DEPARTMENT OF DEFENSE
WASHINGTON HEADQUARTERS SERVICES
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WASHINGTON, DC 20301-1155

JAN 26 2017

John Greenewald, Jr.
[redacted]

Subject: OSD MDR Case 16-M-2595, DTIC Case No. 16-M-2595

Dear Mr. Greenewald:

We have reviewed the enclosed document and have declassified it in full. If you have any questions please contact Mr. John D. Smith by email at whs.mc-alex.esd.mbx.records-and-declassification@mail.mil.

Sincerely,

George R. Sturgis
Deputy Chief, WHS, Records, Privacy, and
Declassification Division, ESD

Enclosures:
1. MDR request
2. Document 1

Hamilton, Michael A CIV DTIC RM (US)

From: John Greenewald <john@greenewald.com>
Sent: Wednesday, August 03, 2016 10:42 AM
To: foia@dtic.mil
Subject: MDR REQUEST

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This is a request for a mandatory declassification review (MDR), under the terms of Executive Order 12958, as amended, of the following document(s):

Accession Number: ADC955131

Corporate Author: ARMY COAST ARTILLERY BOARD FORT MONROE VA

Report Date: 09 Mar 1939

Pages:73 Page(s)

If you regard these documents as potentially exempt from disclosure requirements, I request that you nonetheless exercise your discretion to disclose them. Please release all reasonably segregable nonexempt portions of documents.

Thank you for your time, and I look forward to your response!

Sincerely,

John Greenewald, Jr.

[redacted]

16-M-2595

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FORT MONROE, VIRGINIA

March 9, 1939
(Date)

#1

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AD-C955 131

REPORT
of
THE COAST ARTILLERY BOARD
On Project No. 1153

HEAVY ANTIAIRCRAFT GUN

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COAST ARTILLERY BOARD
FORT MONROE, VIRGINIA

In Reply Refer To

Project 1153

SUBJECT: Heavy Antiaircraft Gun.

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EXHIBITS

A-1 - A-6 - Letter, Chief of Ordnance to Chief of Coast Artillery, January 19, 1939, subject: Heavy antiaircraft gun, mobile type, (OCCA 472.311/BO) with one indorsement and five charts.

B - Letter, President, Coast Artillery Board, to Chief of Coast Artillery, February 4, 1939, subject: Heavy antiaircraft gun, mobile type, (CABoard Project 1153; OCCA 472.311/BO-2) with one indorsement.

C - Chart - Trend of ceiling and speed for U. S. bombing aircraft.

D - Chart - Fuse range curves.

E - Chart - Slant range limit where tracking must begin.

F - Chart - Time of flight vs. slant range.

G - Chart - Target practice hit expectancy, 3-inch Antiaircraft Gun.

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R - Chart - Optimum caliber.
S - Chart - Loss in destructive hit expectancy as compared to optimum caliber.

REFERENCES

1 - Coast Artillery Board Project No. 1116, "Antiaircraft Armament."
2 - Coast Artillery Board Secret Letter, 471.11, January 5, 1939, to Chief of Coast Artillery, subject: Hitting volume, 3-inch AA Shell.

I - THE PROBLEM PRESENTED

1. Object of the project. The object of this project is:

a. To determine whether a mobile antiaircraft gun of caliber heavier than 90 mm is required in the defense of large area targets against aerial attack from extremely high altitudes.

b. To select the most suitable caliber for any such additional weapon required.

II - FACTS BEARING ON THE PROBLEM

2. History of the project.

a. The directive initiating this study is contained in 1st Indorsement, OCCA 472.311/BO, January 27, 1939, on letter, Office, Chief of Ordnance, to the Chief of Coast Artillery, (OO 472.93/6048), January 19, 1939, subject: Heavy antiaircraft gun, mobile type (See Exhibit A-1). This project is related to the study contained in Coast Artillery Board Project 1116, Antiaircraft Armament, listed as Reference 1 hereto, which dealt with the 90 mm antiaircraft gun.

b. Consideration of a heavy antiaircraft gun was prompted by the progress in development of modern bombing airplanes of higher speed and greater ceiling. In the defense against attack of large area targets from high altitudes, possibly from above 40,000 feet, ample range and minimum time of flight for the antiaircraft guns are highly desirable. If practicable, mobile guns used in the defense of large area targets, such as cities, should be capable of taking under fire any hostile bomber at its ceiling.

3. Calibers under consideration. In the selection of a caliber for a heavy antiaircraft gun it is understood that it is not necessary to adhere to the exact size of any one of the various calibers for which data are presented, since a deviation from existing calibers will not complicate greatly the manufacture of the gun. However, this study deals only with calibers of guns projected or now existing in the United States, since these guns are believed to offer a sufficiently wide choice of calibers and also because a certain amount of data concerning these particular weapons are available. The calibers considered are the 90 mm, 105 mm, 5-inch, and 155 mm. It is believed that any one of these antiaircraft guns probably can be developed and manufactured as readily as another.

4. Essential elements to be considered. In approaching the question of the most effective caliber for a mobile antiaircraft gun there appear to be certain essential and controlling factors to be weighed and evaluated. Some of the considerations related to the effectiveness of such a gun are:

Maximum range required,
Limitations imposed by the fire control system,
Time of flight,
Rate of fire,
Effective volume of the shell burst,
Weight of gun and ammunition, and
Mobility.

5. Basic assumptions. To facilitate a study of this character it is necessary to make certain assumptions where essential data based on past experience are not available. It is fully recognized that the outcome of this study is dependent to a large degree on the soundness of these assumptions. Each assumption has therefore been carefully considered with a view to making it conservative within reason while facing future probable technical advances. Several of the most important assumptions are listed below.

a. Fire control.

(1) Target detection. Developments are assumed to be practicable in aircraft detection methods which will enable fire control telescopes to be pointed at the target, either at night or by day, so that tracking may begin in time to meet the target with fire at a fuze range of 30 seconds.

(a) Gun range. The heavy antiaircraft gun must necessarily be capable of reaching targets at any altitude from which hostile aircraft may be able to damage the area defended. If large area targets, such as cities, are to be defended, it is highly desirable that the gun in question should reach at least to the service ceiling of the best bombing airplanes in existence. It would be preferable to develop a weapon whose range capabilities extend well above the highest service ceiling, in order that aircraft development in the immediate future should not outrange the gun defense.

(b) Range of fire control systems.

1. It is at once apparent that no antiaircraft gun can be utilized effectively beyond the range of its fire control system. The range of the present fire control system is limited by its dependence on visual and sound detection of the target, to an extent which does not permit full utilization of the range capabilities of even the 3-inch antiaircraft gun. However, it is believed that the selection of a heavier caliber antiaircraft gun should not be influenced unduly by limited capabilities of the present fire control system. It is desirable to look to future advancement in means of fire control which will make it possible to detect and track targets at extremely long ranges. By such foresight it should be possible to provide a weapon which will be useful for several years, making due allowance for development in both airplanes and fire control equipment.

2. The question of fire control at long ranges presents a serious problem. One of the chief difficulties experienced in target practice firings during the 1938 Fort Bragg exercises concerned detection and visual tracking early enough to meet the target with fire at the 21-second fuze range with the 3-inch gun. With a larger caliber gun of longer range using the 30-second fuze it usually will not be possible to detect an airplane at distances necessary to utilize the maximum fuze range. Attention is invited to Exhibit E which shows graphically the slant ranges at which it is necessary to begin tracking a 300-mile-per-hour incoming target if initial bursts are to meet that target at a fuze range of 30 seconds. Allowing only 15 seconds to establish a smooth flow of data, tracking must begin at about the following slant ranges:

3" AA Gun	- 13,000 to 17,000 yards,
90 mm Gun	- 14,800 to 18,600 yards,
105 mm Gun	- 15,700 to 19,700 yards,
5-inch	- 17,800 to 20,500 yards,
155 mm	- 16,500 to 21,400 yards.

Because of these long slant ranges it was considered necessary to assume that adequate detection methods would be developed which would permit the full utilization of the maximum range of all weapons considered. It is believed that development of a detection device has progressed far enough to warrant this assumption.

(2) Magnitude of fire control errors. Except for prediction errors, fire control errors for antiaircraft guns of all calibers are assumed to be the same as for the 3-inch antiaircraft gun. Prediction errors are assumed to vary directly with time of flight, an assumption which has been generally accepted heretofore.

(a) Fire control errors as related to caliber. No adequate data were available on which to base any assumptions as to variation of fire control errors as a whole for various calibers. Except for prediction errors, the assumption that errors equal to those present in the 3-inch fire control system exist for all calibers is not expected to introduce any serious distortion of the several caliber comparisons presented.

(b) Time of flight. A short time of flight is obviously very advantageous in keeping the prediction errors low. For this reason it is believed important to seek a reduction in time of flight as far as practicable. The vital relation between time of flight and muzzle velocity makes the latter an essential consideration. It is evident that both must be weighed carefully in order to arrive at any sound conclusions. Time of flight having been accepted as being directly related to prediction errors, it will be recognized that for fast moving targets these errors assume sizable proportions if a long time of flight is involved. For this reason it is considered inadvisable to attempt an extension of range by accepting a time of flight longer than 30 seconds. The vital importance of a minimum time of flight in antiaircraft gun fire, particularly at long ranges, makes the outcome of studies on increased muzzle velocity recently undertaken by the Chief of Ordnance (paragraph 8, letter, Chief of Ordnance, January 19, 1939 - Exhibit A-1) of utmost consequence in the development of any new antiaircraft gun.

b. Rate of fire. The rates of fire assumed as practicable for purposes of this study conform to those shown on Exhibit A-3 and for the particular calibers considered herein are as set forth below:

Hand loading:-

3-inch.......... 25 rounds per minute
90 mm........... 20 rounds per minute

Mechanical loading:-

105 mm.......... 20 rounds per minute
5-inch.......... 15 rounds per minute
155 mm.......... 10 rounds per minute

(1) Need for high rate. A high rate of fire is necessary to subject the target to the maximum chance of destruction within a very short period. The high speeds of aircraft which are increasing steadily make it evident that targets will be within range a very short time at the most. The bomb sighting operation which now requires only about 40 seconds may be further shortened, thus requiring rectilinear flight by the target for a time as short as the maximum time of flight for the antiaircraft projectile. These possibilities make both a short time of flight and high rate of fire essential in a defending weapon.

(2) Assumed rates based on actual rates. The rate assumed for the 3-inch gun is based on experience. The rate of 20 rounds per minute assumed for the 105 mm has not been attained in service but it

is believed that the mechanical loading feature can be improved sufficiently to insure the assumed rate. The rates assumed for both the 105 mm and 5-inch are based on those attained by the Navy for its 5-inch antiaircraft gun, which according to official reports has been fired from 15 to 22 rounds per minute using either fixed or separate loading ammunition (see Exhibit B). While it is conceded that fixed guns, with a convenient ammunition supply such as obtains aboard ship, have an advantage over mobile guns as to rate of fire, it is believed that for short periods, aerial targets can be taken under fire by a 5-inch mobile antiaircraft gun with a rate at least equal to the Navy minimum of 15 rounds. Because of the lighter ammunition it is thought that a rate of 20 rounds for the 105 mm seems reasonable. The same rate for 90 mm, though hand loaded, is based on actual tests using a 3-inch gun with 40-pound drill cartridges, approximately the weight of a 90 mm round. Judging from these tests a higher rate of fire for the 90 mm gun is doubtful. (See page 8, paragraph 6 c, Reference 1.) A rate of 10 rounds per minute for the 155 mm gun was based on a consideration of the relative increase in projectile weight over that of the 5-inch and also the rate of six rounds per minute which has been attained with the 155 mm GPF. A rate of six rounds per minute has been attained for the latter with hand loading where projectile and powder must be rammed separately. In view of this fact, it seems within reason that mechanical ramming should raise the rate to at least 10 rounds per minute when both powder and projectile are loaded together.

c. Speed and ceiling of target. Throughout the entire study a speed of 300 miles per hour was assumed for the target. It was further assumed that bombing attacks from an altitude of 40,000 feet would be possible within the near future.

(1) Possible hostile targets. In any effort to select suitable weapons for defense it seems logical first to investigate the type of targets to be taken under fire and the capabilities of these targets. By such a procedure it is possible to determine the minimum requirements for a satisfactory weapon. Consideration of weapons having insufficient range can then be dropped and attention focused on those guns which at least meet the range requirements. The capabilities of bombing airplanes are of primary interest as this type aircraft is expected to be the most usual of hostile targets for a heavy antiaircraft gun. Incidentally this type of U. S. military aircraft appears to be most advanced in its development, being capable of both high speed and high altitude. The past 10 years have marked an increase in maximum altitude from about 10,000 feet to over 30,000 feet. Recently an unloaded, experimental, two-motored plane in the bomber class flew a mission for the Coast Artillery Board during which an altitude of over 38,000 feet was reached. In the 1938 Fort Bragg Air Corps - Antiaircraft exercises, bombing missions were flown on several occasions, according to official reports, at 27,000 feet. Within the same 10-year period speeds for U. S. bombing airplanes have increased from approximately 100 miles per hour to over 250 miles per hour. Other

types of aircraft have had difficulty in matching speed with bombers. From press reports and informal conversations with Air Corps officers it is understood that the order for 415 light bombers recently placed in the United States by the French Government was contingent upon a performance test wherein the plane was required to develop a speed of at least 300 miles per hour with normal load. This type of bomber was understood to carry a load of eighty 40-pound bombs, or 3200 pounds. With world attention focused on military aircraft development, another 10 years probably will see bombing planes capable of operating from altitudes of 40,000 feet at speeds in excess of 300 miles per hour. Exhibit C shows the trend in speed and ceiling for U. S. bombing aircraft since 1928.

(2) Bombing accuracy. It properly may be reasoned that increases in operating speed and altitude decrease bombing accuracy to a high degree and that the difficulties of locating bombing objectives are also multiplied. It should be recognized, however, that large area targets for the defense of which a gun is being selected, do not require a high degree of bombing accuracy and that such targets are not difficult to find.

d. Shell burst hitting volumes. Hitting volumes are assumed herein to vary in a particular manner with the number of useful fragments produced by the shells. A weighted hitting volume was computed for each caliber considered, based on the assumption that a fragment density of one fragment per square yard is required to cause a destructive hit.

(1) How computed. It is easily seen that the chance of damaging a target with any gun is directly related to the volume of its shell burst. That the volumes of bursts vary with the size of the projectiles and are of the same general shape is generally accepted, though the exact relation between bursts of different calibers probably is not known. From a consideration of burst volumes alone, the largest practicable caliber undoubtedly would be sought as a means of increasing hitting probability. The data on shell fragmentation for calibers up to and including five inches were obtained from Ordnance Technical Staff studies dated January 29, 1938, and were the same as used in compiling Exhibit E of Reference 1. The number of useful fragments used are shown in the following table:-

Projectile	Weight (lbs)	Number of effective fragments (Screen No. 1, 2 and 3)
3-inch AA shell	12.5	419
90 mm	26	572
105 mm	33	702
5-inch	52.82	902
155 mm	95	1100

For purposes of this study the 22-pound, 90 mm projectile and the 54-pound, 5-inch projectile were assumed to give the same number of effective fragments as those tabulated above. Accordingly, the last mentioned weights were used throughout. The number of fragments for the 155 shell was obtained by extrapolation based on effective fragment differences between calibers up to five inches. The general form of burst pattern in fragmentation tests, upon which is based the present target practice hitting volume, was accepted as correct. Sections of the volume then were weighted according to the number of fragments per square yard of cross sectional areas in the column and according to number of fragments per square yard of surface on cylinders of differing radii cutting the plinth, assuming the axes of such cylinders to be coincident with the trajectory, or column axis. About 12 percent of the weight of high explosive shells is lost in large fragments of the base which are projected rearward at low velocity. This fact influences the weighted volumes very little because the number of large base fragments which are not effective is low, probably less than six. Since the weighted volumes are computed from the total number of effective fragments ranging from 400 to 1100, a reduction of those numbers by only five or six is negligible. The fragmentation tests themselves have not been as extensive as desirable to establish an accurate relation between various calibers as to number of effective fragments, but error in fragmentation estimates herein should not distort seriously the size relation of various weighted hitting volumes. A sectional view of half the assumed hitting volume is shown by Exhibit H.

(2) Fragment density required for destructive effect. The assumption that a fragment density of one effective fragment per square yard will result in the destruction of an airplane was borrowed from a confidential Navy Board Report No. 15 - "AA Gunnery, Damage Effect as Determined by Tests Against XF7B-1 Airplane (Navy)," dated 27 October 1937 - which covered actual tests wherein 5-inch antiaircraft projectiles were statically detonated near a modern all-metal airplane. From these tests it was found that fatal damage which will bring down an airplane either immediately or later requires on the average an accumulation of 1.0 fragment hits per square yard, a figure which is in agreement with results of tests conducted by the Army with 3-inch antiaircraft projectiles about 10 years earlier. In the Navy tests fatal damage effects were classified as either Class A or B. Class A fatal damage was taken as that type which will bring down a plane immediately and was found to require on the average an accumulation of about 2.8 fragment hits per square yard. Class B fatal damage was taken as that type which will bring down the plane either immediately or later and was found to require only the accumulation of 1.0 hits per square yard. The Class B type of fatal damage was adopted as the basis of comparison used throughout this study.

e. Hit expectancy. Hit expectancy curves for various calibers were assumed to conform generally to the shape of that for the 3-inch gun and to bear a relation thereto based on time of flight ratios and shell hitting volume ratios. Insufficient data were available on firings of guns other than 3-inch on which to base hit expectancy curves, hence the use of the 3-inch curve as a basis became a necessity. Two variables affecting the overall accuracy of the entire system, time of flight and hitting volume, were believed to admit of fairly accurate determination and hence were used as a means of deriving expectancy curves for the various calibers from the 3-inch curve.

III - DISCUSSION

6. Destructive hit expectancy.

a. Definition. A means of comparing calibers has been devised, based on a standard of measure which will be called destructive hit expectancy. This expectancy, also mentioned above in paragraph 5 c, is expressed in percent. One hundred percent hit expectancy is taken to mean that the target has been subjected to gun fire, the cumulative effect of which has equalled a fragment density of one per square yard and that destruction of the target is expected to have been accomplished.

7. Method of obtaining hit expectancy.

a. The first step deemed necessary in obtaining destructive hit expectancy was the construction of hit expectancy curves for single rounds in conformity with the proper basic assumptions. These assumptions will be recalled as: Prediction errors vary directly as the time of flight, and other fire control errors are assumed to be the same as for the 3-inch antiaircraft gun.

(1) Source of basic data.

(a) Time of flight. The slant range limits of the 30-second time of flight for various calibers are shown on a chart marked Exhibit D. The data for the 3-inch and 105 mm curves on Exhibit D were obtained from available firing tables and trajectory charts. Time of flight for calibers for which no firing tables were available was obtained from curves shown on Exhibit F supplemented by data extracted from ballistic tables. The graphical chart marked Exhibit F was constructed by interpolation on Chart 1, inclosed as Exhibit A-2. At least one point on each interpolated curve was checked by means of ballistic tables, assuming form factors for all projectiles to be the same as for the 105 mm AA Shell M38. These curves therefore are believed to be sufficiently accurate for purposes of this study. The curve for the 105 mm projectile with a muzzle velocity of 3200 f.s. in Exhibit F was copied from Exhibit A-6.

