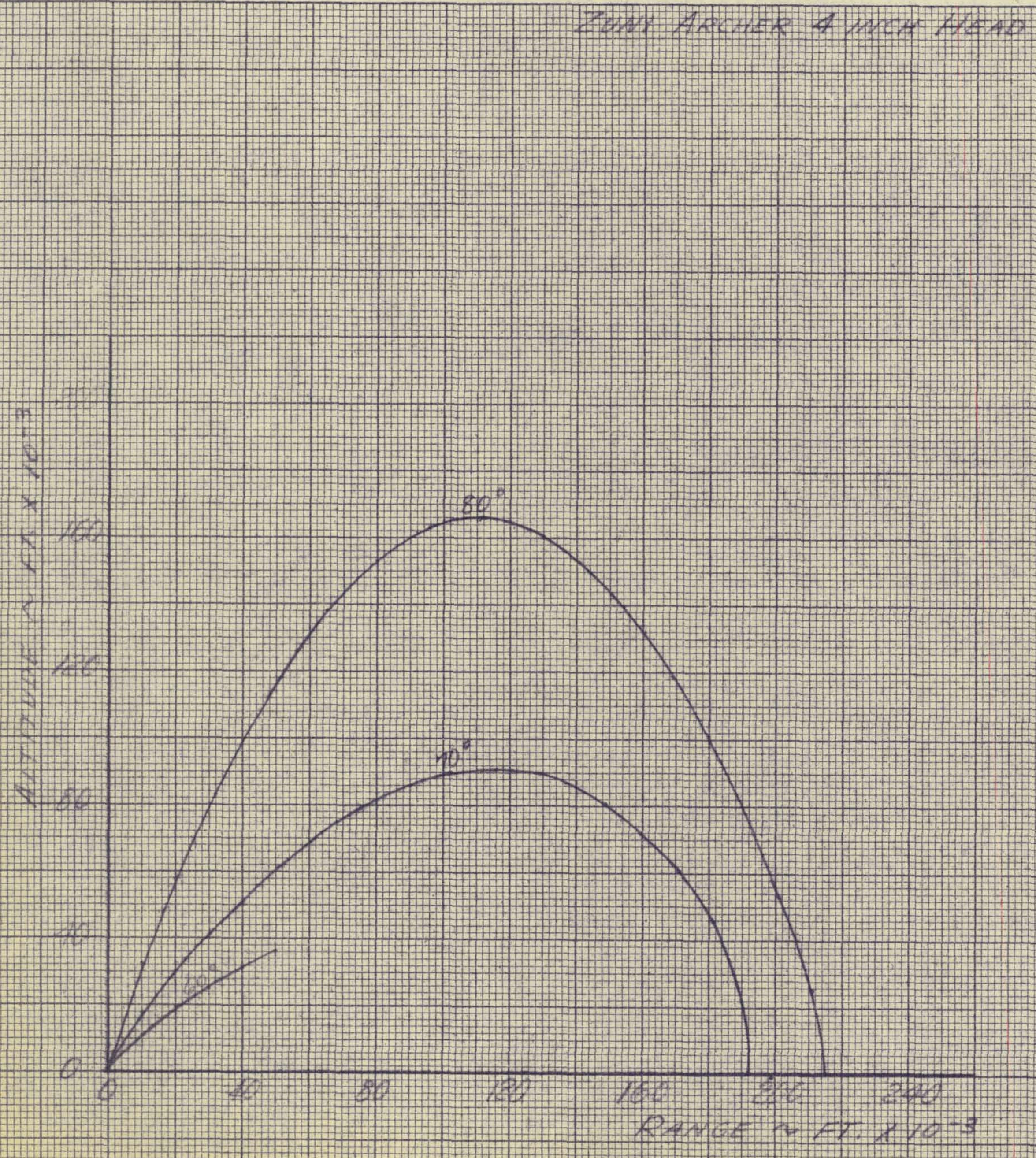

ZUNI ARCHER 4 INCH HEAD
ALTITUDE ~ FT. x 10-3
0
40
80
120
160
80°
70°
0
40
80
120
160
200
240