(b) Three-inch antiaircraft gun target practice results. Since sufficient data based on actual firings were available only for the 3-inch antiaircraft gun, hit expectancy curves for all other calibers necessarily were based on the 3-inch curve. The hit expectancy curve shown on Exhibit G was based on firing table probable errors and the present target practice hitting volume for the 3-inch gun. Points corresponding to the average slant range were plotted on the graph against percentage of hits obtained for each 1938 target practice course, omitting the Fort Bragg firings. Data were thus available, based on 167 courses representing a total of 2662 rounds fired, which approximately confirmed the firing table hit expectancy curve between 5000 and 8000 yards slant range. Since those data confirmed the shape of the curve and the magnitude of the curve ordinates within the limits mentioned, the remaining sections of the target practice curve were made to conform in shape to the firing table probable error curve.

(2) Computation of hit expectancy curves. As set forth in Reference 2 (Secret letter, CABoard 471.11, January 5, 1939, to Chief of Coast Artillery, subject: Hitting volume 3-inch antiaircraft shell), the Coast Artillery Board believes the target practice hitting volume used at present is too large, and consequently gives a hit expectancy considerably higher than reasonably can be expected. Accepting the new hitting volume as being suitable for comparative purposes, ordinates of the 3-inch curve shown on Exhibit I were determined by reducing the ordinates of the 3-inch target practice hit expectancy curve on Exhibit G by an amount proportionate to the difference between the present target practice hitting volume and the weighted hitting volume assumed in Reference 2 and shown on Exhibit H. From the weighted 3-inch hitting volume shown in the last named exhibit, it was found that the probability of one shot being a destructive hit was about 10 percent of the probability that it would fall in the present 3-inch target practice hitting volume. The 3-inch curve shown on Exhibit I is based on this reduced probability. The ordinates of other curves on Exhibit I were based on the 3-inch curve thereon. For instance the value of the ordinate for the 105 mm curve corresponding to the X abscissa for 7000 yards slant range was obtained by the following mathematical operation:

$$O = a \times \frac{b}{c} \times \frac{d}{e}.$$

where O = Y ordinate for the 105 mm curve corresponding to the abscissa for 7000 yards slant range.
a = Y ordinate for the 3-inch curve at 7000 yards slant range, taken from Exhibit I.
b = Time of flight for the 3-inch projectile for 7000 yards slant range at 800 mils angular height.
c = Time of flight for 105 mm projectile for 7000 yards slant range at 800 mils angular height.
d = Assumed 105 mm weighted hitting volume.
e = Assumed 3-inch weighted hitting volume.

To summarize, it should be noted that the single shot destructive hit expectancy curves cover all ranges within thirty seconds time of flight for the calibers in question and incorporate probabilities on:

(a) Prediction errors, which were assumed to vary directly with time of flight.

(b) Hitting volumes, appropriate to each caliber, which were computed on the basis of number of effective fragments.

(c) Other fire control errors inherent in the 3-inch gun system based on actual target practice results.

The single shot destructive hit expectancy, or probability that a particular shot will result in destruction of the target as taken from Exhibit I, hereafter, will be referred to as field probability. At an average range of 9000 yards for the 3-inch gun it will be noted from Exhibit I that the probability of a destructive hit is 3/10 of one percent, or that 333 rounds would be required to destroy the target. Such figures seemed to be within reason and therefore the 3" curve on Exhibit I was accepted as a conservative basis upon which to build a comparison of larger calibers.

b. Determination of number of rounds fired. From the shape of the trajectory envelope it is apparent that a target may be taken under fire for progressively shorter time intervals as the altitude increases. The length of time during which a 3-inch antiaircraft gun can fire at a 300-mile-per-hour incoming target, before it reaches the overhead dead area, was computed for various altitudes and is shown graphically by Exhibit L. Using a rate of fire of 25 rounds per gun per minute and horizontal distances obtained from the breakdown chart marked Exhibit J, the number of rounds which can be fired by a 4-gun battery was computed. The same data for other calibers were computed using applicable rates of fire and charts similar to Exhibit J, and from these data were drawn the curves on Exhibit K showing maximum number of rounds which a 4-gun battery of given caliber can fire on an incoming target. It will be noted that for altitudes up to 10,000 yards the 105 mm gun exceeds the other calibers in number of rounds fired but that above 10,000 yards altitude the guns soon arrange themselves according to magnitude of caliber. If a minimum of 10,000 yards altitude is considered the 105 mm is obviously indicated as the optimum caliber from the standpoint of possible rounds fired. However, the effective volume of burst also must be taken into consideration in order to determine a more nearly correct measure of hit expectancy. Attention is invited to the fact that the length of time during which a battery can fire on a directly incoming target ($R_m = 0$) before it reaches the dead area above the battery is found as follows:

$$x = 30 + a - b,$$

where x equals the time in seconds during which battery is firing;
a equals the time in seconds for the target to travel from fuse range 30 to the intersection of its path with the trajectory for a quadrant elevation of 85 degrees.
b equals the time of flight of the projectile to the intersection mentioned for "a" next above.

c. Cumulative fire effect.

(1) Incoming targets ($R_m = 0$). The breakdown chart (marked Exhibit J) was also used in conjunction with field probabilities taken

from Exhibit J to find when the cumulative expected effect of rounds fired would amount to one destructive hit for a 3-inch four-gun battery. In each case the bursts of the first salvo were assumed to occur at the instant when the target came within 30 seconds fuze range. It will be noted that the horizontal lines corresponding to altitudes at 1000-yard intervals have been divided into zones between slant range intervals of 1000 yards. By use of a rate of fire versus travel scale the number of rounds for each 1000-yard slant range zone was found and to this was added the number of rounds gained during a time interval equal to the time of flight difference for the limiting slant ranges.

(a) Location of target when destruction may be expected. Using the average slant range for each 1000-yard slant range zone, the probability of obtaining a destructive hit in each zone was computed by multiplying the number of rounds falling therein by the appropriate field probabilities taken from curves on Exhibit I. Beginning with the destructive hit probability for the 1000-yard slant range zone next inside the 30-second fuze range curve, the probabilities for such zones were added successively along each 1000-yard altitude level until the sum equaled unity. A curve drawn through the points at which these sums equaled unity was taken as the limit of maximum slant ranges at which it could be expected to destroy an aircraft approaching in rectilinear flight at 300 miles per hour. Such limiting curves, both for 3/10 of one destructive hit and also for one full destructive hit, were computed from charts similar to Exhibit J for four-gun batteries of each caliber under study and are shown on Exhibit M. From Exhibit M it will be noted that the 5" gun battery gives the optimum hit expectancy, although it shows only a slight advantage over either the 105 mm or 155 mm guns. The chart indicates that, under the assumptions of this study, none of the batteries considered is capable theoretically of attaining an entire destructive hit on an incoming target, at altitudes of 7200 yards or above, before it reaches a point over the battery. Maximum altitudes at which a target may be brought under fire together with the number of rounds which can be fired on a 300-mile-per-hour incoming target are not shown on Exhibit M but may be read directly from Exhibit K.

(b) Fire effect at various altitudes. Since Exhibit M investigates only altitudes below 10,000 yards altitude it is thought desirable to investigate the effects of fire at higher altitudes. In order to present a graphical comparison, charts marked Exhibits N-1 and N-2 were prepared from data available on the breakdown charts similar to Exhibit J. From these curves may be read the cumulative fire effect at any altitude from 3000 yards to the maximum within range. Exhibit N-2 deals with altitudes above about 7000 yards and Exhibit N-1 on a smaller scale, with all altitudes above 3000 yards. At each altitude there is included the entire cumulative effect of fire of a four-gun battery engaging a 300-mile-per-hour incoming target ($R_m = 0$) with initial bursts at fuze range 30 and firing at the assumed rate until quadrant elevation reaches 85°. From these graphs it appears that at altitudes between six and nine thousand yards the 105 mm, 5-inch and 155 mm calibers have about the same hit expectancy, with the 5-inch leading. From an altitude of 6000 yards down to 3000 yards the 5-inch hit expectancy increases considerably over the other calibers considered. Above 9000 yards altitude the expectancy curves soon arrange themselves in order of caliber size, the 155 mm leading. Based on data taken from Exhibit N-2 there has been prepared the chart marked Exhibit O from which an idea may be gained quickly as to the relative efficacy of various calibers at altitudes of 10,000 yards and above. It is readily apparent that no gun considered gives hit expectancies as great as are needed at the extremely high altitudes and that an increase of caliber is essential as the altitude of target increases. On the other hand it appears that practical limitations in the weight and size of a portable gun make it necessary to compromise by accepting a smaller caliber with a somewhat lower hit expectancy at the necessary high altitudes, but which can develop comparatively high hit expectancies throughout the remainder of its useful range.

(c) Increased muzzle velocity effect. Referring again to the question of muzzle velocity, which was previously mentioned in paragraph 5 a (2) (b), it is possible that an increased muzzle velocity may be found feasible for calibers up to a certain size but perhaps impracticable for larger calibers. Higher muzzle velocity is expected to give increased range and reduced time of flight, two most desirable improvements in the characteristics of any weapon. In order to compare the effects of higher muzzle velocity on hit expectancies developed at 2800 f.s. under the conditions of this study a graph marked Exhibit P has been prepared. On this chart are shown four hit expectancy curves, the 105 mm and the 5-inch 2800 f.s. curves taken from Exhibit N-1 and the 3200 f.s. curves for the same calibers. The two latter curves were constructed in the same manner as were the 2800 f.s. curves, utilizing data from special charts similar to those presented by Exhibits F, I and J. It is of special interest to note from these curves that the order of arrangement for the hit expectancy curves developed on a basis of 2800 f.s. muzzle velocity for the calibers considered, is not disturbed by a change in muzzle velocity. A gain of about 3000 yards in maximum vertical range also is indicated for the 400 f.s. increase in muzzle velocity. This chart also tends to show that were an increased muzzle velocity attained in a caliber of about 105 mm and not for a gun of approximately 5-inch caliber, the former might possibly become the more effective gun, both as to maximum range and hit expectancy. At the present time it seems difficult to foresee what improved muzzle velocities may develop in the near future, or whether such improved velocities will be attainable for all calibers within the size bracket under study. For this reason it is believed that a proper selection of caliber, suitable for any heavy AA gun considered necessary, may be contingent on the outcome of Ordnance studies on increased muzzle velocity mentioned above in par. 5 a (2) (b). The maximum caliber for which an increase of muzzle velocity is feasible may vary considerably. Furthermore the amount by which muzzle velocity may be increased for a given caliber also may vary, thus introducing such a great number of possible combinations as to make impracticable any conclusions before muzzle velocity limits are known. It is therefore considered necessary in this study to draw comparisons on a basis of equal muzzle velocity for all calibers.

(2) Targets at selected altitudes, on various courses. In order to extend the investigation of comparative capabilities of AA batteries of various calibers, hit expectancy curves at three selected altitudes were constructed as shown in Exhibits Q-1, Q-2, and Q-3. Heretofore only directly incoming courses have been dealt with and it is believed profitable to study other types of courses to insure that other possible trends of hit expectancy curves will not be ignored. The cumulative fire effect for each of several rectilinear passing courses at various minimum horizontal ranges was computed for the entire time the target was within range. The value of the cumulative hit expectancy was then plotted as an ordinate with an abscissa corresponding to the minimum horizontal range of the course. The loci of such points formed the curves as shown for the particular calibers. From the method of construction it is seen that ordinates of each curve show the total cumulative effect of fire by a battery of given caliber on courses which come within range at the particular altitude for which the graph was prepared. Altitudes of 7000, 10,000 and 12,000 yards were chosen to make comparisons possible at higher altitudes. From these charts it should be noted that the results of the comparisons based on incoming targets as shown in Exhibits N-1 and N-2 are confirmed by a consideration of all other rectilinear courses. Exhibit Q-1 also confirms the indication by previous exhibits that fire effect for the 2800 f.s. 105 mm gun will be negligible at altitudes of 12,000 yards and above.

8. The optimum caliber.

a. Relation to altitude of attack. By utilizing data taken from curves presented in Exhibits N-1 and N-2 it was found that curves of equal destructive hit expectancy could be constructed as shown in Exhibit R. For example, by taking from Exhibit N-2 the altitudes at which various calibers show a destructive hit expectancy of 100 percent, replotting caliber against altitude, and connecting these points, there can be formed a smooth curve from which can be read the maximum altitude of attack at which a particular caliber may expect a full destructive hit. In other words, this curve shows the maximum altitude at which a particular caliber four-gun battery may expect to destroy a directly incoming target by the time it reaches a quadrant elevation of 85 degrees. From an inspection of Exhibit R it will be noted that for altitudes up to about 10,000 yards the curves of equal hit expectancy show a point of maximum altitude value, or hump, near a caliber of approximately 5 inches. Above about 10,000 yards altitude it will be seen that the curves contain no humps and that if such maximum points occur they would be off the chart toward a higher caliber than 155 mm. If the points of maximum ordinate value for these curves be connected by a smooth curve it is obvious that such a curve will indicate the optimum caliber for any particular altitude. This curve is considered to indicate that:

(1) The optimum caliber against attacks between 3000 and 10,000 yards altitude varies between approximately 4.5 and 5.5 inches.

(2) For attacks above 10,000 yards the optimum caliber increases rapidly from about 5.5 inches to an undetermined limit.

b. Relation of optimum caliber to other calibers. An optimum caliber having been accepted as approximately that indicated by the optimum caliber curve constructed on Exhibit R, it is now possible to compare the efficacy of particular calibers with that of the optimum. Since the optimum caliber has been shown to vary with the altitude of attack the comparison will necessarily be made throughout the altitude zones which fall within range of a particular gun. This comparison has been effected graphically on the chart marked Exhibit S. On this chart has been drawn a curve corresponding to each of the calibers treated specifically in this study. From the graph marked Exhibit R was taken the fractional part of one destructive hit by which the caliber in question was exceeded by the optimum caliber at a particular altitude of attack. This fractional part of a destructive hit was replotted along the abscissa in percent, with an ordinate equal to altitude of attack, as a point on a caliber curve of Exhibit S. The curves constructed on this exhibit are the loci of similar points for which data were taken from Exhibit R. The optimum caliber on Exhibit S is, of course, represented by the vertical line at the zero abscissa. An inspection of the last named exhibit further assists in the interpretation of the data presented by Exhibits N-1 and N-2, the same data being presented graphically in a somewhat different manner. Exhibit S also indicates that:-

(1) The 5-inch caliber is nearer to the optimum than the other calibers shown when an average loss in efficacy is considered throughout the altitude range.

(2) Calibers larger than five inches are nearer the optimum only for attacks above 10,000 yards altitude.

(3) Below 6000 yards altitude the 5-inch caliber is nearest the optimum by a wide margin, considering only the calibers for which curves are drawn.

c. Influence of future aircraft development. It is very obvious from a consideration of the data thus far presented, that future improvements in aircraft performance may force the adoption of special weapons selected to give ranges long enough to reach the target even at the sacrifice of efficient performance at medium ranges. The maximum altitude which can be reached by the 5-inch gun, even with increased muzzle velocity, and a fuze range extended beyond 30 seconds, may not be enough to take under fire bombers of the future. Until that time comes it seems logical to consider the longest range weapon giving acceptable performance throughout its effective range, provided that range reaches above present ceilings of bombing aircraft by a reasonable margin. In the opinion of the Coast Artillery Board, five inches is approximately the caliber of the antiaircraft gun which fulfills these conditions.

9. Need for a mobile heavy antiaircraft gun. From standpoints of economy, ease of manufacture and tactical organization and control of antiaircraft artillery, it would be highly advantageous to employ only one caliber of antiaircraft gun. Since now we are to have two guns, the 3-inch and 90 mm, it is the more important to avoid a third caliber if practicable. However, a study of the comparative data presented is convincing as to the need for a weapon more powerful than the 90 mm if attacking aircraft are to be taken under fire at the altitudes visualized. An inspection of Exhibit O and N-2 seems amply to indicate the necessity for an antiaircraft gun of larger caliber than 90 mm. From these charts it is seen that the 90 mm and 105 mm guns reach maximum altitudes of 11,000 and 12,000 yards, respectively. If aircraft flying at altitudes of 12,800 yards are to be taken under fire, a gun of less than 5-inch caliber with 2800 f.s. muzzle velocity cannot fulfill the requirement unless a time of flight longer than 30 seconds is employed. All points considered, it is believed preferable to accept the increases implied by a larger caliber weapon rather than to employ the longer time of flight required by a smaller caliber. While it is true that large increases in maximum range at high quadrant elevations are not attained by an increase of caliber from about 105 mm to five inches, a small extension of range at the altitudes in question assumes great importance when aircraft ceilings

are considered. It is known that every 1000 feet added to the ceiling of a loaded bomber introduces additional technical difficulties in aircraft design and operation. If the defense can develop an AA gun with a range long enough to extend into the future such difficulties for the aerial attacker, it is believed worthwhile to accept some of the objectionable features of a heavier AA gun. For the defense of large area targets the Coast Artillery Board believes that a heavy AA gun having a longer range than the 105 mm, 2800 f.s. weapon is definitely indicated.

10. Weight. a. Since high mobility is not essential for a gun with this tactical role, the overall weight of the gun and carriage is not believed to prohibit a caliber as great as 155 mm. Component loading could be resorted to if the weight of a single unit mount became prohibitive for road movements. Although an increase in muzzle velocities above 2800 f.s. will necessitate somewhat heavier construction of guns and mounts in order to cope with resultant increases in muzzle energy, it is believed that such added weight in itself will not make impracticable a caliber as great as 155 mm. No data are available as to what maximum muzzle velocities may be expected for various caliber AA guns within practicable weight limits, but it is understood that should higher muzzle velocities be attained for a given caliber, equal velocities may be practicable for larger calibers without reduction of accuracy life beyond an acceptable minimum. The overall weight of the gun and mount therefore has not been considered to impose a restriction on the size of caliber for AA guns up to and including 155 mm.

b. Ammunition. Service of the piece and ammunition supply should be considered. As the caliber increases above a certain point it becomes necessary to resort to separate loading ammunition because of the great weight of a single round. However, the assumed rates are expected to be met through improved mechanical ramming features, whether fixed or separate loading ammunition is used. As the caliber increases, fewer shells are expended as a result of a reduced rate of fire; hence the total weight of ammunition used is not expected to change greatly, nor is ammunition manufacture and supply expected to be made more difficult.

11. Mobility. A design which admits of portability; that is, movement of the gun in one or more loads over good roads and at low speeds, is considered acceptable for weapons of this type. The employment of this gun as now visualized probably will not require rapid road movements and sufficient time will be available for emplacement. Special preparation of emplacement positions probably would be acceptable if not extensive. Large area targets of such importance as to make AA defense imperative will not be subject to frequent change of status, hence the defending guns, having once been assigned to an area, will be required to move infrequently.

12. Summary.

a. Given the problem of determining the adequacy of existing and projected antiaircraft artillery and of deciding on the nature of developments in the immediate future to meet such inadequacies as might be found to exist, the Coast Artillery Board devised a technique for predicting the destructive effect of any antiaircraft cannon under any given set of conditions. This technique is based on the following facts and assumptions:

(1) Rate of fire and weight of projectile.

Caliber	Weight of projectile	Rate of fire (Rounds per minute)
3-inch	12.5 lbs.	25 (Hand loaded)
90 mm	22	20 " "
105 mm	33	20 (Automatic rammer)
5-inch	54	15 " "
155 mm	95	10 " "

(2) Destructive effect of one projectile. Considering one fragment per square yard (cumulative) to be destructive, available fragmentation data were extrapolated to include the shells under consideration, the areas covered by each with various fragment densities were integrated, and the resultant weighted danger spaces compared with that of the 3-inch shell Mark IX (assumed to be unity) as follows:

Caliber	Ratio to 3-inch shell
3-inch	1.00
90 mm	1.38
105 mm	1.79
5-inch	2.50
155 mm	3.21

(3) The target. This was assumed to be a bombardment airplane flying at 300 miles per hour on various courses and at various altitudes up to 40,000 feet.

(4) The probability of hitting. Target practice results with 3-inch materiel were compared with firing table probabilities and with the destructive effect of one projectile (subparagraph (2), above) and the probable number of rounds required to assure one destructive hit by a 4-gun battery was established for various slant ranges. Time of flight data for the various projectiles under consideration were determined from ballistic tables. Then, for any projectile under consideration, the probability of one destructive hit at any range was considered to be the probability for a battery of 3-inch guns multiplied by the ratio of the time of flight for the 3-inch projectile to the time of flight for the other projectile under consideration and further by the ratio of the danger spaces as listed in subparagraph (2), above. On any given course, the number of rounds bursting in the vicinity of the target from the battery under consideration was readily established

from the time of flight, rate of fire, and target speed data available. From the probability of hitting data, the number of destructive hits to be expected at all representative altitudes on all representative courses was determined for each type of weapon under consideration. These data are shown graphically in the exhibits attached.

b. The ideal antiaircraft cannon, or that one which will assure the maximum number of destructive hits, is found to be elastic, varying in caliber as altitude increases. Above 7200 yards altitude no battery of four guns can fire enough rounds to assure positively one destructive hit in the time available before an incoming 300-mile-per-hour target reaches a quadrant elevation of 85 degrees. Above about 10,800 yards, no 4-gun battery can fire enough rounds in this available time to assure the destruction of more than one in five of the targets taken under fire. This destructive power decreases rapidly above 10,000 yards altitude, becoming zero at the maximum fuze range of the gun under consideration. This was taken in every case to be 30 seconds.

c. Antiaircraft cannon for future development. The Board then considered the foregoing data and decided that the probability of ultra-high altitude bombing in the near future up to 40,000 feet was such as to make necessary the development of a cannon capable of taking under fire targets up to approximately that altitude. Examination of the capabilities of various weapons indicated that a 5-inch caliber firing at 2800 f.s. muzzle velocity is the minimum capable of reaching about to that altitude with a 30-second fuze range. At 8800 yards altitude, five inches represents the ideal caliber. Below 8800 yards, the difference in destructive power between a 5-inch and the ideal caliber is negligible. The Board therefore believes that development of a 5-inch gun should be initiated. In arriving at this belief the Board took into consideration the probability that fire control developments under way will make practicable the utilization of the range and power of such a gun. The Board considered also the importance in the accuracy of antiaircraft fire attributed to a short time of flight to any given range and believes that the muzzle velocity of the proposed gun should be increased above 2800 f.s. to as near 3200 f.s. as practicable. The conclusions and recommendations of the Board are presented in detail in the succeeding paragraphs.

IV - CONCLUSIONS

15. The Coast Artillery Board concludes that:

a. In the near future effective bombardment of large area targets from altitudes as high as 40,000 feet may well be feasible.

b. Present antiaircraft guns either built or projected are not effective against targets at such altitudes.

c. A need will exist in the near future for an antiaircraft gun capable of taking under fire targets at altitudes mentioned in a, above.

d. It is both desirable and economical in the long run to develop a weapon with ample range to meet expected advances in high altitude performance [illegible] bombing aircraft for several years to come.

e. The important characteristics of such a heavy antiaircraft gun are as follows:

(1) The gun should be reasonably effective against targets at extremely high altitudes.

(2) A comparatively high hit expectancy is desirable throughout the effective range of the weapon without sacrificing efficiency at short and medium ranges.

(3) Limited mobility; i.e., portability, is acceptable.

(4) The highest practicable muzzle velocity compatible with an accuracy life of at least 1000 rounds is desirable.

(5) Mechanical ramming and separate loading ammunition may be necessary and are considered acceptable.

f. When over-all hit expectancy is considered, both above and below 9000 yards altitude, a 5-inch gun is nearest the optimum caliber, guns being compared on the same muzzle velocity basis.

g. Since the 5-inch caliber is nearest the optimum, all calibers for which data have been presented being compared on the basis of the same muzzle velocity, it follows that some other caliber may prove to be nearer to the optimum if that other caliber can be made to utilize a higher muzzle velocity than is practicable with the 5-inch.

h. If the research now being conducted by the Chief of Ordnance indicates the possibility set forth in subparagraph g, next above, then the study contained in this report is inadequate to determine the caliber nearest the optimum and additional studies should be authorized based on the facts then apparent.

V - RECOMMENDATIONS

14. The Coast Artillery Board recommends that:

a. Pending the outcome of investigations mentioned in the next succeeding subparagraph, five inches be considered the most desirable caliber for a heavy antiaircraft gun.

b. The Chief of Ordnance be requested to expedite the investigations outlined by him in paragraph 8 of his letter of January 19, 1939, included as Exhibit A-1, with a view to increasing the muzzle velocity of the antiaircraft cannon from 2800 f.s. to as near 3200 f.s. as may be practicable.

c. In the event that any feasible increase in muzzle velocity for the 105 mm gun is also found practicable for 5-inch guns, the Chief of Ordnance be requested to initiate development of a heavy antiaircraft gun with the following general characteristics:

(1) Caliber: Approximately five inches.

(2) Muzzle velocity: Not less than 2800 f.s. (See subparagraph b, above.)

(3) Mobility: Limited. (See paragraph 11, above.)

(4) Rate of fire: At least 15 rounds per minute and higher if practicable.

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(5) Elevation: Gun to be capable of firing from 0 degrees to 85 degrees and to be stable at all elevations above 200 mils.

d. In the event that such increase in muzzle velocity above 2800 f.s. as may be found practicable with the 105 mm gun cannot be applied to the proposed 5-inch gun without greatly increasing its overall weight or decreasing its accuracy life to less than 1000 rounds, the question as to the caliber of the proposed weapon be reopened and again referred to the Coast Artillery Board for study.

.. S. BO..,
Colonel, Coast Artillery Corps,
President.

Exhibits A to S, inclusive,
accompanying.

DECLASSIFIED IN FULL
Authority: EO 13526
Chief, Records & Declass Div, WHS
Date: NOV 2 3 2016

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IAW EO 13526, Section 3.5
Date:
NOV 23 2016

EXHIBIT A TO C.A.B. PROJECT NO. 1153

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EXHIBIT A-1
Coast Artillery Board Project 1153
Heavy Antiaircraft Gun

WAR DEPARTMENT
Office of the Chief of Ordnance
Washington

O 472.93/6048

January 19, 1939.

SUBJECT: Heavy Antiaircraft Gun, Mobile Type.

TO: Chief of Coast Artillery.

1. The design of the 90 mm Antiaircraft Mobile Gun and Carriage has advanced to such a point it is now possible to start the design of a larger caliber antiaircraft gun and mobile mount.

2. Comparative studies have been made of antiaircraft guns of calibers above 90 mm, as follows:

105 mm Gun
5-Inch Navy Gun
155 mm Gun

In these studies, the following factors have been taken into consideration:

a. Time of flight of 5", 105 mm and 155 mm projectiles - Chart #1.

b. Rates of fire.

c. Number of effective fragments per minute for above calibers - Chart #2.

d. Estimated weight in traveling position and costs of the above units.

e. Probability of hitting vs. time of flight - Chart #3.

f. Travel of plane between shots vs. caliber - Chart #4.

g. Time of flight - 105 mm A.A. Gun special projectile - Muzzle Velocity 3200 f/s - Chart #5.

3. Referring to Chart #1, showing the time of flight as a function of slant range, it will be noted that the Navy 5-inch 38 caliber gun gives longer times of flight for various slant ranges than the Army 105 mm A.A. Gun. The Navy 5-inch gun was therefore dropped from further consideration.

4. A study of the time of flight data (See Chart #1) for the 105 mm and 155 guns, indicate that there is little or no choice between the two

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weapons up to a slant range of some 8,000 yards. Beyond this range, the 155 mm gun gives increasingly shorter times of flight until at a range of say 14,000 yards, the difference becomes 5 seconds in favor of the 155 mm gun.

5. The rates of fire as estimated for the two calibers are - 20 rounds for the 105 mm antiaircraft gun, and 10 rounds for the 155 mm antiaircraft gun. In both cases, it is assumed that mechanical loading devices would be used. While the rate of fire of the present 105 mm antiaircraft fixed gun has been somewhat less than the above figure (12 to 15 r.p.m.), it is believed that with improvements which can be made in the rammer system and the scheme of loading a rate of fire of 20 r.p.m. is feasible. In the case of the 155 mm gun, it will be necessary to use semi-fixed ammunition, as otherwise the length of the round would be too great. While undoubtedly difficulty would be experienced in handling the heavy 155 mm round, it is estimated that a rate of fire of 10 r.p.m. could be obtained through the use of mechanical devices.

6. Chart #2 indicates the number of effective fragments per minute as a function of the caliber of the gun.

7. The weights and costs of these guns mounted on mobile carriages would be as shown below:

	Total Weight in Traveling Position	Estimated Cost
105 mm A.A. Gun	25,000 lbs.	$50,000
155 mm Gun	45,000 lbs.	$90,000

It is estimated that the comparative weights given in the above table can be met. The weight of the 155 mm gun was obtained by a consideration of the changes which would have to be made in the present 155 mm Field Gun M1 which mounts a 155 mm gun with a muzzle velocity of 2800 f/s and weighs 30,500 pounds.

8. A study is also being made of the possibility of increasing the muzzle velocity of the 105 mm gun to approximately 3200 f/s. The present 105 mm gun was designed for a muzzle velocity of 3000 f/s, but has been used in service at a muzzle velocity of 2800 f/s. It is planned to conduct experimental firings with the 105 mm gun at the Proving Ground to determine its life when fired at 3200 f/s and the rate of decrease in the muzzle velocity. There is also a possibility of improving the present projectile for the 105 mm antiaircraft gun. If these improvements can be made the time of flight for various ranges will be reduced as shown on Chart #4. Thus, at a slant range of 14,000 yards, the time of flight for the high velocity 105 mm gun would be 24 seconds, compared to the time of

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flight of 26 seconds for the 155 mm gun with a velocity of 2900 f/s.

9. On Chart #3 is shown the probability of hitting as a function of time of flight for the 105 mm and 155 mm guns. These probabilities are based upon gun and ammunition probabilities and assume perfect fire control. The probability of hits per gun per minute appears to be in favor of the smaller caliber.

10. It is requested that a study be made of the caliber desired for the heavy antiaircraft gun and that your recommendations be forwarded at the earliest practicable date as it is desired to proceed with the design of a larger caliber gun.

C. M. Wesson,
Major General, Chief of Ordnance.

5 Inclosures (Charts)

472.311/BO   1st Ind.

War Department, Office, Chief of Coast Artillery, January 27, 1939 - To: President, Coast Artillery Board.

1. For comment.

2. As now visualized the larger caliber gun proposed herein would be utilized in the defense of large area targets susceptible of attack from extremely high altitudes.

3. High mobility for such a weapon would be unnecessary though the weapon should be of the mobile type.

By order of the Chief of Coast Artillery:

J. A. GREEN,
Colonel, C. A. C.
Executive.

5 Incls--No change.

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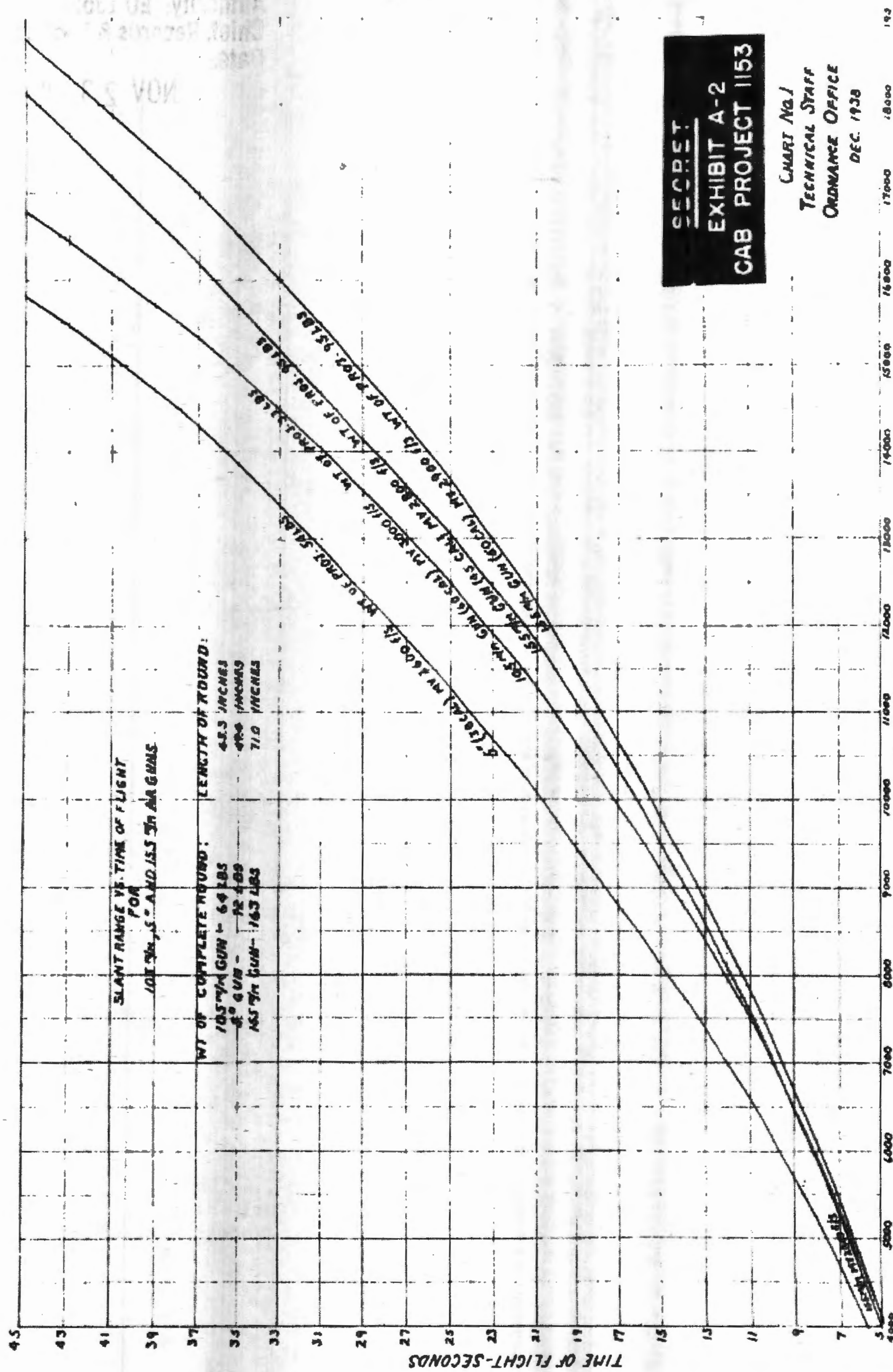
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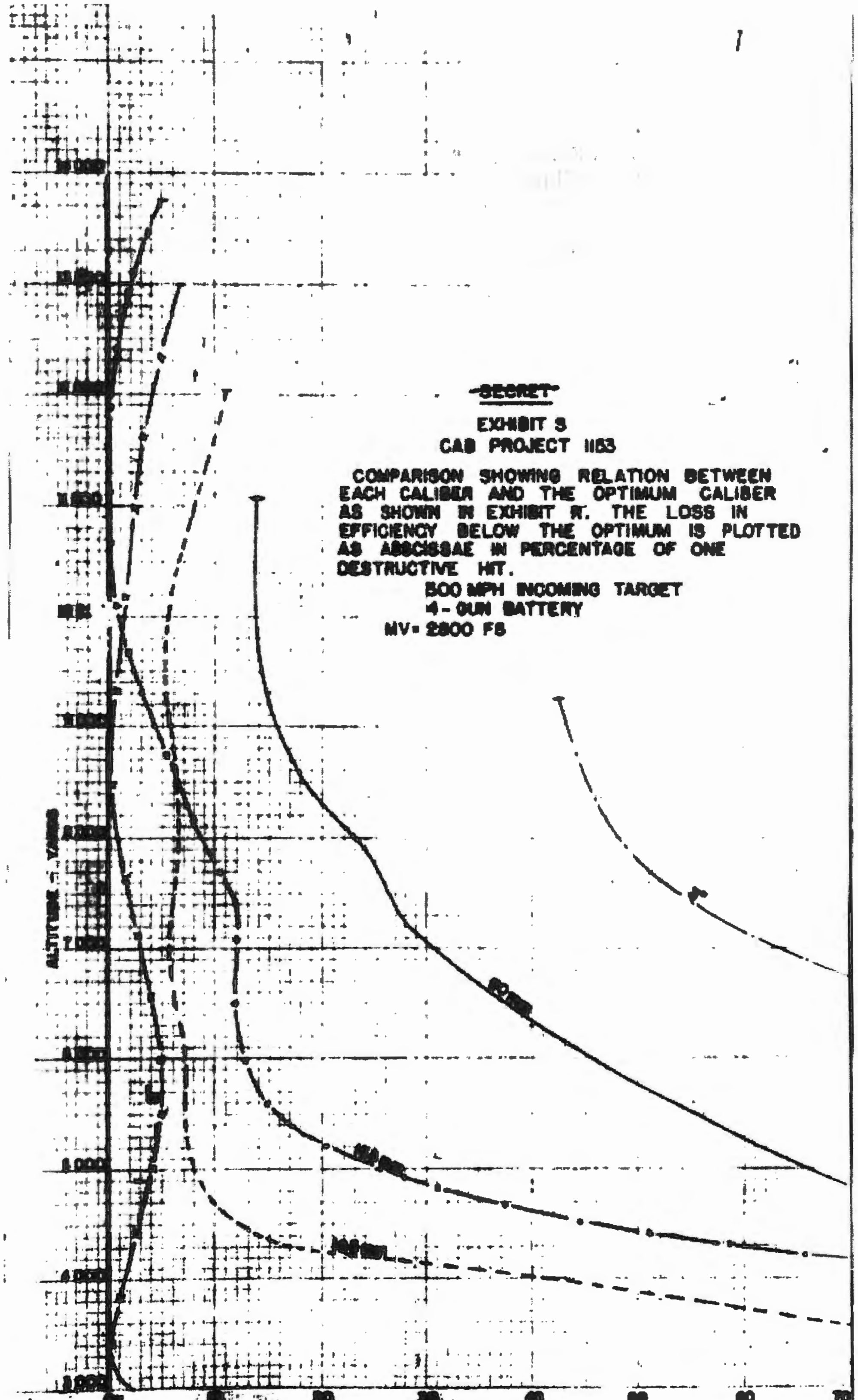
EXHIBIT A-2
CAB PROJECT 1153
CHART No. 1
TECHNICAL STAFF
ORDNANCE OFFICE
DEC. 1938
SLANT RANGE VS. TIME OF FLIGHT
FOR
WT OF COMPLETE ROUND:
LENGTH OF ROUND:
43.3 INCHES
71.0 INCHES
163 LBS
TIME OF FLIGHT-SECONDS
SLANT RANGE - YARDS



LOSS OF DESTRUCTIVE HITS BY GUNS OTHER THAN THE OPTIMUM - PER CENT

ABSCISSAE ARE PERCENTAGES OF ONE DESTRUCTIVE HIT. A BATTERY OF GUNS OF THE OPTIMUM CALIBER IS CONSIDERED TO HAVE ZERO LOSS.