RANGE ~ FT. x 10-3

FIG. 9.1.15

-ESTIMATED SCHEDULE-

CLEANSWEEP II + SWORD

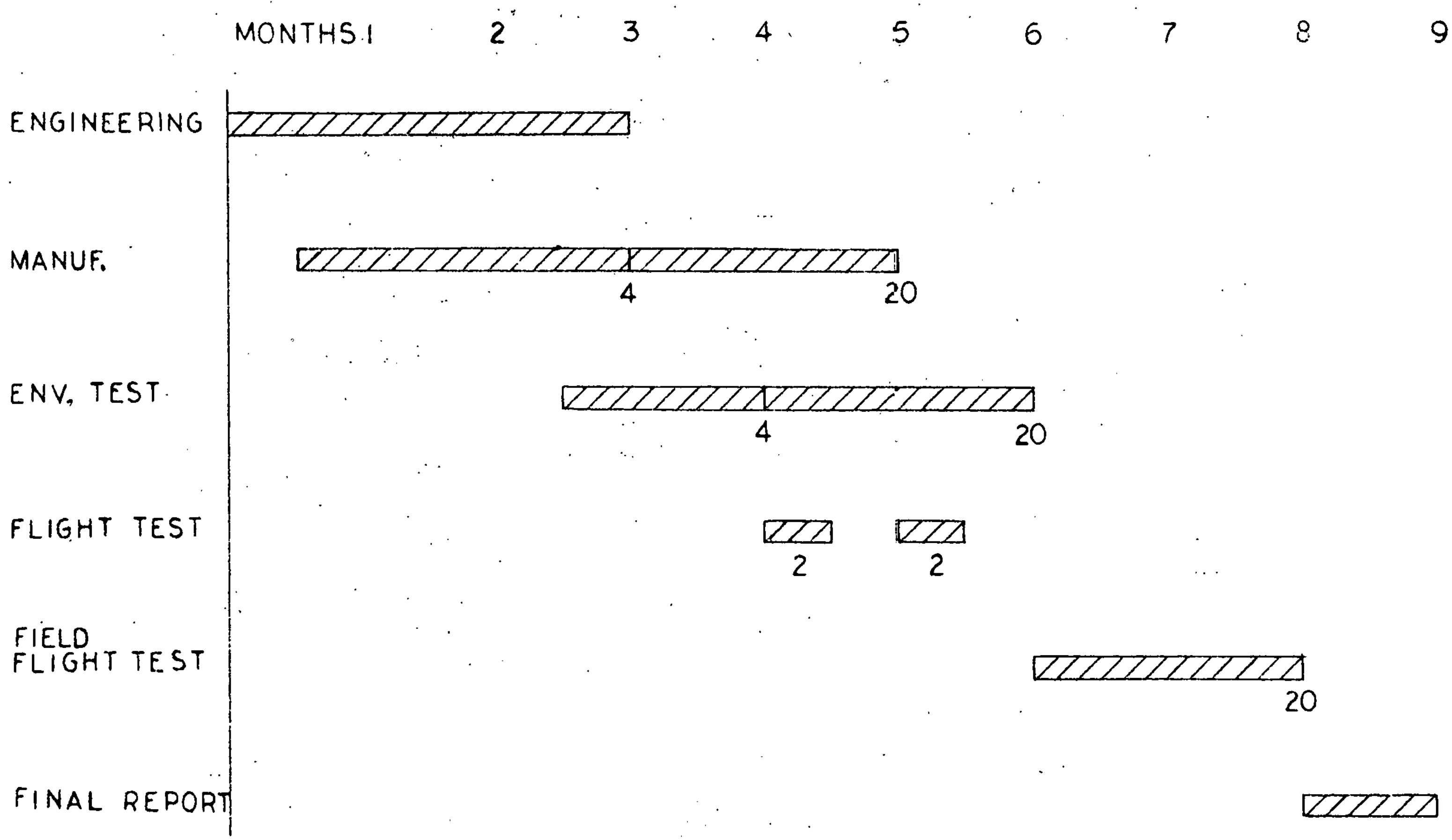


FIG. 9.2.1