EXHIBIT 5 TO C.A.B. PROJECT NO. 1153

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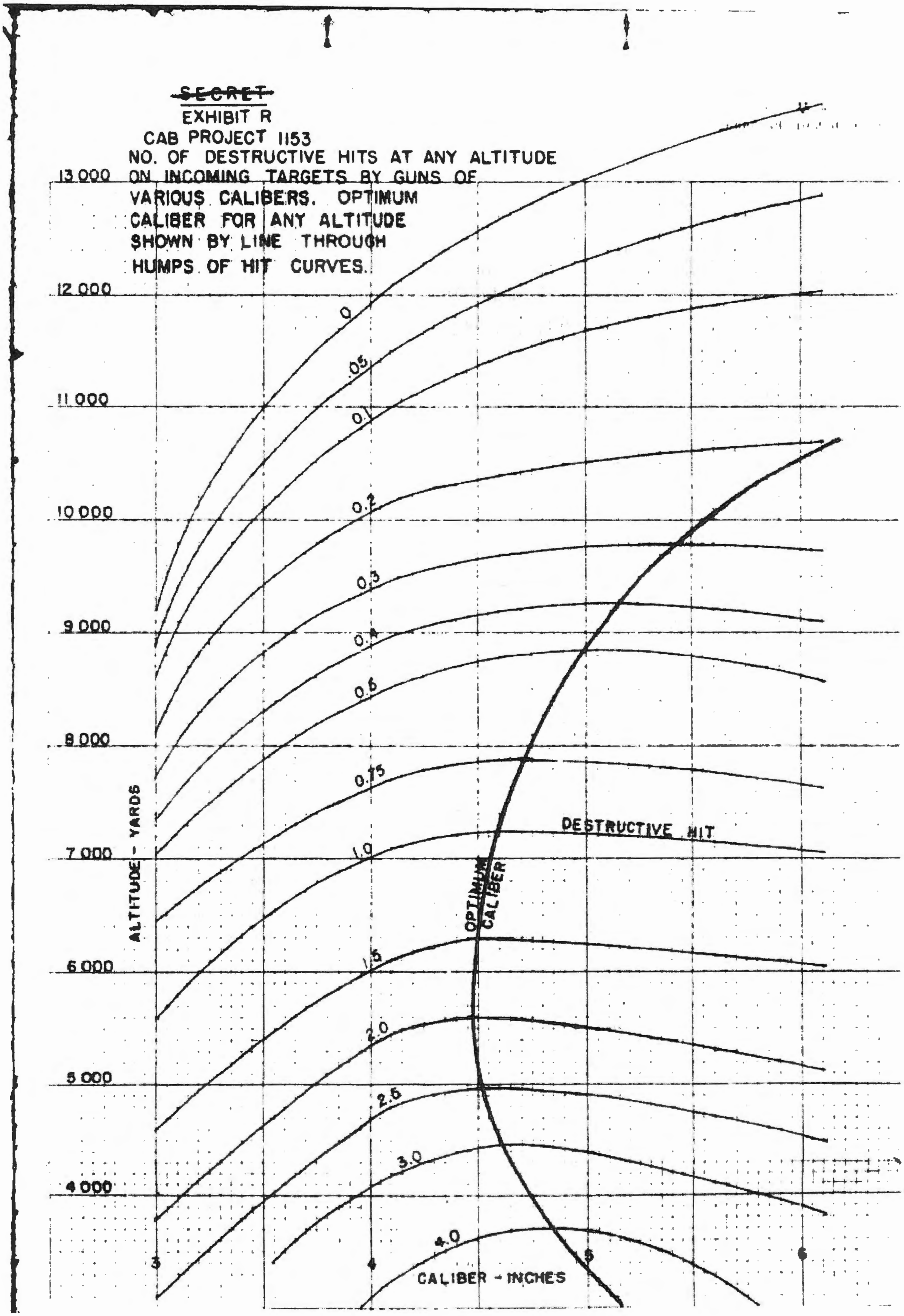
EXHIBIT R

CAB PROJECT 1153

NO. OF DESTRUCTIVE HITS AT ANY ALTITUDE ON INCOMING TARGETS BY GUNS OF VARIOUS CALIBERS. OPTIMUM CALIBER FOR ANY ALTITUDE SHOWN BY LINE THROUGH HUMPS OF HIT CURVES.



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Date: NOV 2 3 2016

EXHIBIT R TO C.A.B. PROJECT NO. 1153

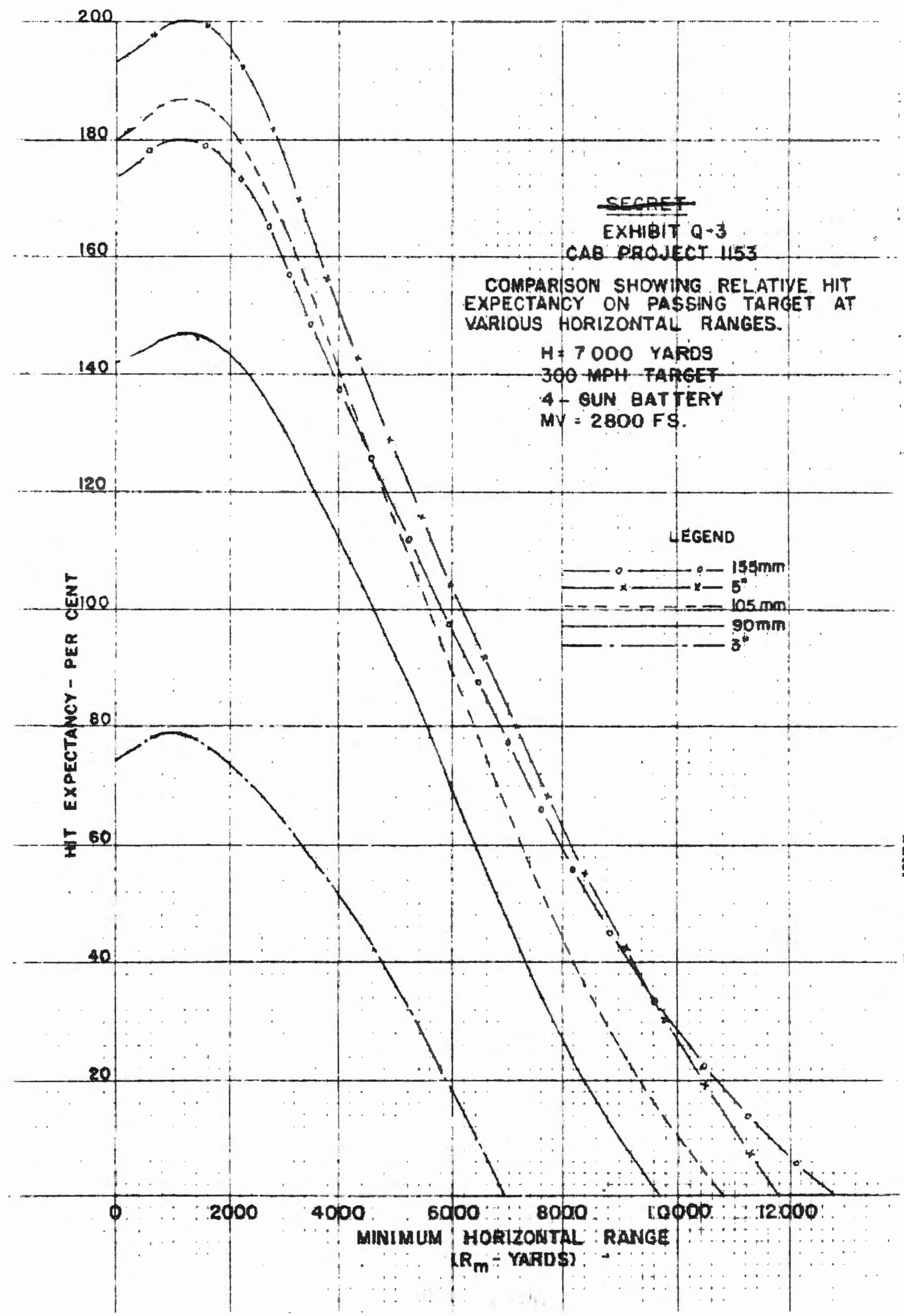
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EXHIBIT Q-3
CAB PROJECT 1153
COMPARISON SHOWING RELATIVE HIT EXPECTANCY ON PASSING TARGET AT VARIOUS HORIZONTAL RANGES.
H = 7000 YARDS
300 MPH TARGET
4 - GUN BATTERY
MV = 2800 FS.
LEGEND
155mm
5"
105 mm
90mm
3"
HIT EXPECTANCY - PER CENT
200
180
160
140
120
100
80
60
40
20
0
2000
4000
6000
8000
10000
12000
MINIMUM HORIZONTAL RANGE
(R_m - YARDS)

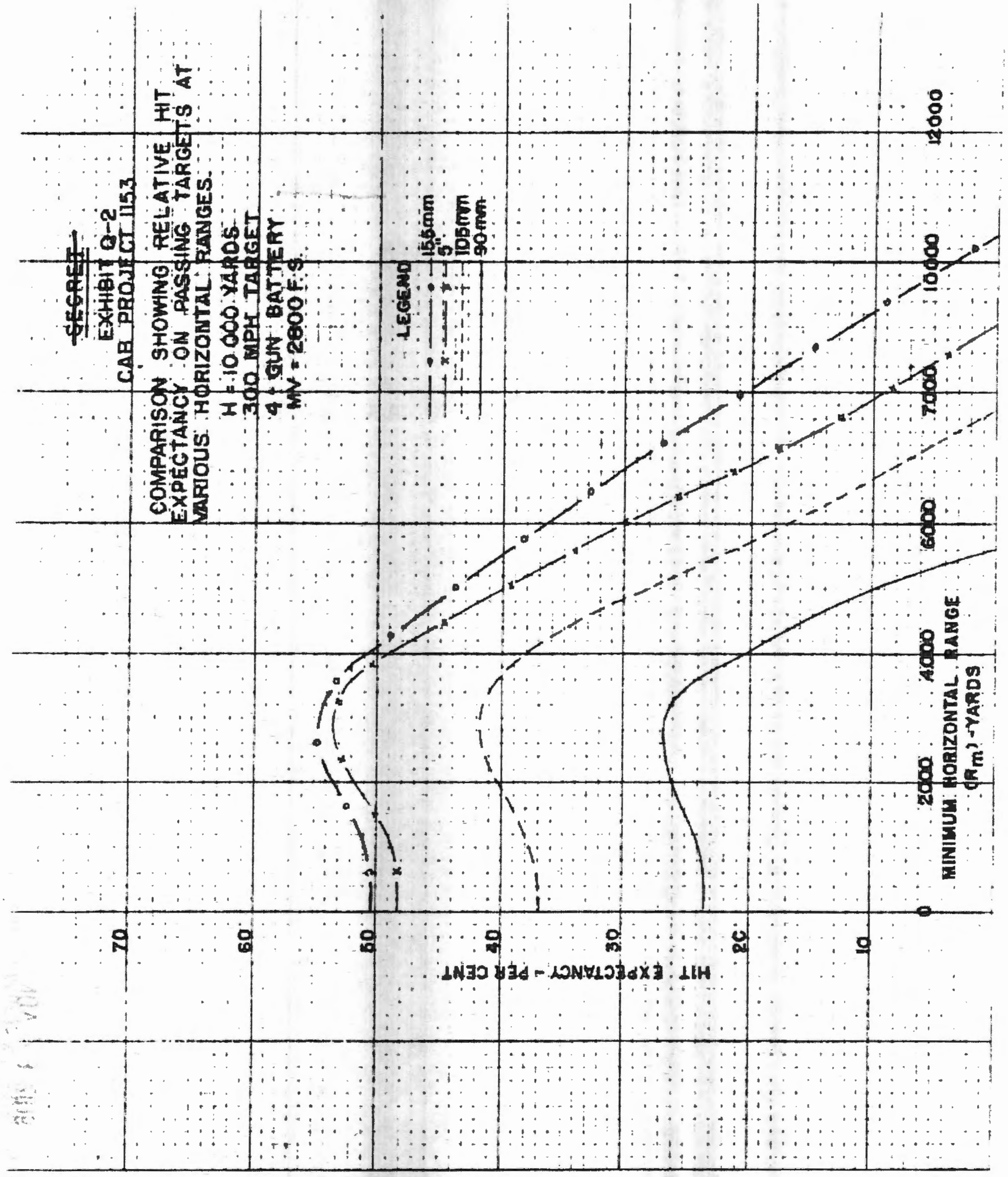
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EXHIBIT Q-2
CAB PROJECT 1153
COMPARISON SHOWING RELATIVE HIT EXPECTANCY ON PASSING TARGETS AT VARIOUS HORIZONTAL RANGES.
H = 10 000 YARDS
300 MPH TARGET
4 GUN BATTERY
MV = 2600 F.S.
LEGEND
155mm
5"
105mm
90mm
HIT EXPECTANCY - PER CENT
70
60
50
40
30
20
10
0
2000
4000
6000
10000
12000
MINIMUM HORIZONTAL RANGE (Rm) - YARDS

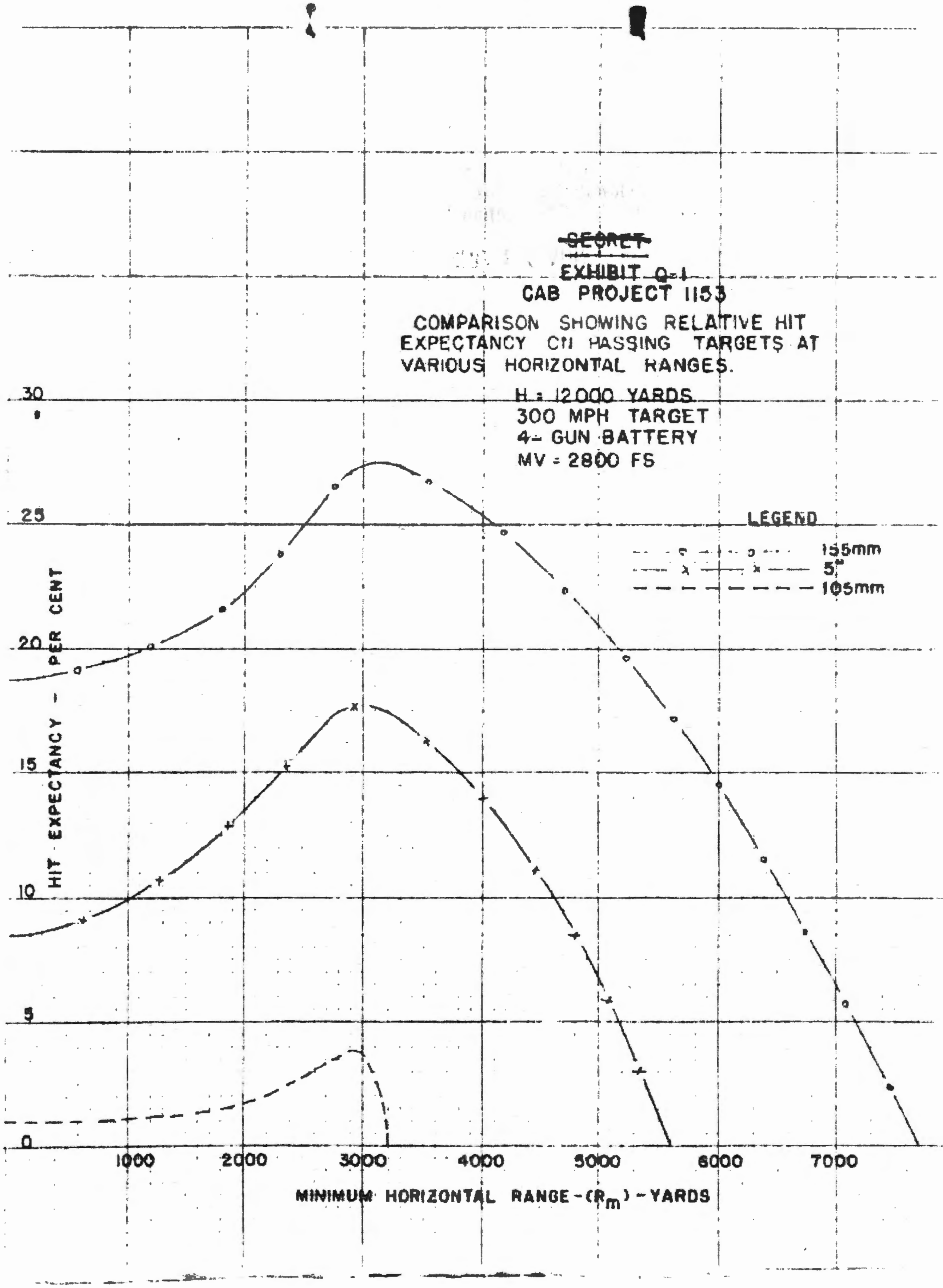
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EXHIBIT Q-1
CAB PROJECT 1153
COMPARISON SHOWING RELATIVE HIT EXPECTANCY ON PASSING TARGETS AT VARIOUS HORIZONTAL RANGES.
H = 12000 YARDS
300 MPH TARGET
4- GUN BATTERY
MV = 2800 FS
LEGEND
155mm
5"
105mm
HIT EXPECTANCY - PER CENT
30
25
20
15
10
5
0
1000
2000
3000
4000
5000
6000
7000
MINIMUM HORIZONTAL RANGE - (R_m) - YARDS

EXHIBIT Q TO C.A.B. PROJECT NO. 1153

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Authority: EO 13526
Chief, Records & Declass Div, WHS
Date: NOV 2 3 2016

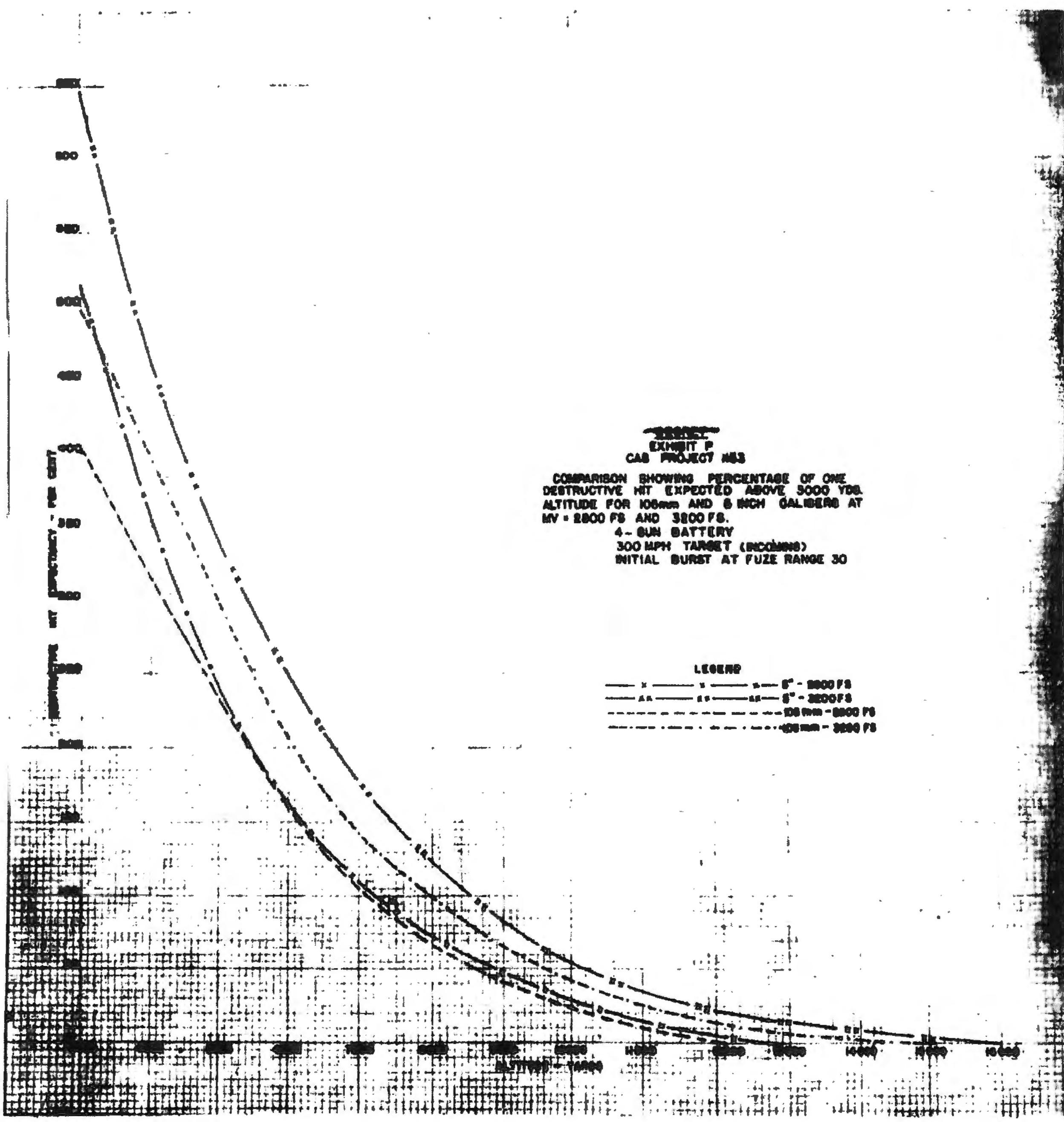

EXHIBIT P TO C.A.B. PROJECT NO. 1153

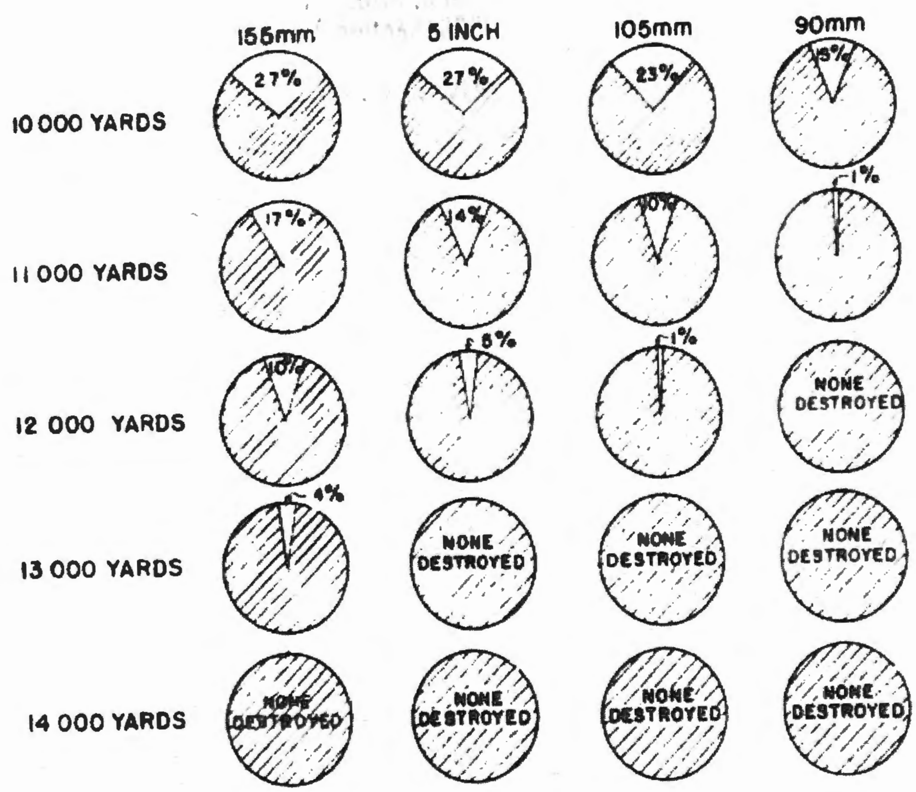

CHART SHOWING PERCENTAGE OF TARGETS ENGAGED, AT ALTITUDES OF 10 000 YARDS AND ABOVE, WHICH WOULD THEORETICALLY BE DESTROYED BY ONE 4-GUN BATTERY BEFORE EACH TARGET REACHES DEAD AREA ABOVE BATTERY.

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EXHIBIT O

CAB PROJECT 1153

EXHIBIT 2 TO C.A.B. PROJECT NO. 1153

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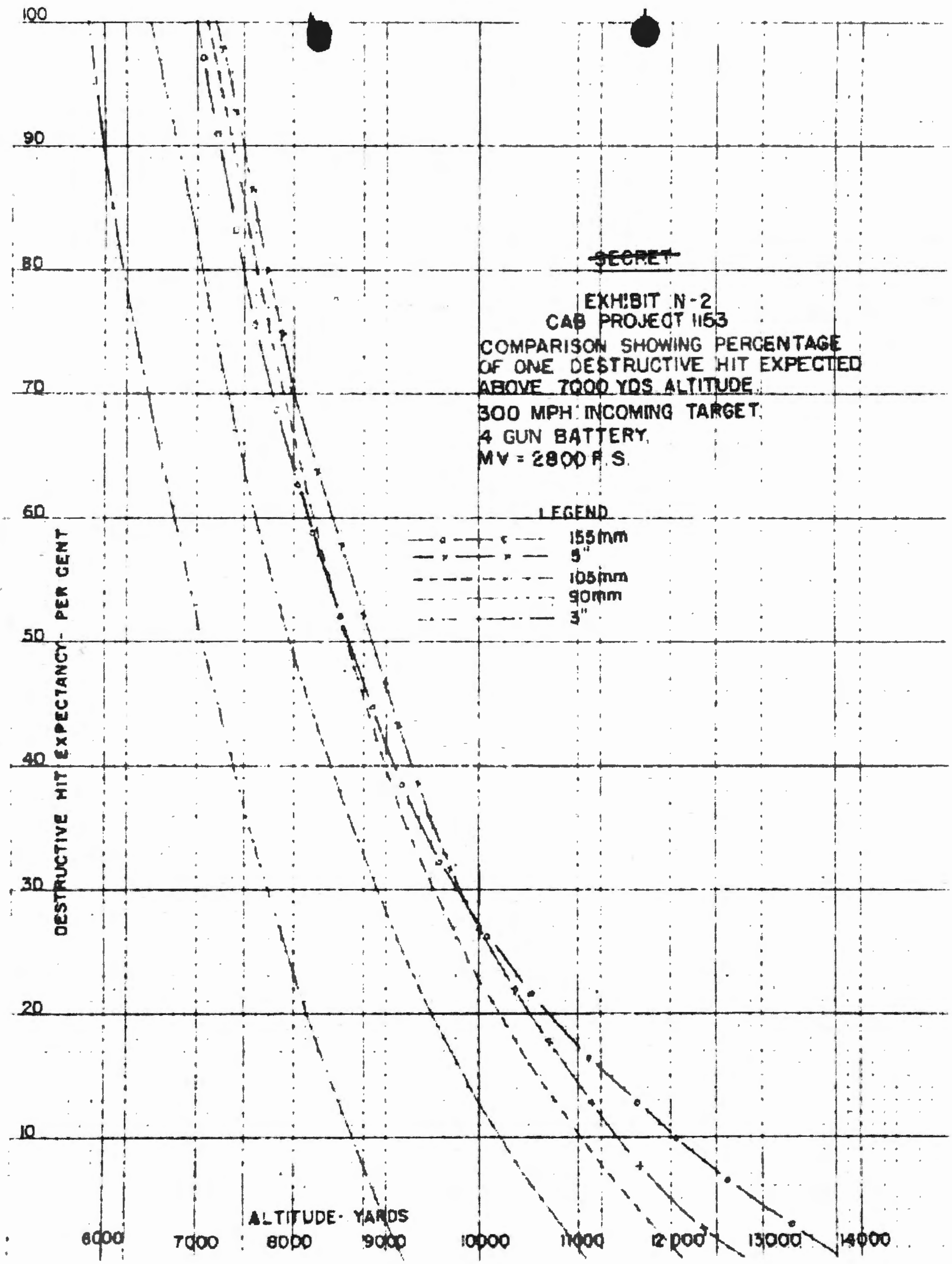
Date: NOV 2 3 2016



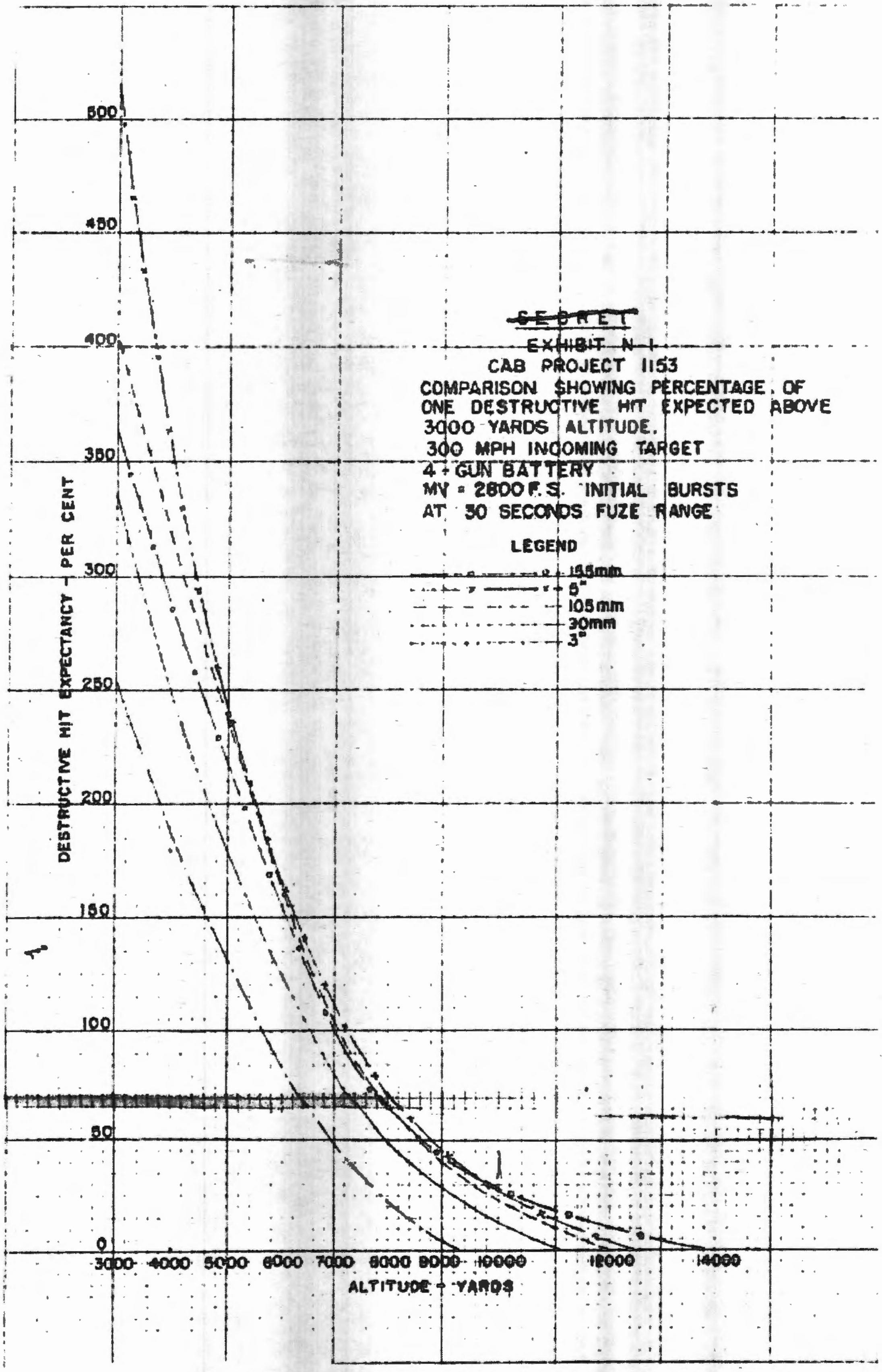

SECRET
EXHIBIT N-1
CAB PROJECT 1153
COMPARISON SHOWING PERCENTAGE OF ONE DESTRUCTIVE HIT EXPECTED ABOVE 3000 YARDS ALTITUDE.
300 MPH INCOMING TARGET
4 - GUN BATTERY
MV = 2600 F.S. INITIAL BURSTS AT 30 SECONDS FUZE RANGE
LEGEND
155mm
5"
105mm
90mm
3"
DESTRUCTIVE HIT EXPECTANCY – PER CENT
0
50
100
150
200
250
300
350
400
450
500
3000
4000
5000
6000
7000
8000
9000
10000
12000
14000
ALTITUDE – YARDS

EXHIBIT N TO C.A.B. PROJECT NO. 1153

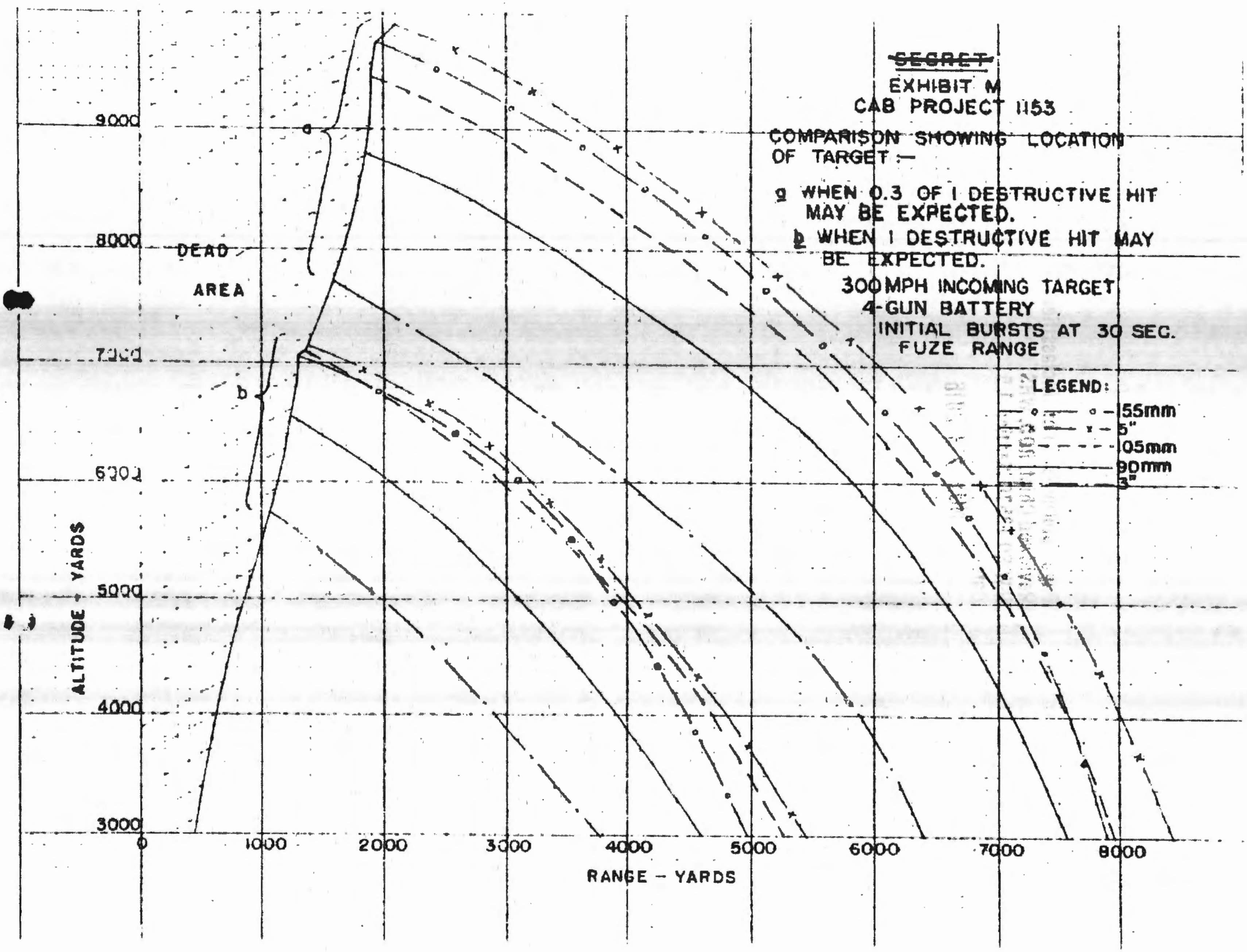

SECRET
EXHIBIT M
CAB PROJECT 1153
COMPARISON SHOWING LOCATION OF TARGET —
a WHEN 0.3 OF 1 DESTRUCTIVE HIT MAY BE EXPECTED.
b WHEN 1 DESTRUCTIVE HIT MAY BE EXPECTED.
300 MPH INCOMING TARGET
4-GUN BATTERY
INITIAL BURSTS AT 30 SEC. FUZE RANGE
LEGEND:
155mm
5"
105mm
90mm
3"
DEAD AREA
a
b
ALTITUDE - YARDS
9000
8000
7000
6000
5000
4000
3000
RANGE - YARDS
0
1000
2000
3000
4000
5000
6000
7000
8000

EXHIBIT M TO C.A.B. PROJECT NO. 1153

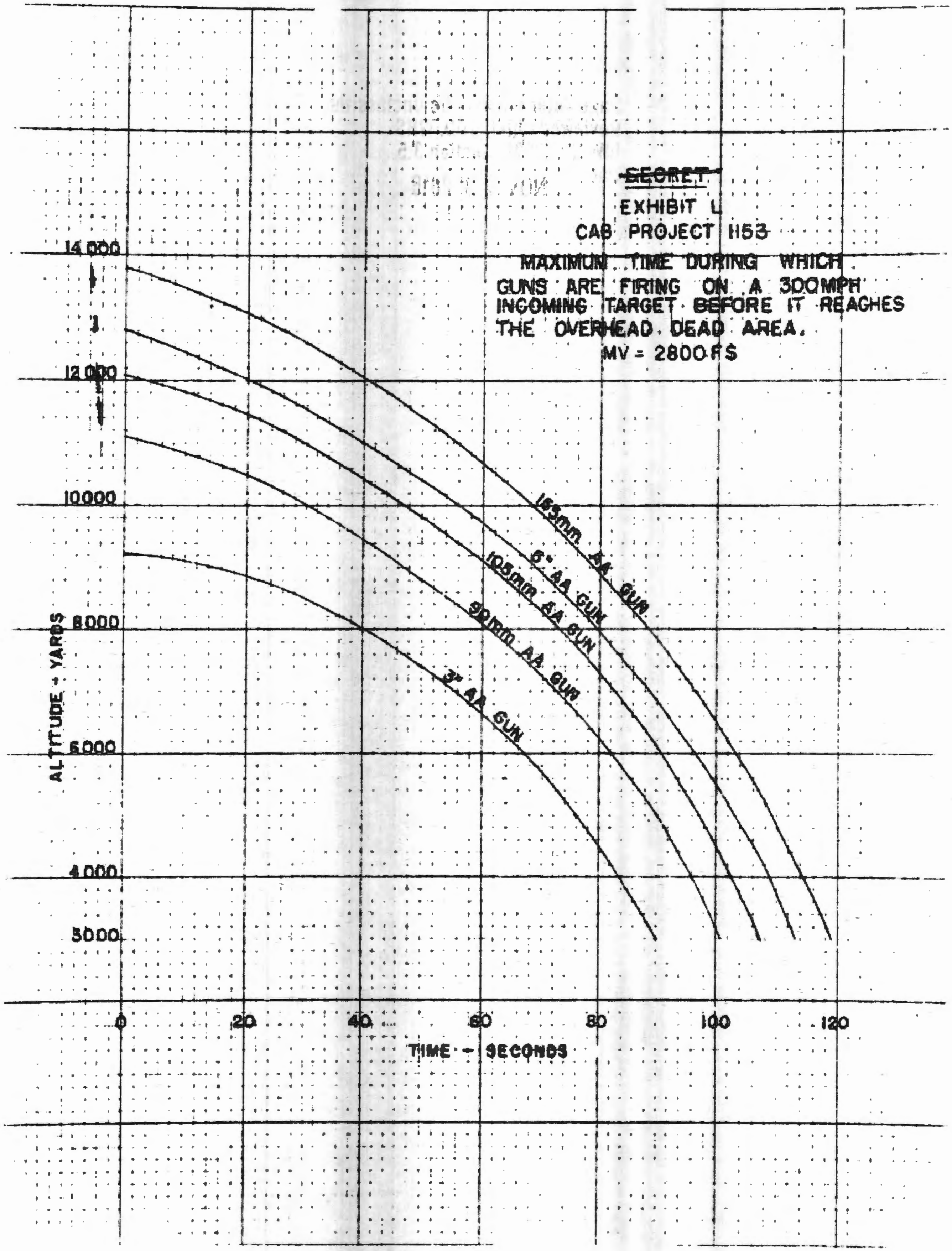

SECRET
EXHIBIT L
CAB PROJECT II53
MAXIMUM TIME DURING WHICH GUNS ARE FIRING ON A 300MPH INCOMING TARGET BEFORE IT REACHES THE OVERHEAD DEAD AREA.
MV = 2800 FS
155mm AA GUN
5" AA GUN
105mm AA GUN
90mm AA GUN
3" AA GUN
ALTITUDE - YARDS
14 000
12 000
10000
8000
6000
4000
3000
0
20
40
60
80
100
120
TIME - SECONDS