— ESTIMATED SCHEDULE —

DIFFUSER DEVELOPMENT

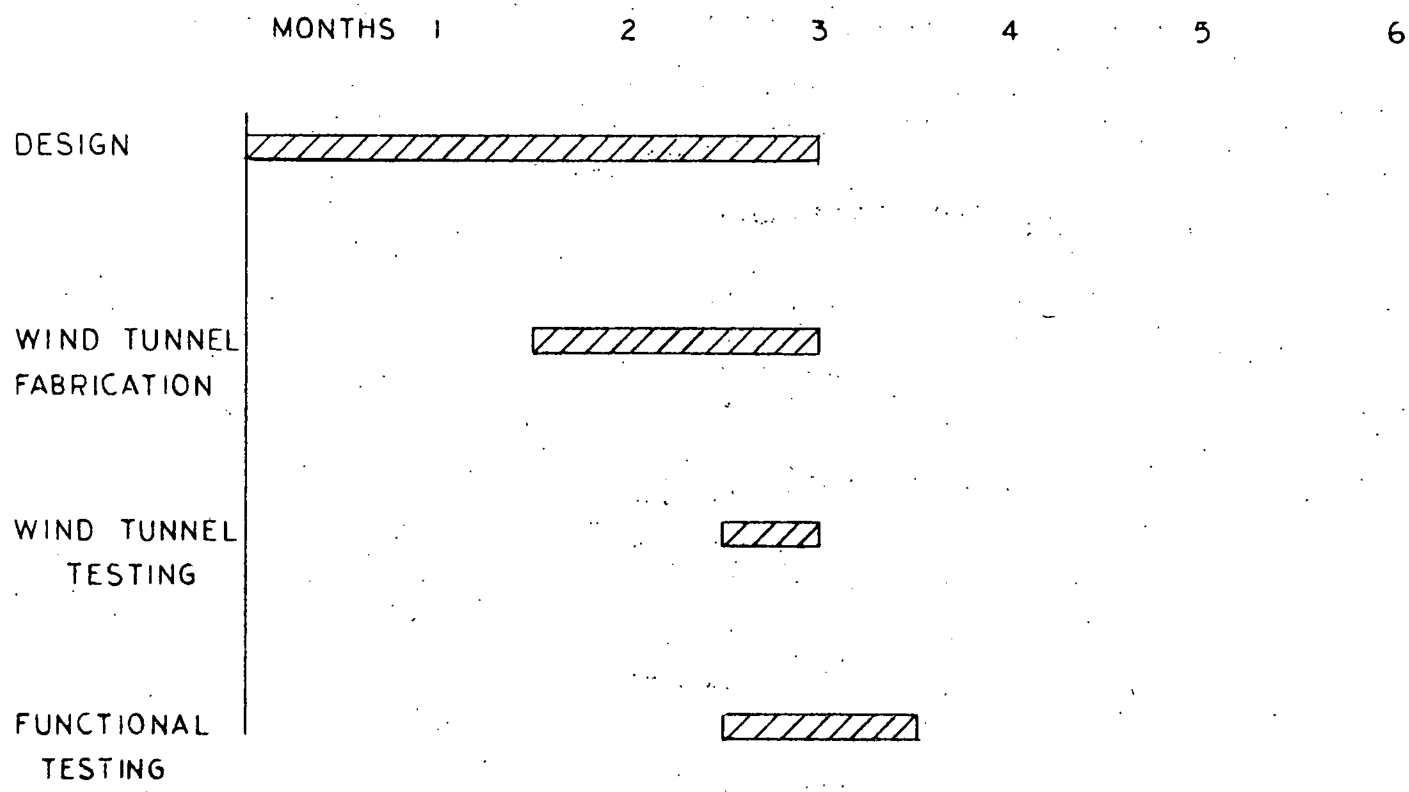


FIG. 5.2.2

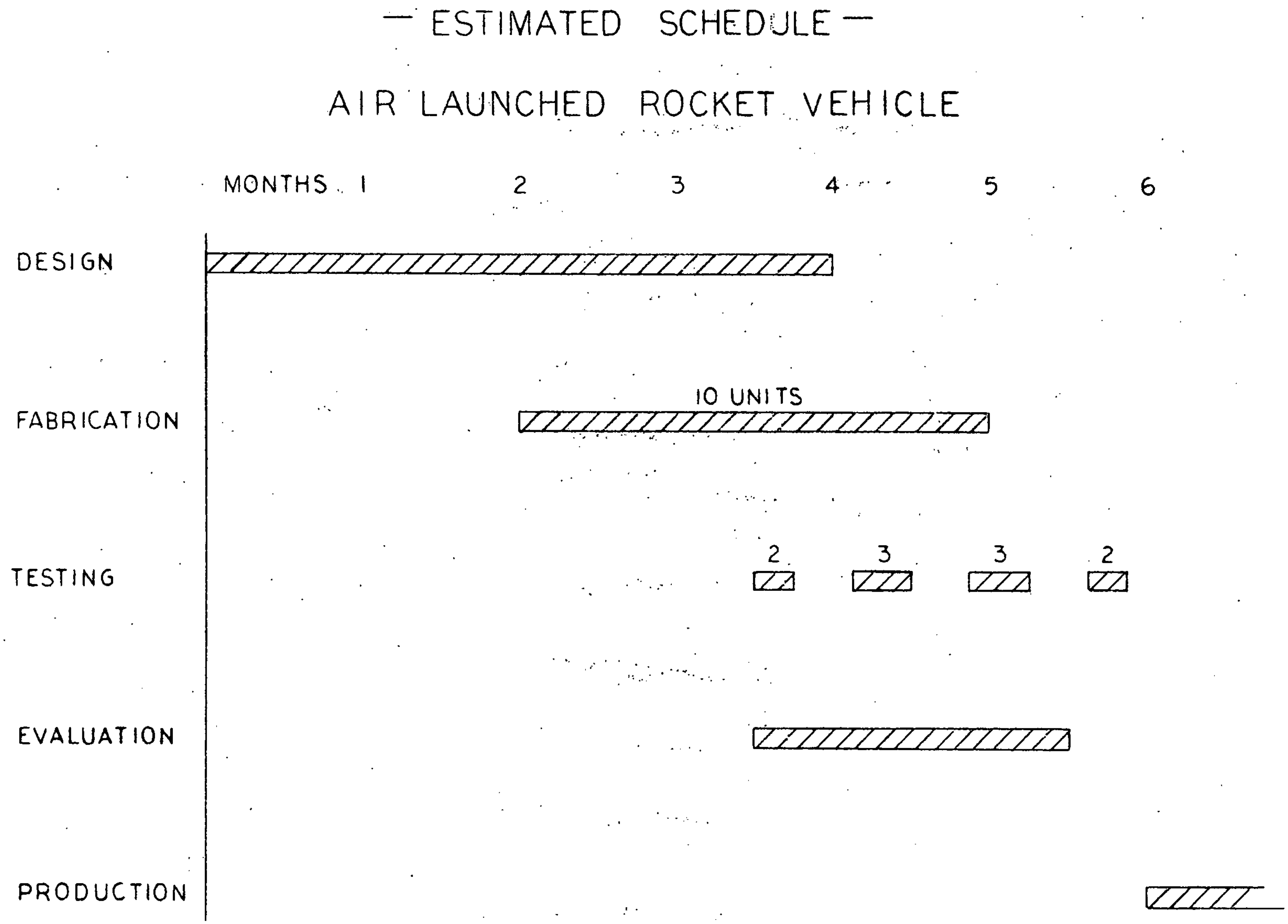

— ESTIMATED SCHEDULE —
AIR LAUNCHED ROCKET VEHICLE
MONTHS 1
2
3
4
5
6
DESIGN
FABRICATION
10 UNITS
TESTING
2
3
3
2
EVALUATION
PRODUCTION