EXHIBIT 6 TO C.A.B. PROJECT NO. 1153

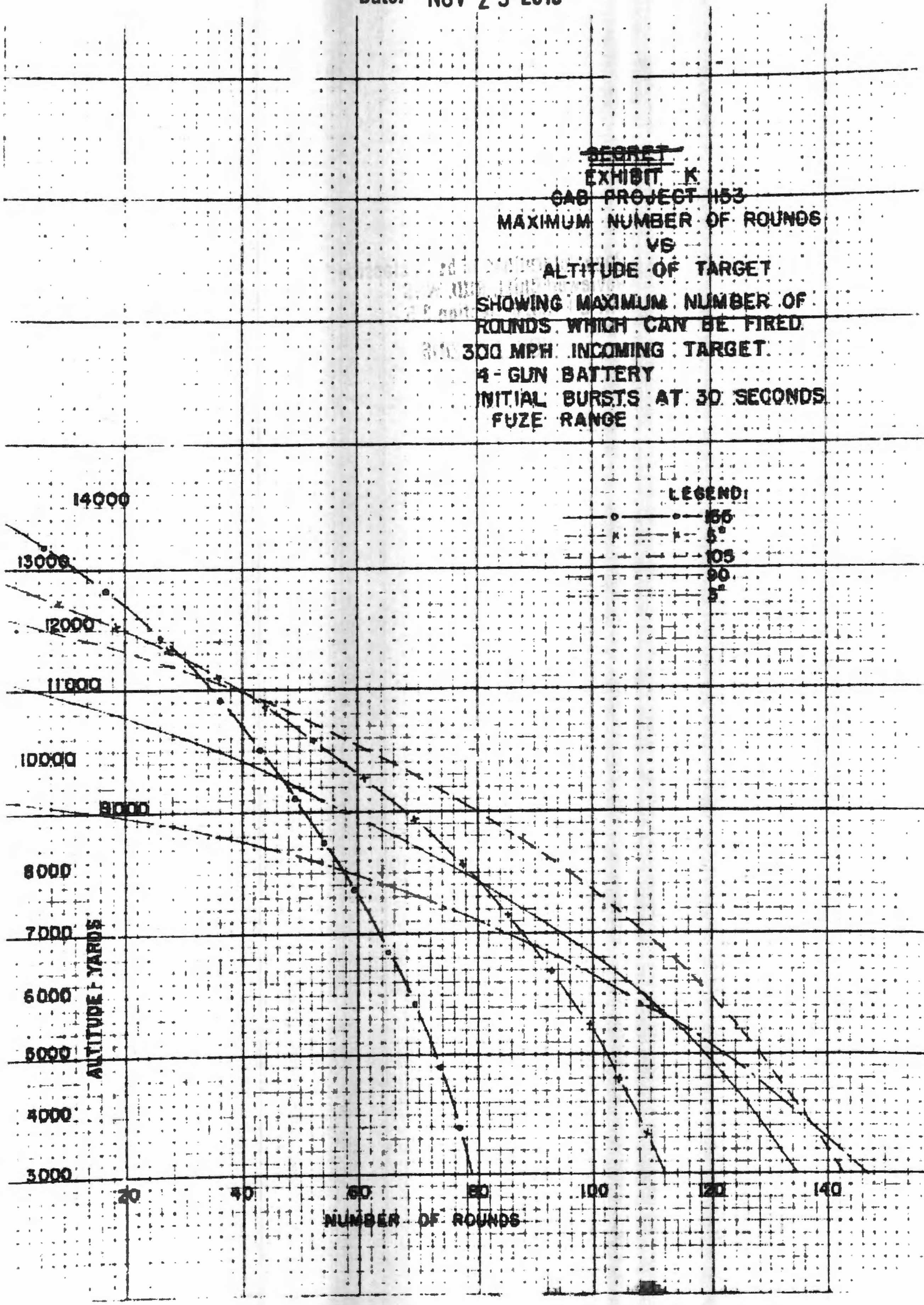

SECRET
EXHIBIT K
SAB PROJECT 153
MAXIMUM NUMBER OF ROUNDS
VS
ALTITUDE OF TARGET
SHOWING MAXIMUM NUMBER OF ROUNDS WHICH CAN BE FIRED.
300 MPH INCOMING TARGET.
4 - GUN BATTERY
INITIAL BURSTS AT 30 SECONDS FUZE RANGE
LEGEND:
155
5"
105
90
3"
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
ALTITUDE - YARDS
20
40
60
80
100
120
140
NUMBER OF ROUNDS

EXHIBIT K TO C.A.B. PROJECT NO. 1153

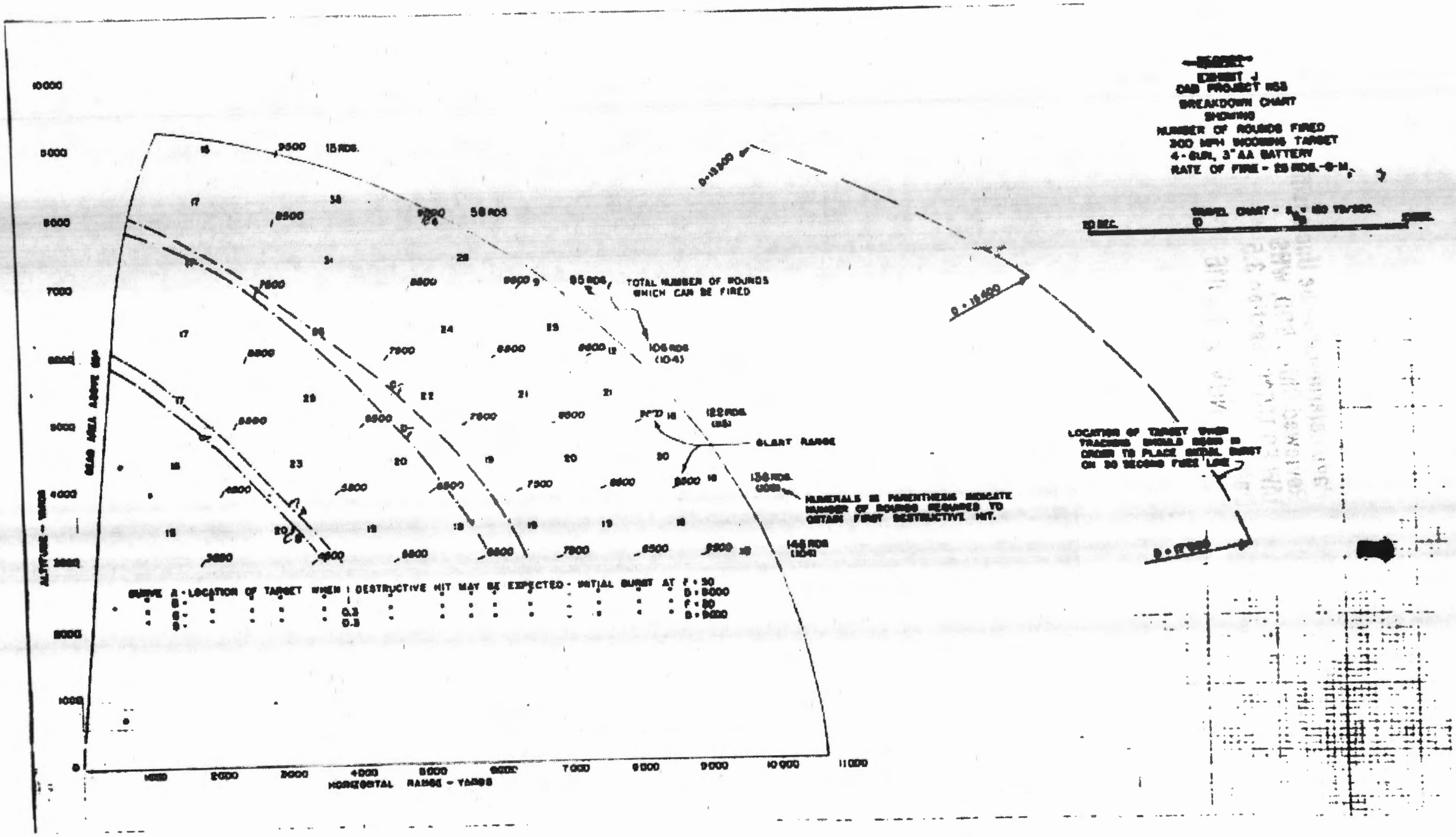
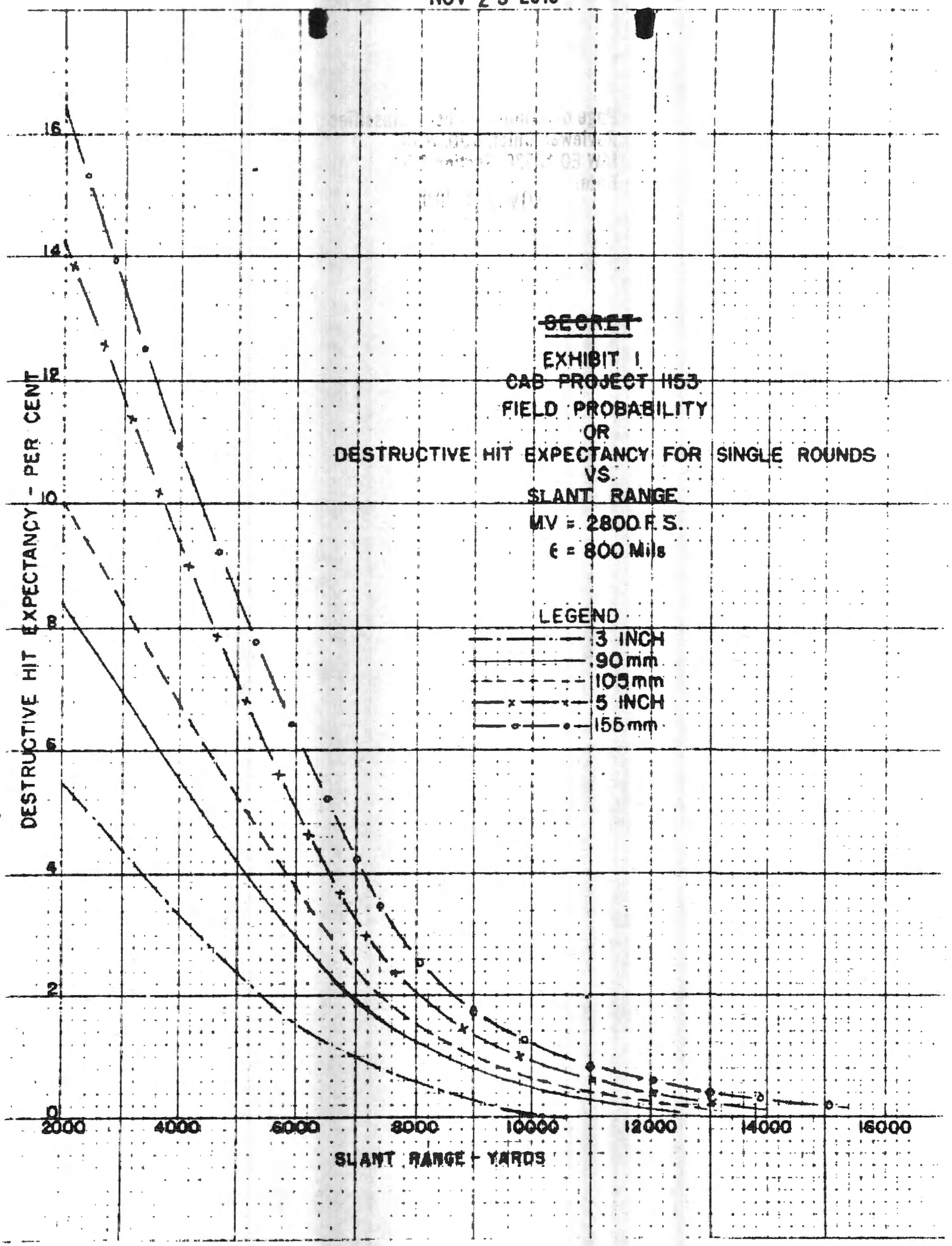

BREAKDOWN CHART
SHOWING
NUMBER OF ROUNDS FIRED
300 MPH INCOMING TARGET
4-GUN, 3" AA BATTERY
TOTAL NUMBER OF ROUNDS WHICH CAN BE FIRED
SLANT RANGE
NUMERALS IN PARENTHESIS INDICATE NUMBER OF ROUNDS REQUIRED TO OBTAIN FIRST DESTRUCTIVE HIT.
ALTITUDE - YARDS
HORIZONTAL RANGE - YARDS

EXHIBIT J TO C.A.B. PROJECT NO. 1153


SECRET
EXHIBIT I
CAB PROJECT 1153
FIELD PROBABILITY
OR
DESTRUCTIVE HIT EXPECTANCY FOR SINGLE ROUNDS
VS.
SLANT RANGE
MV = 2800 F.S.
ε = 800 Mils
LEGEND
3 INCH
90mm
105mm
5 INCH
155mm
DESTRUCTIVE HIT EXPECTANCY - PER CENT
0
2
4
6
8
10
12
14
16
2000
4000
6000
8000
10000
12000
14000
16000
SLANT RANGE - YARDS

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NOV 2 3 2016

EXHIBIT I TO C.A.B. PROJECT NO. 1153

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EXHIBIT H
CAB PROJECT 1163

CROSS SECTIONS OF HITTING VOLUMES
ANTIAIRCRAFT SHELLS

NOTE:
UPPER HALF ONLY OF CROSS-SECTION
SHOWN. FIGURE IS SYMMETRICAL WITH
RESPECT TO X AXIS.