FIG. 9.2.3

— ESTIMATED SCHEDULE —

SURFACE LAUNCHED VEHICLE (LAND & SEA)

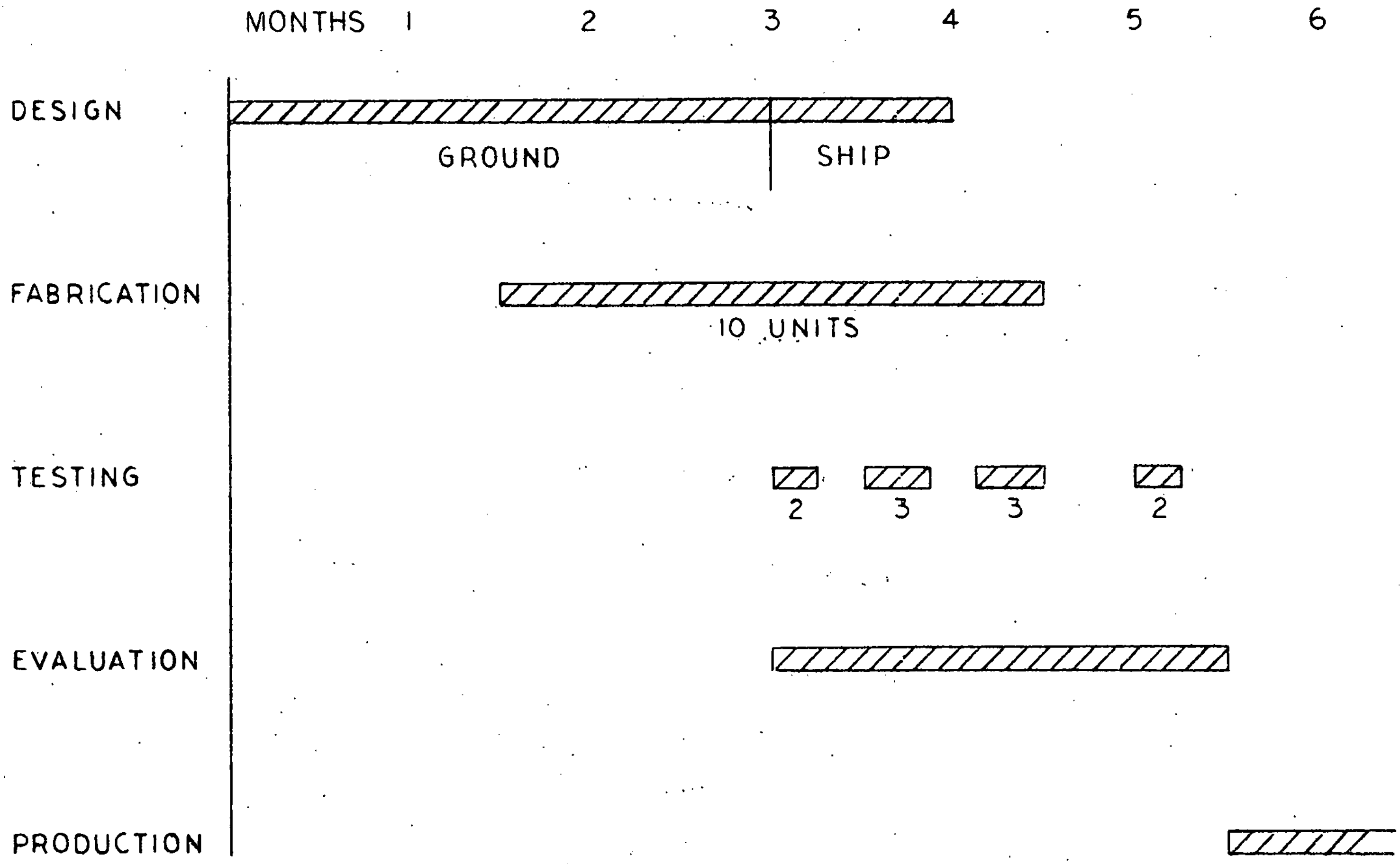


FIG. 9.2.4