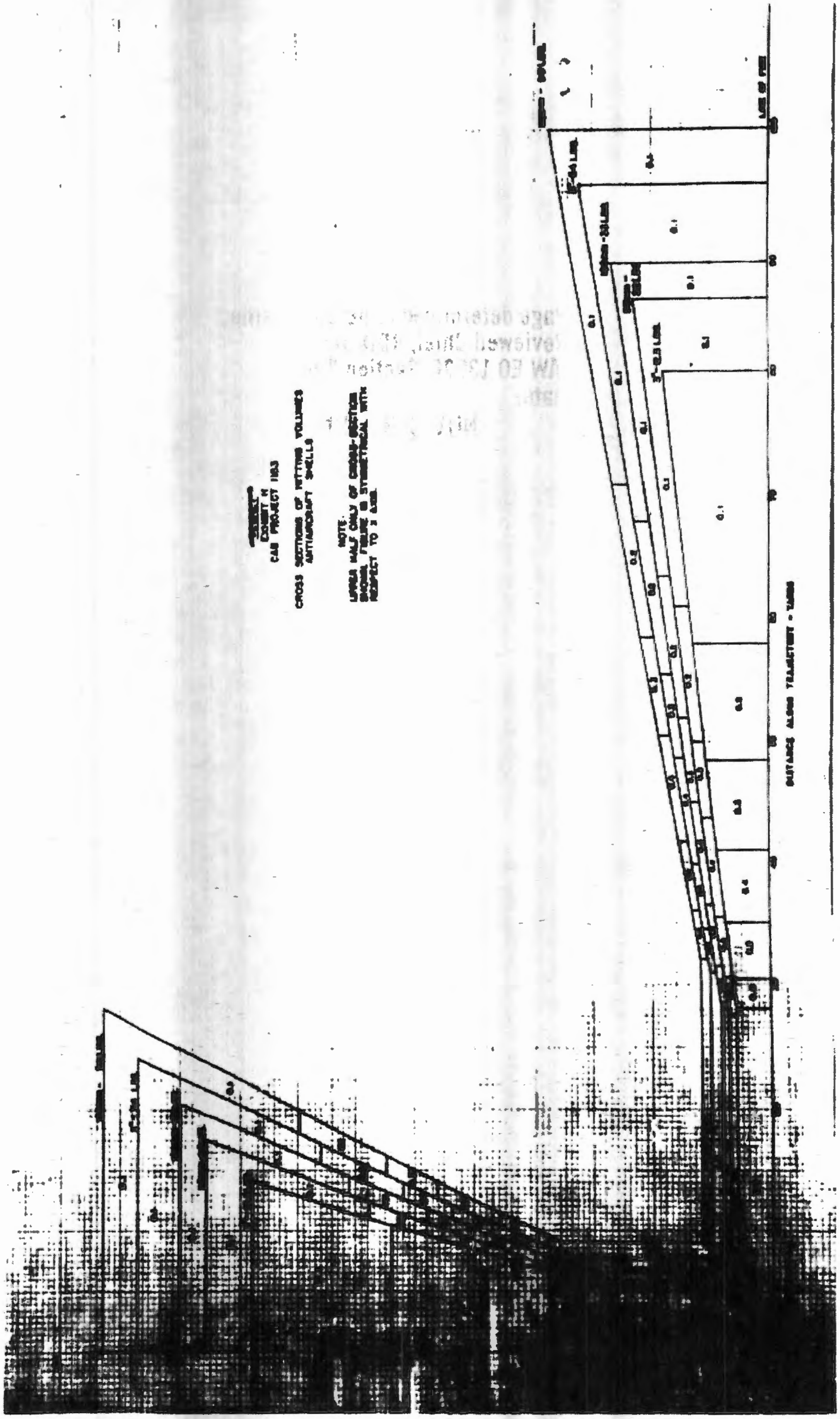

EXHIBIT H TO C.A.B. PROJECT NO. 1153

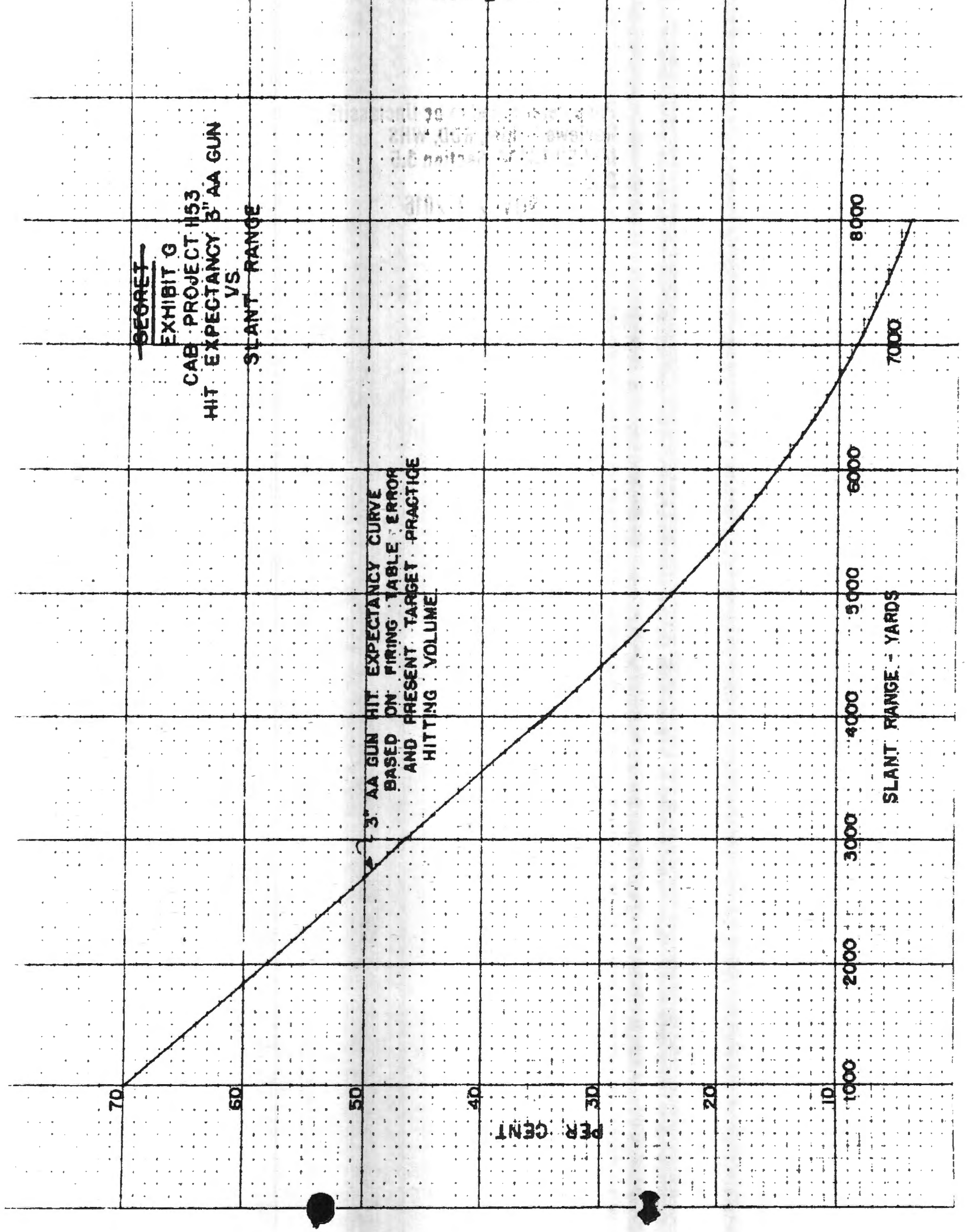
SECRET
EXHIBIT G
CAB PROJECT H53
HIT EXPECTANCY 3" AA GUN
VS.
SLANT RANGE
3" AA GUN HIT EXPECTANCY CURVE
BASED ON FIRING TABLE ERROR
AND PRESENT TARGET PRACTICE
HITTING VOLUME
70
60
50
40
30
20
10
PER CENT
1000
2000
3000
4000
5000
6000
7000
8000
SLANT RANGE - YARDS

EXHIBIT 6 TO C.A.B. PROJECT NO. 1153

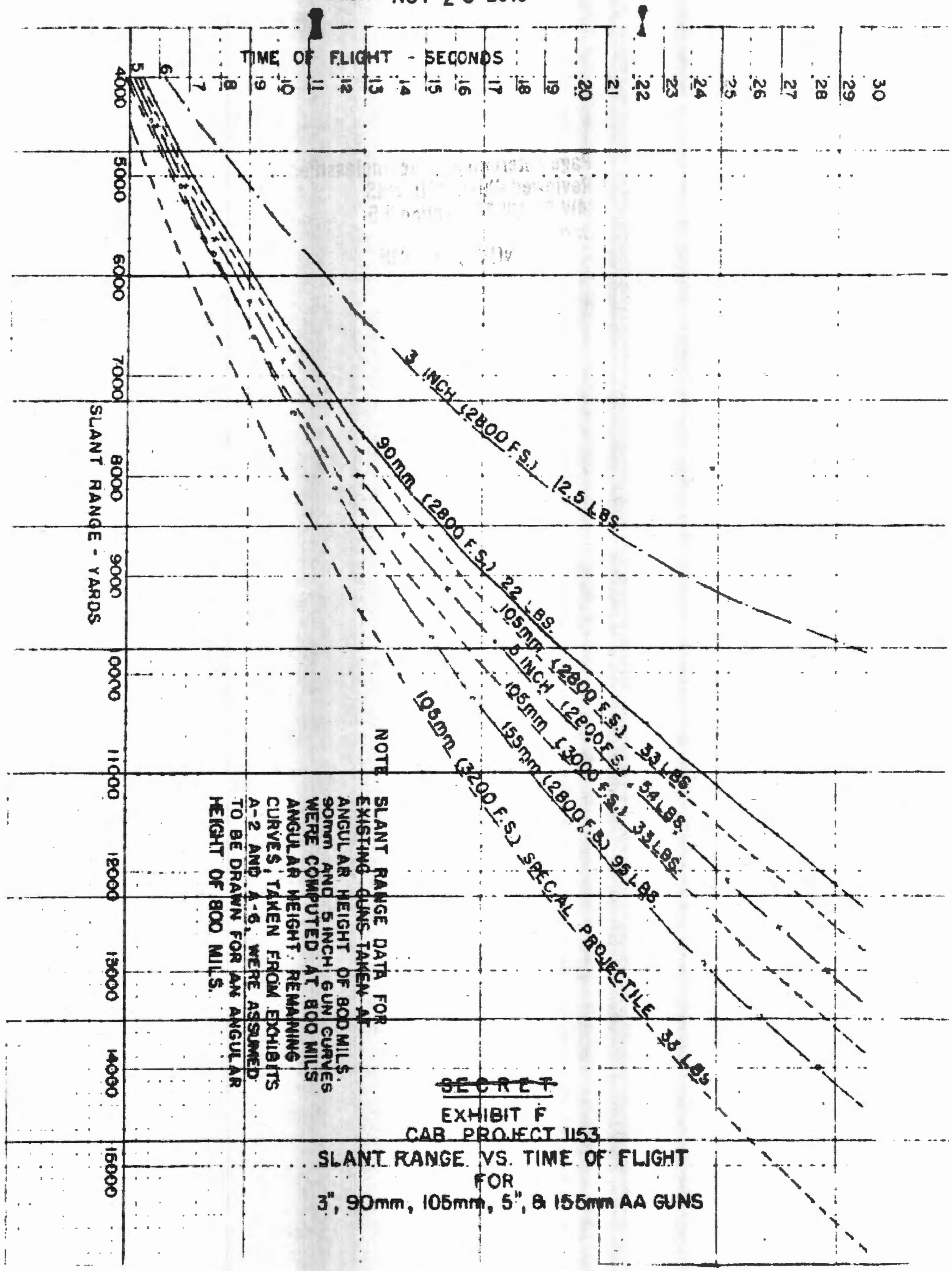

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EXHIBIT F

CAB PROJECT 1153

SLANT RANGE VS. TIME OF FLIGHT FOR 3", 90mm, 105mm, 5", & 155mm AA GUNS

EXHIBIT E TO C.A.B. PROJECT NO. 1153

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EXHIBIT E
CAB PROJECT 1153

SLANT RANGE AT WHICH TRACKING MUST START TO HAVE INITIAL BURST ON 30-SECOND FUZE CURVE.
300 MPH INCOMING TARGET

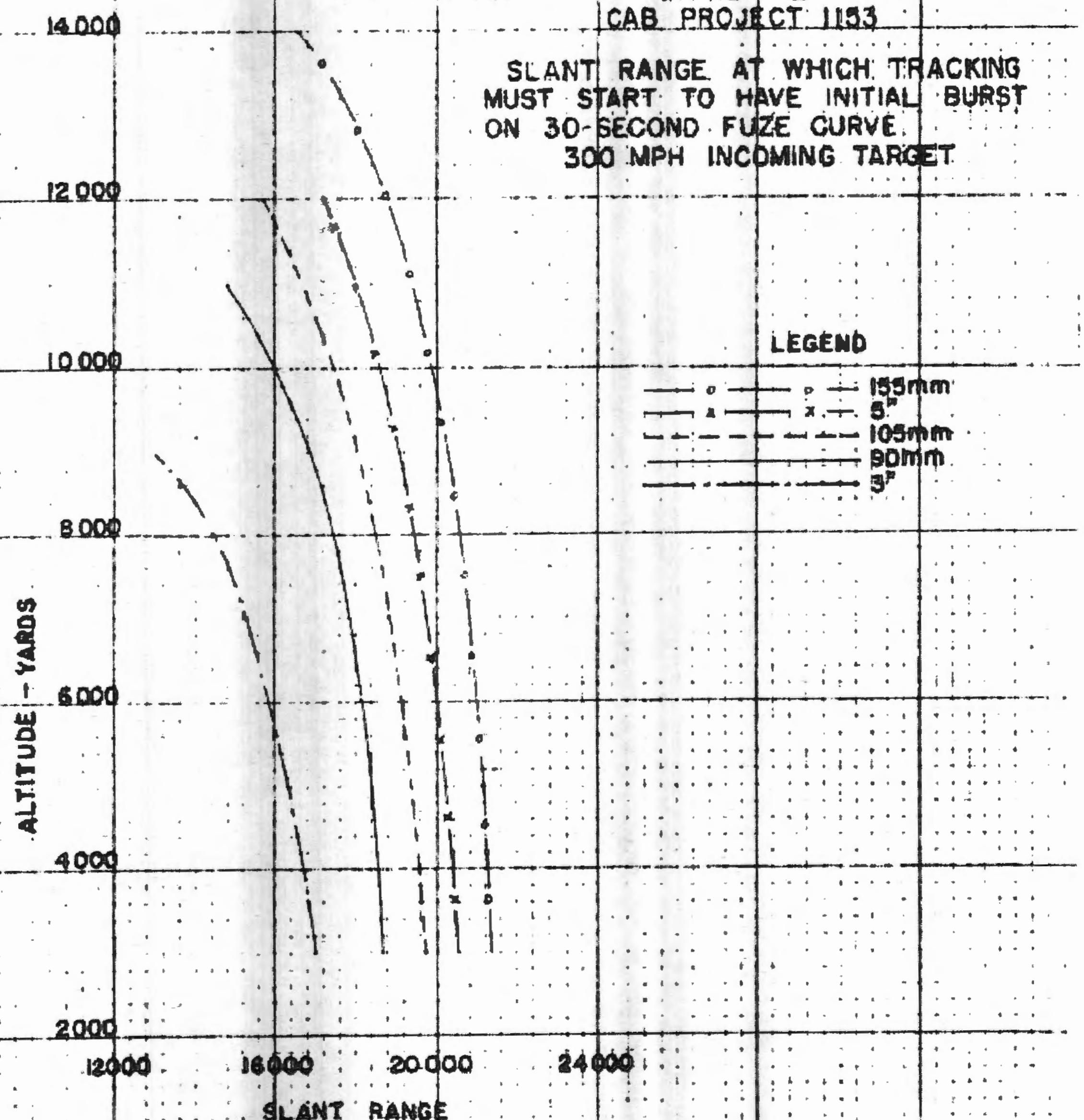

EXHIBIT E TO C.A.B. PROJECT NO. 1153

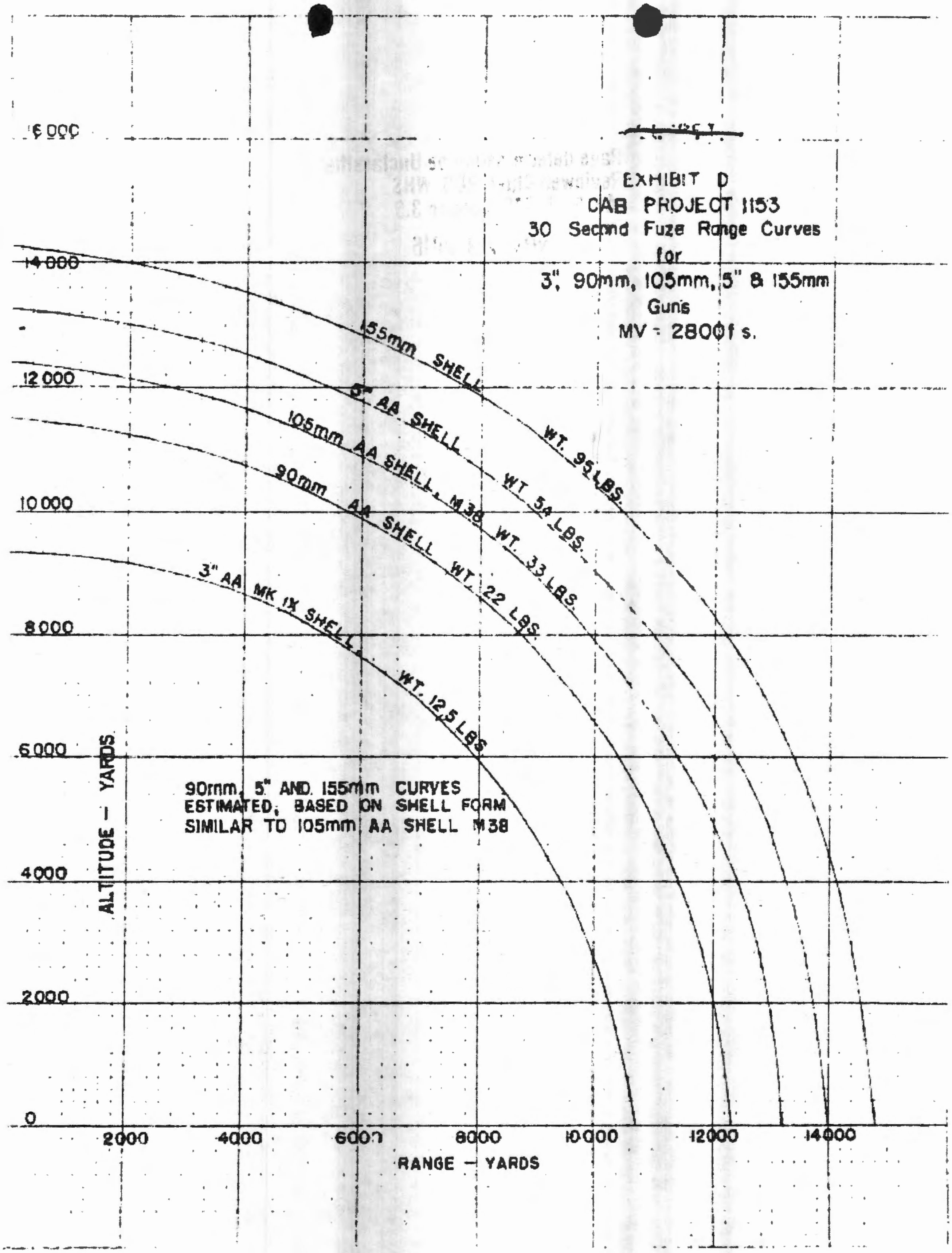
EXHIBIT D
CAB PROJECT 1153
30 Second Fuze Range Curves
for
3", 90mm, 105mm, 5" & 155mm
Guns
MV = 2800f s.
155mm SHELL WT. 95 LBS.
5" AA SHELL WT. 54 LBS.
105mm AA SHELL, M38 WT. 33 LBS.
90mm AA SHELL WT. 22 LBS.
3" AA MK IX SHELL WT. 12.5 LBS.
90mm, 5" AND 155mm CURVES
ESTIMATED, BASED ON SHELL FORM
SIMILAR TO 105mm AA SHELL M38
ALTITUDE — YARDS
16 000
14 000
12 000
10 000
8 000
6 000
4000
2000
0
2000
4000
6000
8000
10000
12000
14000
RANGE — YARDS

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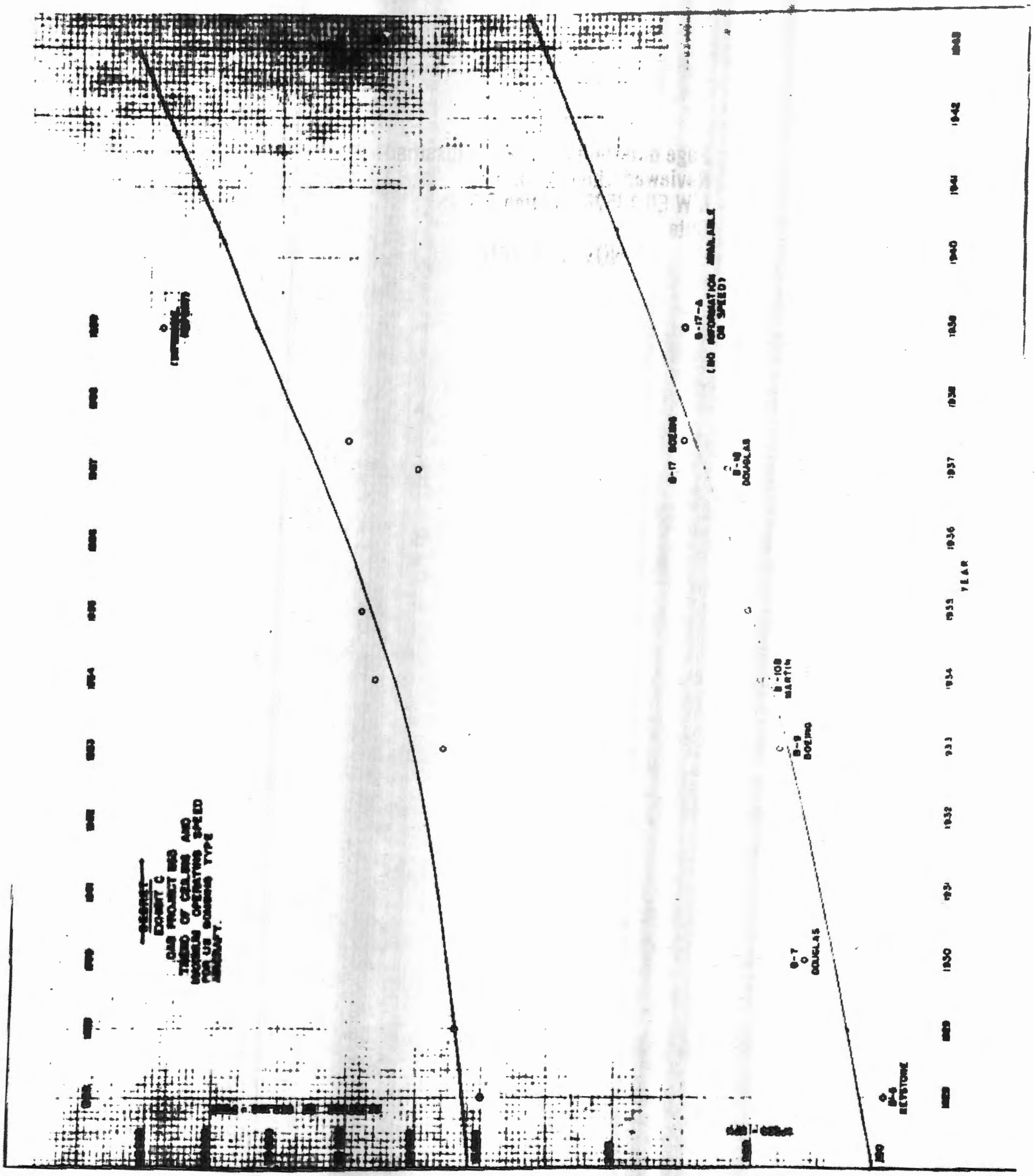
EXHIBIT D TO C.A.B. PROJECT NO. 1153



B-17 BOEING
B-17-A
(NO INFORMATION AVAILABLE ON SPEED)
B-18 DOUGLAS
B-10B MARTIN
B-9 BOEING
B-7 DOUGLAS
B-6 KEYSTONE
YEAR
1930
1932
1934
1936
1937
1940
1941
1942

EXHIBIT C TO C.A.B. PROJECT NO. 1153

~~SECRET~~

472.311/BO-2 1st Ind.

War Department, Office, Chief of Coast Artillery, February 5, 1935 - To President, Coast Artillery Board.

1. Available information indicates that rates of fire of from 15 to 22 rounds per minute are attained normally with both the 5-inch 25 caliber and the 5-inch 38 caliber Navy antiaircraft gun. It is stated that rates of fire up to 30 rounds per minute have been attained in isolated cases.

2. The 25 caliber gun uses fixed ammunition and the 38 caliber gun uses separate loading ammunition. The latter is claimed to be at least as fast as the former.

3. As a matter of general interest, Captain Schuyler, Bureau of Ordnance, Navy Department, has expressed the belief that Navy rates of fire are aided greatly by the use of three-pot fuze setters, automatic firing, and power rammers.

4. It is understood that no rates of fire are prescribed by the Navy Department except in the case of short range battle practice where an upper limit has sometimes been established in the interest of safety. It is believed that the use of such limitation is not universal. No information concerning limits that have been used could be obtained.

By order of the Chief of Coast Artillery:

J. . . . ,
Colonel, C.A.C.,
Executive.

~~SECRET~~

~~SECRET~~

EXHIBIT B
Coast Artillery Board Project 115[illegible]
Heavy Antiaircraft Gun

COAST ARTILLERY BOARD
Fort Monroe, Virginia

Project 115[illegible]

February [illegible], 1939.

SUBJECT: Heavy Antiaircraft Gun, Mobile Type.

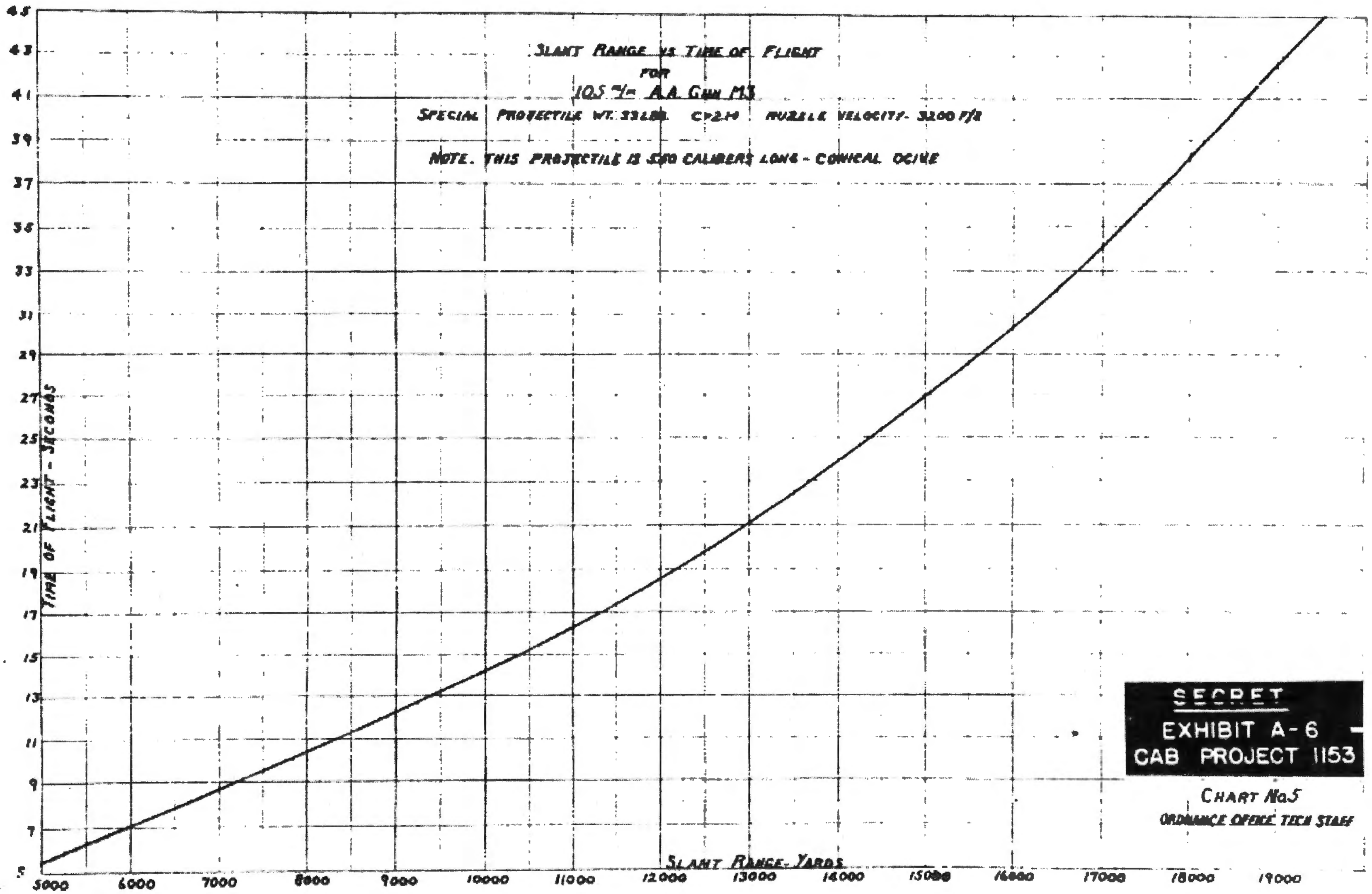
TO: Chief of Coast Artillery, Washington.

In connection with the study of antiaircraft gun calibers undertaken pursuant to 1st Indorsement, OCCA 472.311/BO, January 27, 1939, on letter Office, Chief of Ordnance, to the Chief of Coast Artillery (OO 472.93/6048), January 19, 1939, subject: Heavy antiaircraft gun, mobile type, information is requested as to service rates of fire prescribed for and attained by the 5-inch 25 caliber and 5-inch 38 caliber (and 5-inch 50 caliber, if any) Navy antiaircraft guns.

[illegible],
Colonel, Coast Artillery Corps,
President.

~~SECRET~~

EXHIBIT B TO C.A.B. PROJECT NO. 1153



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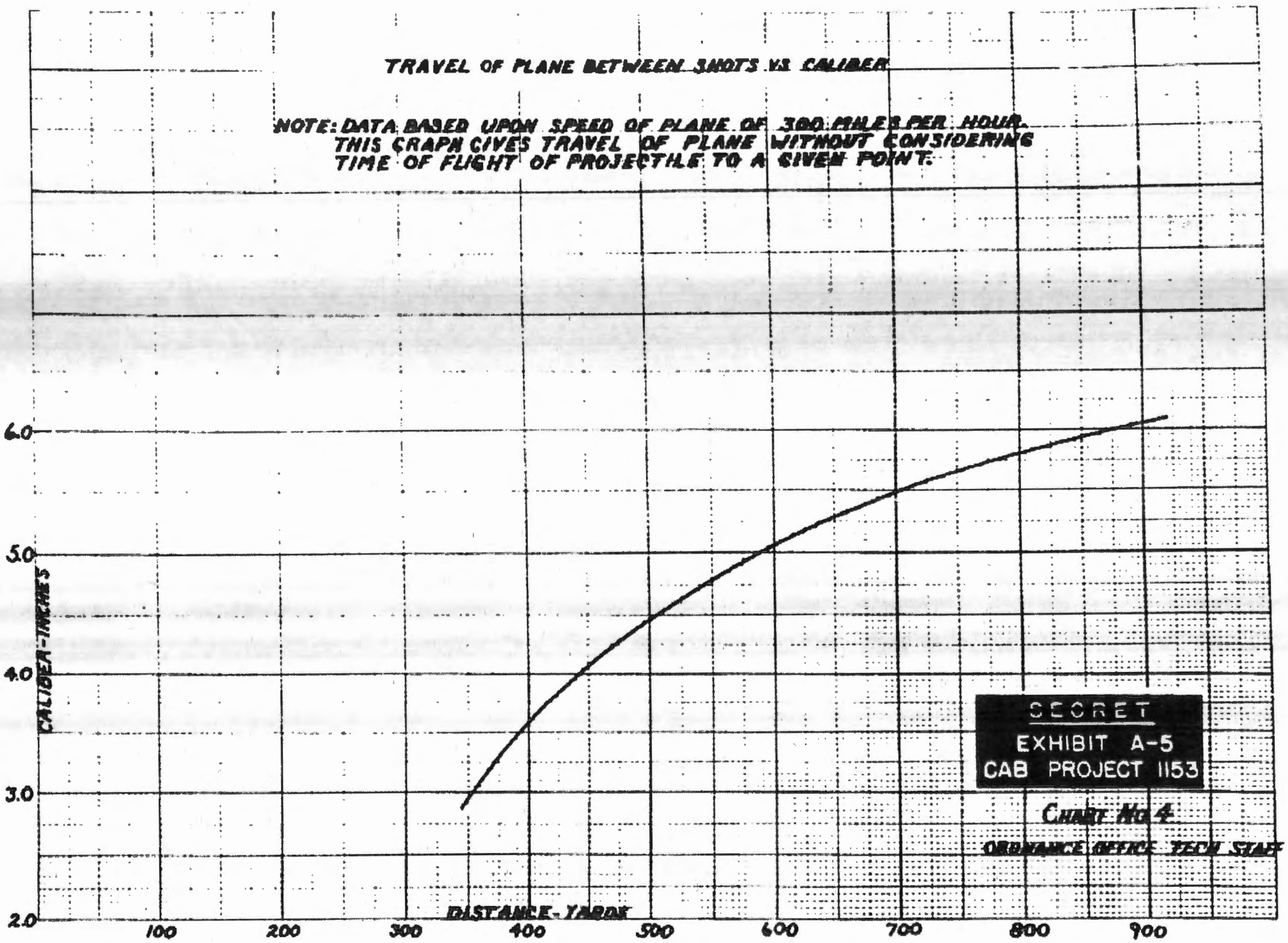
Date: NOV 23 2016



TRAVEL OF PLANE BETWEEN SHOTS VS CALIBER
NOTE: DATA BASED UPON SPEED OF PLANE OF 300 MILES PER HOUR. THIS GRAPH GIVES TRAVEL OF PLANE WITHOUT CONSIDERING TIME OF FLIGHT OF PROJECTILE TO A GIVEN POINT.
CALIBER-INCHES
2.0
3.0
4.0
5.0
6.0
DISTANCE-YARDS
100
200
300
400
500
600
700
800
900
SECRET
EXHIBIT A-5
CAB PROJECT 1153
CHART NO 4
ORDNANCE OFFICE TECH STAFF

No. 317 N

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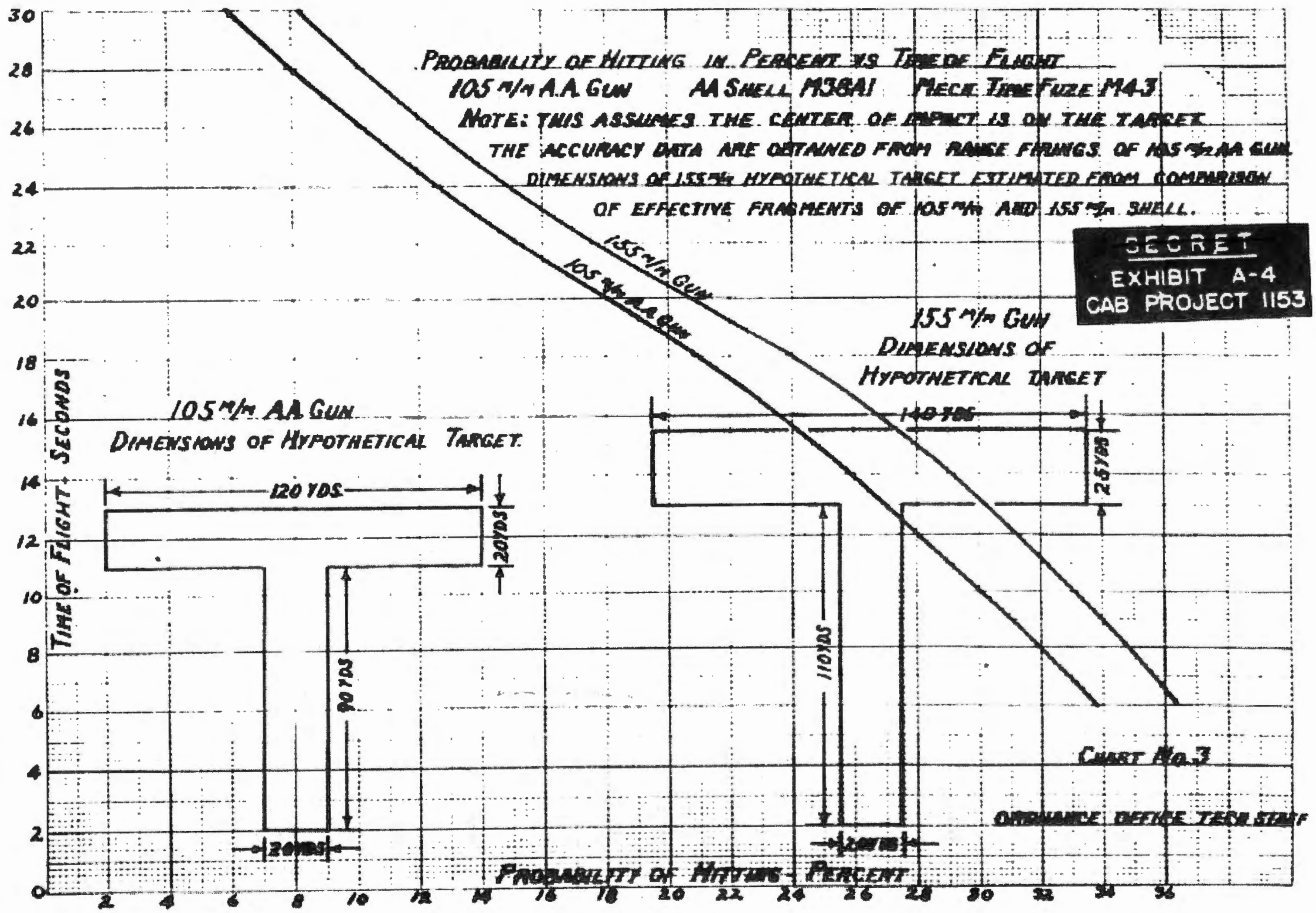

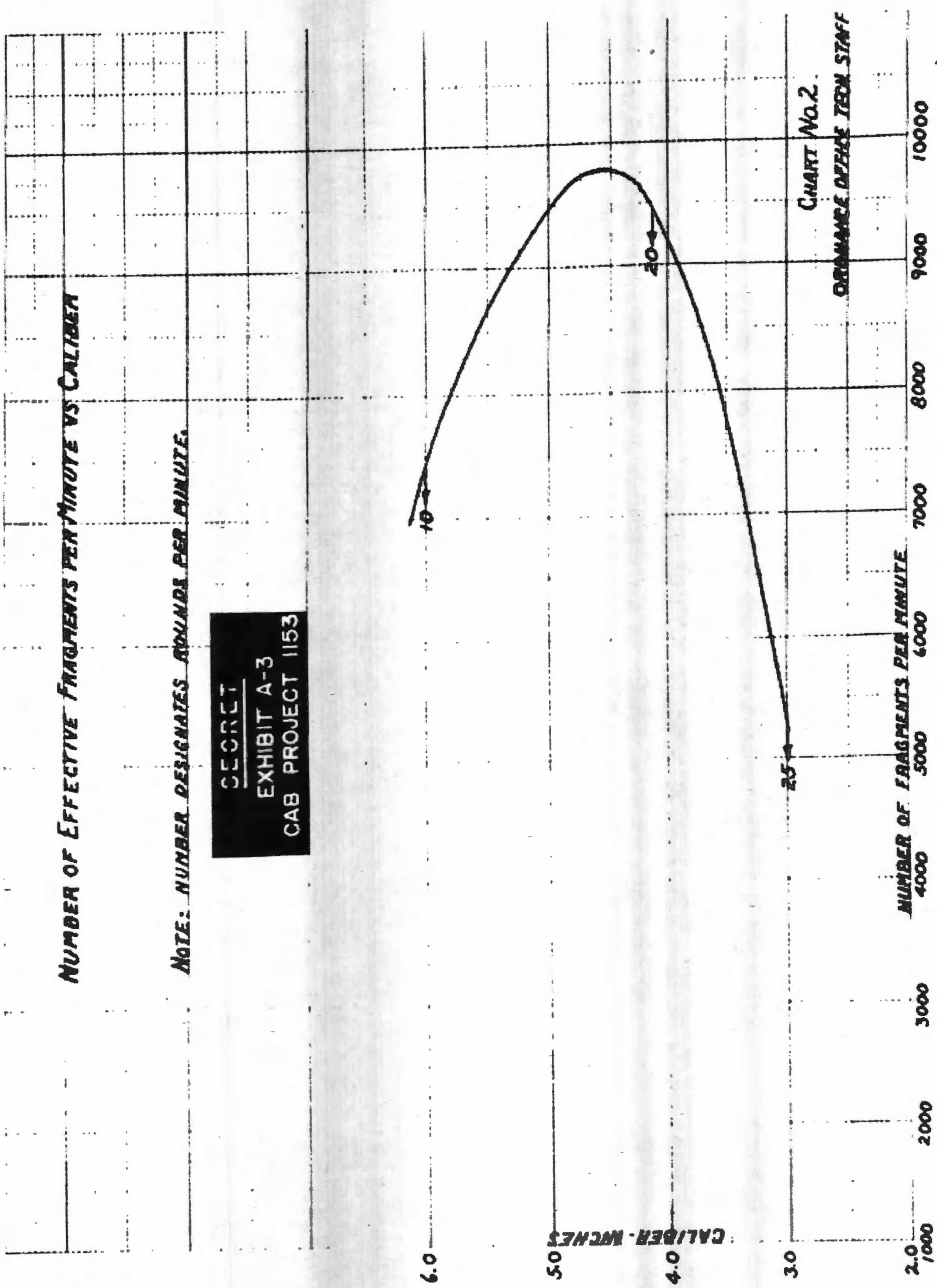

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EXHIBIT A-3
CAB PROJECT 1153

No. 317 N